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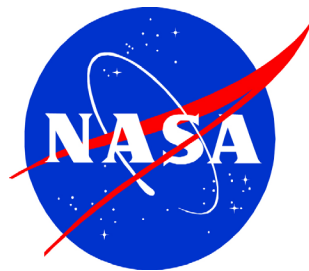


NASA's Management of the Artemis Supply Chain



October 19, 2023

IG-24-003



Office of Inspector General

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RESULTS IN BRIEF



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IG-24-003 (A-22-014-00-HED)

WHY WE PERFORMED THIS AUDIT

The Artemis campaign is NASA's signature space flight endeavor, aiming to return humans to the Moon and send crewed missions to Mars. This complex effort involves multiple programs and projects across many NASA Centers, including the Space Launch System (SLS) heavy-lift rocket; the Orion Crew Vehicle; Exploration Ground Systems that support launch and recovery; Extravehicular Spacesuits for the crew; a Human Landing System to take crew to and from the lunar surface; and the Gateway, a space station in orbit around the Moon. The first mission, Artemis I, was a 25.5 day uncrewed test flight around the Moon that returned to Earth in December 2022. Artemis II, the first crewed mission, is scheduled to launch in the fall of 2024, with Artemis III—a lunar landing involving two astronauts—planned for 2025.

Each of these Artemis-related programs rely on specialized parts supplied by contractors and subcontractors from across the United States and around the world. To support the Artemis campaign, NASA obligated approximately \$40 billion to 860 contractors from fiscal years 2012 to 2022. NASA's contractors employ a network of subcontractors and suppliers to provide the hardware, raw materials, electronic parts, and other resources needed to fulfill their contracts. However, numerous challenges to these supply chains—from the COVID-19 pandemic to workforce retention—have resulted in limited supplies and materials that, in turn, have affected the Artemis campaign's schedule and costs.

Proper supply chain management is essential to ensuring the Artemis campaign can meet its exploration goals. In this audit, we assessed NASA's management of the Artemis campaign's supply chain, including reviewing supply chain challenges and risks, as well as how supply chain issues are identified and mitigated. To understand NASA's visibility into the Artemis campaign's supply chain, we interviewed officials from NASA's supply chain management and logistics groups, and staff from the Office of the Chief Engineer, Office of Procurement, and Artemis campaign. We also sent detailed questionnaires to Artemis-related program and procurement officials and prime contractors, reviewed federal and NASA requirements, examined supplier data, and researched best practices from other government agencies and private sector industries.

WHAT WE FOUND

NASA and its prime contractors continue to experience challenges obtaining key components and necessary supplies to meet Artemis goals. The inability to obtain critical components and resources, such as space-grade valves and helium, in a timely manner has resulted in program cost increases and schedule delays. For example, program officials identified \$18.5 million in increased costs for the SLS Core Stage 2 attributable to supply chain impacts as well as \$41 million in projected cost increases for the Orion capsule due to component shortages. Worse yet, given the difficulty in identifying and quantifying supply chain impacts, these numbers do not represent the total effect of supply chain disruptions on the Artemis campaign.

Supply chain delays and disruptions over the past several years have resulted from a variety of factors, many of which are outside the Agency's control, including the COVID-19 pandemic, inflation of wages and material costs, the Russia-Ukraine conflict, and difficulties in maintaining a qualified workforce. NASA's supplies can also be delayed when higher-priority national security projects require parts and materials from the same contractors. That said, we found several factors related to managing Artemis supply chain issues that are within NASA's purview. Most importantly, the Agency lacks visibility into its critical suppliers with many Artemis programs and projects not tracking their prime contractors' supply chain impacts. Even when issues with subcontractors and suppliers are identified, performance

challenges are not shared across Artemis teams to enable effective procurement decisions. Moreover, we found that NASA’s Logistics Management Division (LMD)—which could be a useful resource to help plan for supply chain issues—is not utilized by Artemis programs and projects.

In contrast, we found that other government agencies and private industry use more proactive supply chain monitoring and management practices than NASA. For example, several government agencies maintain advanced supplier databases, require supplier information from contractors, and incorporate logistics experts into contracts from their inception. In addition, private industries’ ability to identify “bottleneck” suppliers is a particularly critical capability in supply chain oversight.

NASA is undertaking efforts to better understand supply chain issues and manage them more proactively, but these initiatives are still in the early stages. Two internal Agency databases—Insight Central and PrimeE—could provide increased awareness of NASA’s supply chains, but only if the databases are used consistently. At this time, program personnel across the Agency are not regularly inputting data into or consistently using Insight Central. PrimeE, managed by the LMD, is designed to visualize supply chain data and identify sole- and alternate-source suppliers. LMD hopes PrimeE will become a complement to Insight Central and other supply chain tools.

Two internal collaborative efforts at NASA—the Supply Chain Resiliency Forum and the Holistic Agency Study—were designed to improve NASA’s understanding of its supply chain issues. The Forum convenes representatives from across the Agency to coordinate supply chain-related activities, but the group has not yet finalized an official charter. The Holistic Agency Study, conducted by the Office of Technology, Policy and Strategy and the Office of the Chief Engineer, took place from late 2021 to 2023. The group used a broad survey of NASA stakeholders to examine supply chain issues and related management issues across the Agency. Initial results of the study show that supply chain issues at NASA are usually a surprise to the Agency, with mitigation therefore reactive rather than proactive. However, none of these collaborative efforts to date have significantly improved NASA’s visibility into its Artemis supply chain.

WHAT WE RECOMMENDED

To improve NASA’s management and visibility into its supply chain, we recommended the Executive for the Supply Chain Resiliency Forum (1) establish a charter for the existing Supply Chain Resiliency Forum; (2) complete the Supply Chain Visibility Data Requirement Description effort; and (3) provide training to ensure contracting officers will utilize available supplier data. Further, to improve NASA’s management of the Artemis supply chain, we recommended the Associate Administrator for Exploration Systems Development Mission Directorate (4) centralize supply chain management for the Artemis campaign within the Moon to Mars Program Office; (5) ensure data is regularly entered into a supplier database; (6) incorporate a representative from the LMD into each Artemis-related program; and (7) ensure an Artemis-specific industrial base and supply chain study is completed on a recurring basis.

We provided a draft of this report to NASA management who concurred with recommendations 1, 2, 3, 4, 5, and 7 and partially concurred with recommendation 6. We consider management’s comments responsive to recommendations 1, 3, 4, 5, and 7 and therefore those recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions. However, we found the Agency’s response to recommendations 2 and 6 unresponsive. Consequently, those recommendations will remain unresolved pending further discussions with the Agency.

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Acronyms

| | |
|----------|---|
| CARITL | Critical At-Risk Industrial Technology List |
| CLPS | Commercial Lunar Payload Services |
| COVID-19 | Coronavirus Disease 2019 |
| DCMA | Defense Contract Management Agency |
| DoD | Department of Defense |
| DPAS | Defense Priorities and Allocations System |
| DRD | Data Requirement Description |
| EEE | Electrical, Electronic, and Electromechanical |
| EGS | Exploration Ground Systems |
| ESA | European Space Agency |
| ESDMD | Exploration Systems Development Mission Directorate |
| FAR | Federal Acquisition Regulation |
| FY | fiscal year |
| GFP | government furnished property |
| HLS | Human Landing System |
| LMD | Logistics Management Division |
| ML-1 | Mobile Launcher 1 |
| ML-2 | Mobile Launcher 2 |
| MOU | Memorandum of Understanding |
| OIG | Office of Inspector General |
| PDREP | Product Data Reporting and Evaluation Program |
| SCRF | Supply Chain Resiliency Forum |
| SCRM | Supply Chain Risk Management |
| SLS | Space Launch System |

INTRODUCTION

The Artemis campaign is NASA's signature space flight endeavor and an ambitious and costly effort that aims to return humans to the Moon and eventually send crewed missions to Mars. To accomplish these goals, NASA relies heavily on contractors to build key systems such as the Space Launch System (SLS), a two-stage, heavy-lift rocket that will launch the Orion Multi-Purpose Crew Vehicle (Orion) into space. In addition, mobile launchers will serve as ground platform structures that will launch the integrated SLS/Orion system under the Exploration Ground Systems (EGS) Program. To conduct a lunar landing, the Agency must develop advanced spacesuits to protect astronauts on the Moon's surface; a Human Landing System (HLS) to transport crew from Orion in lunar orbit to and from the Moon's surface; and the Gateway to provide a staging location for lunar missions and future deep space operations. Each of these complex systems requires numerous specialized parts supplied by contractors and subcontractors from around the world.

From fiscal years (FY) 2012 to 2022, NASA obligated approximately \$40 billion to 860 contractors in support of the Artemis campaign, with nearly \$6 billion obligated in FY 2022 alone.¹ Fifty-nine contractors support the five major human space flight Artemis programs—SLS, Orion, EGS, HLS, and Gateway.² In turn, NASA's contractors employ a network of subcontractors and suppliers to provide necessary hardware and services, such as raw materials, electronic parts, and fuel. However, numerous challenges to these supply chains—from a narrow space industrial base to workforce challenges—have resulted in several cases of limited supplies and materials. In any event, proper management of its supply chain for Artemis is essential to ensuring the Agency can meet its significant exploration goals. In this audit, we examined NASA's management of the Artemis campaign's supply chain. Details of the audit's scope and methodology are outlined in Appendix A.

Background

The Artemis campaign seeks to return humans to the Moon by 2025 and ultimately send crewed missions to Mars by the 2030s. The first flight—Artemis I—was an uncrewed mission that successfully launched the SLS and Orion from the Mobile Launcher 1 (ML-1) in November 2022 and returned to Earth after spending 25.5 days in space and circling the Moon. Artemis II is scheduled to launch in the fall of 2024 as the first crewed Artemis mission and will remain in Earth's orbit for several days to test numerous systems, such as the Orion's maneuverability and its life support and habitation equipment, before proceeding to an orbit around the Moon. Artemis III, planned for 2025, will take two astronauts to the Moon's surface on the first crewed demonstration of the HLS.³ NASA's plans for future Artemis missions, beginning in 2028 with Artemis IV, will incorporate the Gateway—a lunar outpost—and a bigger, more powerful SLS configuration known as Block 1B. This larger configuration enables the rocket

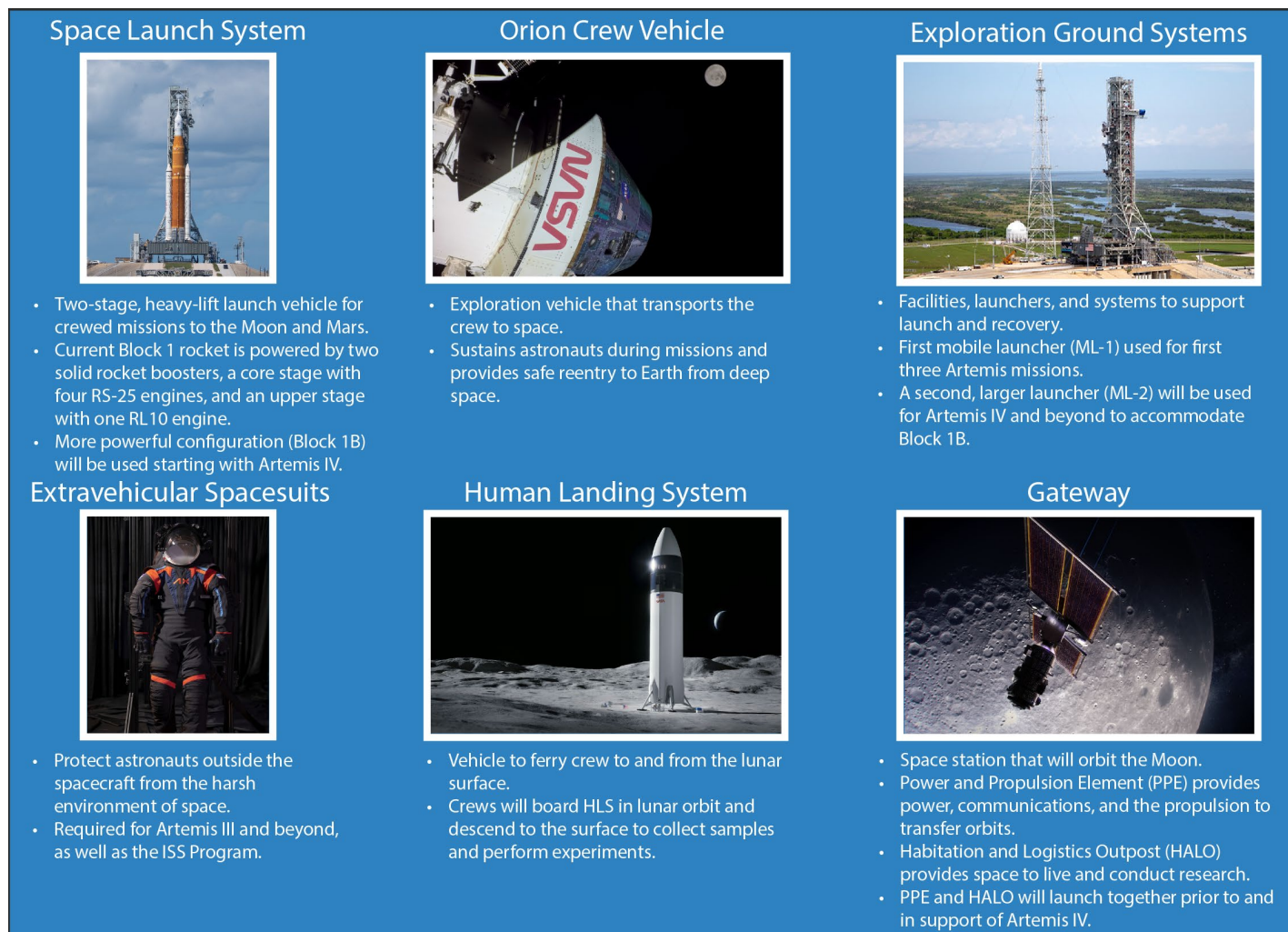
¹ The \$40 billion includes funds obligated for the following five programs: SLS, Orion, EGS, HLS, and Gateway. The 860 contractors include any vendor paid directly by NASA in support of any of the five programs. The 860-contractor count does not include the subcontractors and suppliers employed by NASA's contractors.

² The Extravehicular Activity and Human Surface Mobility Program was not included in our analysis, as there was not yet relevant data within NASA's accounting system at the time of our analysis.

³ Even though the planned Artemis III launch date is 2025, in June 2023 a NASA official publicly stated that this date will probably slip to 2026.

to launch 40 percent more payload to the Moon than the SLS Block 1 used for the first three Artemis missions. Figure 1 provides a more detailed description of the programs and projects necessary to the Artemis campaign.

Figure 1: Artemis Systems in Development (as of July 2023)



Source: Spacesuit photo credit: Axiom Space. Other photos: NASA.

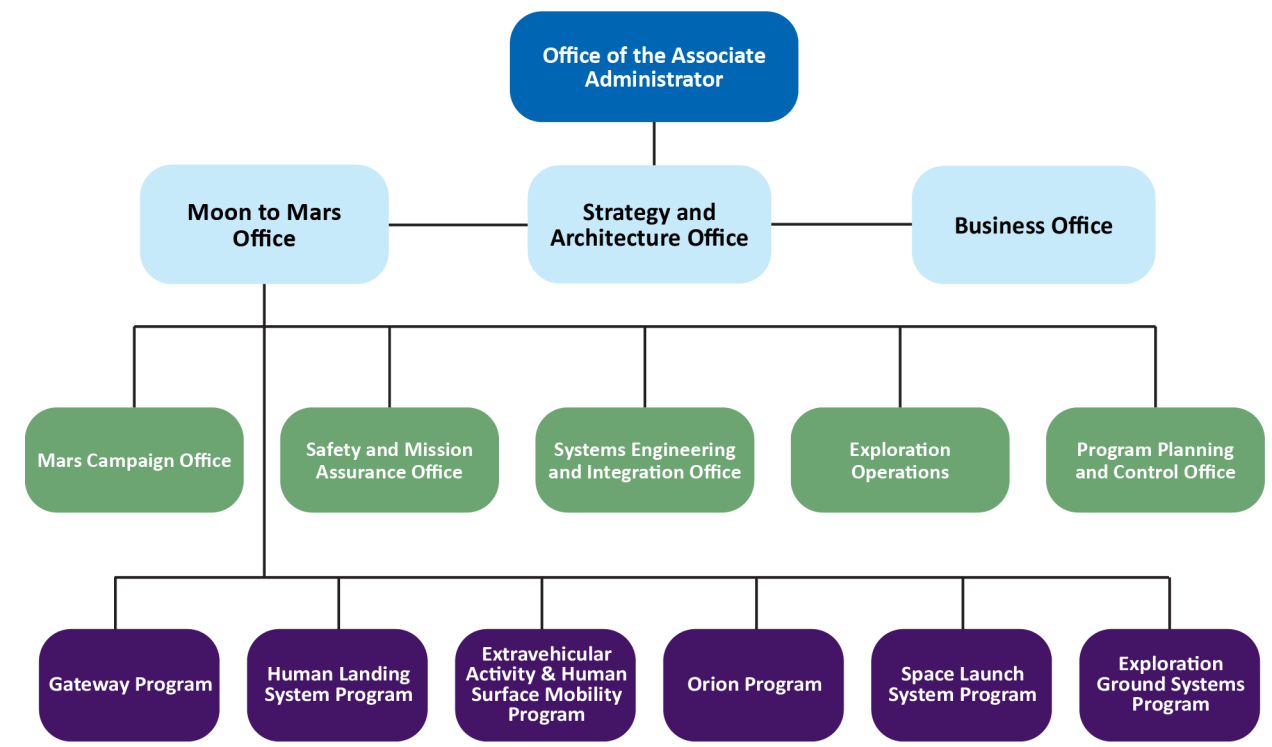
Artemis Organizational Structure

NASA’s Exploration Systems Development Mission Directorate (ESDMD) manages the human exploration system development for lunar orbital, lunar surface, and Mars exploration.⁴ In April 2023, NASA established the Moon to Mars Program Office within ESDMD to focus on hardware development, mission integration, and risk management functions for programs critical to the agency’s exploration goals. The Moon to Mars Program Office oversees the development of the programs and projects

⁴ While other NASA Mission Directorates are also involved in the science and technology development necessary to the Artemis campaign, this audit focused on the programs and projects managed by ESDMD.

critical to the Artemis campaign—SLS, Orion, supporting ground systems, HLS, spacesuits, and Gateway. Figure 2 provides the current ESDMD organizational structure.

Figure 2: NASA’s ESDMD Organizational Chart (as of May 2023)



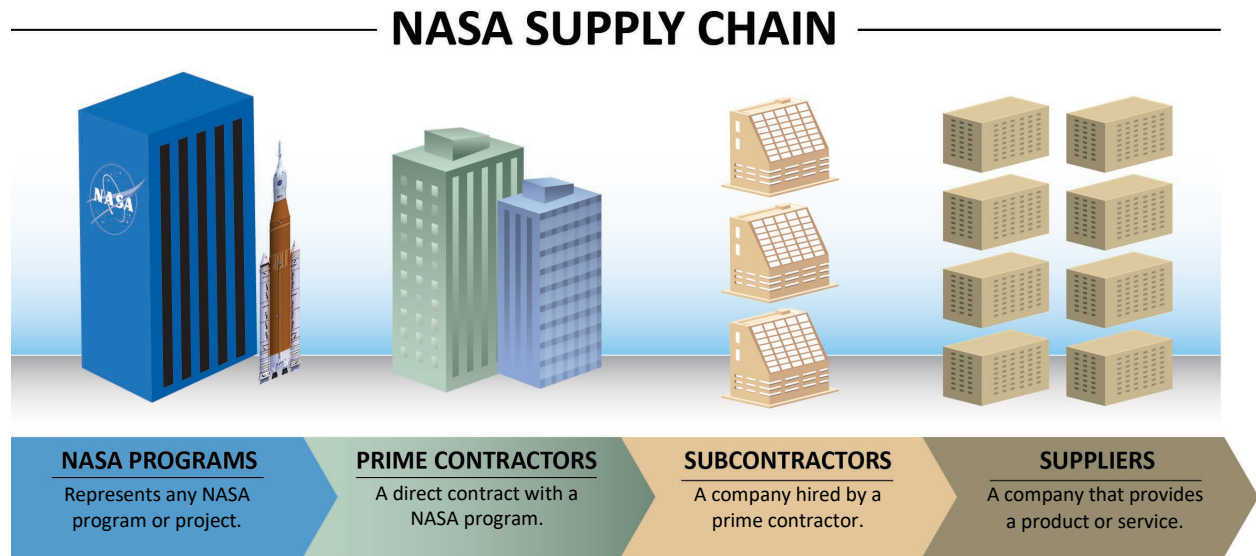
Source: NASA OIG presentation of Agency information.

Supply Chain Flow

The programs that make up the Artemis campaign—as illustrated in Figure 2—each rely on multiple contractors responsible for products and services related to their portion of the mission. Generally, a program will award a contract to a company to act as the “prime contractor.” The prime contractor is ultimately responsible for delivering the final product, as well as managing any companies that it in turn contracts with; these second-tier companies are known as “subcontractors.”⁵ Subcontractors often turn to additional suppliers for parts and raw materials, further expanding the web of companies involved in a program. The network of companies involved in the production of each piece of hardware—from the raw materials all the way through final processing—is known as the “supply chain.” A generalized supply chain is illustrated in Figure 3 below.

⁵ Subcontractors enter into a subcontract to furnish supplies or services for performance of a prime contract or another subcontract.

Figure 3: Representation of a NASA Supply Chain



Source: NASA OIG summary.

However, a program’s supply chain is not always linear. NASA programs will sometimes provide a prime contractor with “government-furnished property” (GFP), which refers to any equipment, software, or other materials that the government owns. Contracting officers can choose to provide GFP to a prime contractor if that is in the government’s interest and the requirements of the contract cannot otherwise be met.

While often confused with supply chain, the “industrial base” refers to the available companies that make up a worldwide industry. For example, when NASA purchases a piece of hardware from a specific company, all suppliers that company uses to produce the hardware comprise the supply chain for that item. However, all other companies capable of producing that hardware—including those that were not chosen—comprise the industrial base.

Supply Chain
The network between a company and its suppliers to produce a specific product.

Industrial Base
The wider network of all companies and suppliers with the capacity to produce a specific product.

NASA Supply Chain Management

There is no formal office assigned to manage the Artemis campaign’s supply chain and related risks; the Artemis programs and projects are individually responsible for monitoring and tracking risks, to include any supply chain concerns. The programs rely on the prime contractors to identify, communicate, mitigate, and forecast any supply chain challenges. The method and level of detail in which the primes communicate supply chain issues to NASA can vary by contractor and by NASA program. Over the last few years, NASA has begun to recognize the need for increased visibility into its supply chain and has several internal efforts underway to identify and mitigate supply chain risks Agency wide. In 2021, NASA partnered with The Aerospace Corporation to develop the Critical At-Risk Industrial Technology List (CARITL), which includes 63 items such as valves, helium, and liquid hydrogen, that are vital to NASA



projects but may have only one source, a limited market, or require specialized workers or equipment.⁶ After the conclusion of The Aerospace Corporation effort, NASA established the Holistic Agency Study group to provide recommendations to Agency officials to improve management and oversight of NASA’s supply chain. In addition, NASA implemented the Supply Chain Forum Working Group in early 2022 to better coordinate across the Agency and benchmark with other government agencies and industries. During the audit, the group was renamed the Supply Chain Resiliency Forum (SCRF) and, as of August 2023, was in the process of establishing a formal charter.

One of NASA’s primary supply chain efforts is implementing a database, known as Supply Chain Insight Central (Insight Central), to track and communicate supply chain issues. The Supply Chain Risk Management (SCRM) Program, within NASA’s Office of Safety and Mission Assurance, is leading this effort. To improve oversight and gain visibility, Insight Central combines information from NASA and contractors to develop a repository of prime contractors, subcontractors, and suppliers that provide mission hardware.

Prime Contractors and Critical Suppliers for the Artemis Campaign

While NASA has directly contracted with 860 contractors since 2012 in support of the Artemis campaign, 17 of those are major prime contractors with 23 separate contracts. As shown in Table 1, these 23 contracts alone are valued at over \$63 billion and procure services and hardware for each of the Artemis systems. Eleven of the 23 contracts are cost-reimbursement contracts under which NASA pays all allowable contractor expenses, and the remaining 12 are fixed-price contracts under which NASA pays a predetermined value for the goods or services and any overruns are the responsibility of the contractor.⁷






Table 1: Major Prime Contractors for Artemis Systems and Total Contract Value (as of April 2023)

| Artemis Component | Prime Contractors | Part and Contract | Contract Type | Contract Value ^a |
|---|--------------------|--|--------------------|-----------------------------|
|  | Lockheed Martin | Orion development | Cost-reimbursement | \$15.0 billion |
| | Lockheed Martin | Orion Production and Operations Contract | Cost-reimbursement | \$4.9 billion |
|  | Boeing | Core stages and Exploration Upper Stage | Cost-reimbursement | \$9.7 billion |
| | Boeing | Interim Cryogenic Propulsion Stage | Fixed-price | \$1.0 billion |
| | Aerojet Rocketdyne | RS-25 engines adaptation | Cost-reimbursement | \$580.9 million |
| | Aerojet Rocketdyne | RS-25 engines restart production | Cost-reimbursement | \$3.6 billion |
| | Northrop Grumman | Boosters | Cost-reimbursement | \$4.4 billion |

⁶ The CARITL identifies NASA space industrial base at-risk items used for NASA’s launch vehicles and spacecraft systems. It includes items such as raw materials, parts, components, and subsystems.

⁷ Using a cost-reimbursement approach, NASA approves all designs, manages all development and schedules, and owns the vehicle after delivery by the contractor. While this process gives NASA maximum control over the contractor’s design and final product, the majority of the cost, schedule, and outcome risks are borne by the federal government. A fixed-price contract provides a set price that does not change if the contractor’s costs increase during the period of performance due to inflation or supply chain issues, resulting in less risk to the government from subcontractors and suppliers.

Table 1: Major Prime Contractors for Artemis Systems and Total Contract Value (as of April 2023)

| Artemis Component | | Prime Contractors | Part and Contract | Contract Type | Contract Value ^a |
|---|---------------------------|--------------------------------|--|--------------------|-----------------------------|
| | | Teledyne Brown Engineering | Launch Vehicle Stage Adapter | Cost-reimbursement | \$350.0 million |
| | | Dynetics | Universal Stage Adapter | Cost-reimbursement | \$273.2 million |
|  | Mobile Launcher-1 | Hensel Phelps | Structure construction | Fixed-price | \$144.1 million |
| | | JP Donovan Construction | Structure modifications and ground support equipment installation and construction (two different contracts) | Fixed-price | \$217.9 million |
| | | Vencore Services and Solutions | Kennedy Space Center engineering services | Cost-reimbursement | \$228.0 million |
| | | Reynolds, Smith & Hills | Developed designs for structural modifications (two different contracts) | Fixed-price | \$55.6 million |
| | | Jacobs Technology | Kennedy Space Center test and operations support | Cost-reimbursement | \$2.1 billion ^b |
|  | Gateway | Maxar Technologies | Power and Propulsion Element | Fixed-price | \$730.9 million |
| | | Northrop Grumman | Habitation and Logistics Outpost Module | Fixed-price | \$1.5 billion |
| | | SpaceX | Launch services | Fixed-price | \$331.8 million |
| | | | Logistics services | Fixed-price | \$7.0 billion ^c |
|  | Mobile-Launcher 2 | Bechtel | Mobile Launcher-2 | Cost-reimbursement | \$1.0 billion |
|  | Human Landing System | SpaceX | Landing system | Fixed-price | \$3.5 billion |
| | | Blue Origin ^d | Landing system | Fixed-price | \$3.4 billion |
|  | Extravehicular Spacesuits | Axiom Space | Extravehicular spacesuits | Fixed-price | \$3.5 billion |
| | | Collins Aerospace | Extravehicular spacesuits | Fixed-price | |

Source: OIG summary of NASA data.

^a Contract values are current as of April 18, 2023. The contract value is the total amount of the base contract and any options that have been exercised.

^b The Jacobs Technology test and operations support contract includes other EGS support and services for other programs, including the Launch Services Program and the International Space Station.

^c The Gateway Logistics Services contract has a maximum contract value of \$7 billion to deliver cargo, experiments, and other supplies to the Gateway in lunar orbit over a 15-year period.

^d NASA awarded this contract to Blue Origin after our analysis was complete, so Blue Origin's suppliers were not included in the critical supplier analysis.

NASA has limited insight into its subcontractors and sub-tier suppliers when using cost-reimbursement contracts and even less insight under fixed-price contracts. If prime contractors do not have a purchasing system approved by NASA, they are required by federal law to report their subcontractors for both contract types, known as the consent to subcontract clause.⁸ The report is also required if the contracting officer determines there is a risk that requires special surveillance, such as major systems acquisitions and high risk, critical subsystems, components, or services.⁹ In addition, NASA can gain further visibility into fixed-price subcontracts if the subcontract or unpriced action is: (1) greater than the simplified acquisition threshold of \$250,000 or (2) greater than 5 percent of the total estimated cost of the contract.¹⁰ However, even when the above conditions are met, the prime contractor is only required to submit the names of its subcontractors, not its sub-tier suppliers—that is, the suppliers used by the subcontractors. For example, NASA provided the OIG with approximately 1,000 subcontractor names from the 17 major prime contractors supporting the Artemis campaign. However, five prime contractors—Aerojet Rocketdyne, Boeing, Jacobs, Lockheed Martin, and Northrop Grumman—together have reported using over 3,200 subcontractors and suppliers for the Artemis I launch.

Further, of the 860 contractors NASA pays directly in support of the Artemis campaign, we identified 59 separate contractors or suppliers that support five major Artemis programs—SLS, Orion, EGS, HLS, and Gateway—making them critical to the success of the Artemis missions.¹¹ These 59 critical suppliers provide essential components and services such as valves, fuel, electronic parts, and engines necessary to develop the Artemis systems. Figure 4 provides a breakdown of the total number of Artemis suppliers and the obligations by Artemis program.

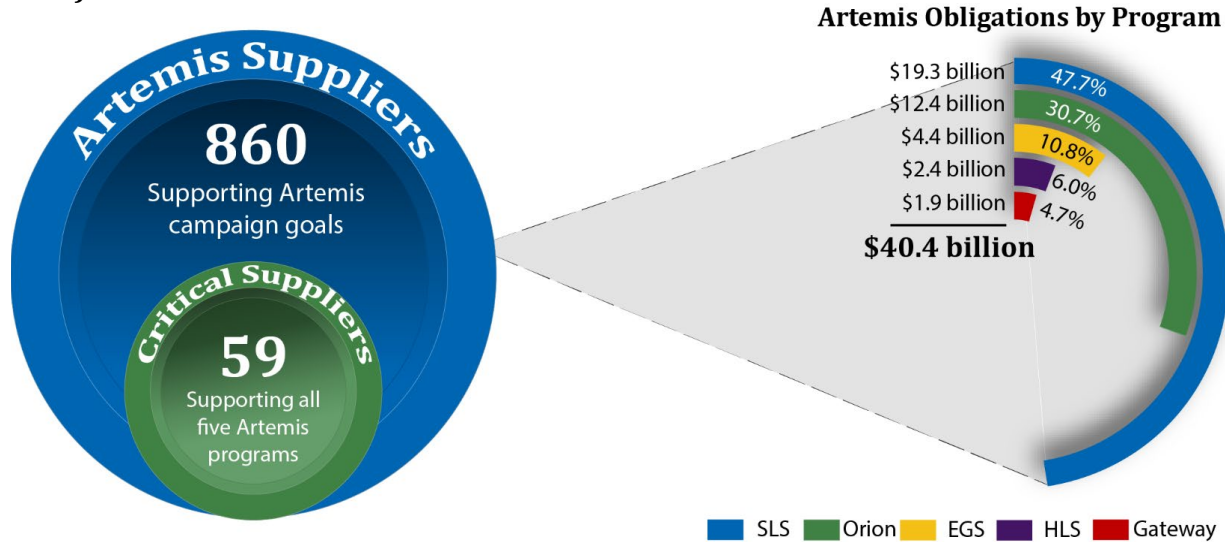
⁸ Purchasing system refers to the contractor's system or systems for purchasing and subcontracting, including make-or-buy decisions, the selection of vendors, analysis of quoted prices, negotiation of prices with vendors, placing and administering of orders, and expediting delivery of materials. Federal Acquisition Regulation (FAR) Subpart 44.2, *Consent to Subcontracts*. According to the NASA FAR supplement, a contractor's purchasing system can be approved by NASA or the Defense Contract Management Agency, depending on the cognizant administrative contracting officer. NASA FAR Supplement: Subpart 1844.3, *Contractors' Purchasing Systems Reviews*.

⁹ FAR Subpart 42.202, *Assignment of contract administration*. Further, FAR Part 34, *Major System Acquisition*, defines major systems acquisitions as those that, as determined by the agency head, (1) are directed at and critical to fulfilling an agency mission need, (2) entail allocating relatively large resources for the particular agency, and (3) warrant special management attention, including specific agency-head decisions.

¹⁰ The simplified acquisition threshold is \$250,000, except for conditions specified within FAR 2.101, *Definitions*. An unpriced order is an order for supplies or services, the price of which is not established at the time the order is issued.

¹¹ Some companies—whether as a prime or subcontractor—provide products or services to several Artemis programs and are thus considered “critical” for the purpose of this report.

Figure 4: Total Artemis Suppliers and Obligations by Artemis Program (FY 2012 through FY 2022)



Source: NASA OIG summary of NASA accounting system data.

Note: The term “suppliers” is used as a generic term to indicate any contractor. The supplier count and obligations are derived from NASA’s accounting system. The total Artemis obligations indicates any action that legally binds NASA to pay funds immediately or in the future.

We further identified 11 suppliers that support at least two key Artemis programs and are classified as critical according to NASA’s Critical At-Risk Industrial Technology List (CARITL). NASA has obligated nearly \$15 billion to these 11 suppliers over the last decade—nearly 40 percent of the total amount NASA has obligated to all 860 suppliers supporting the Artemis campaign. Further, 6 of these 11 suppliers are also subcontractors to NASA’s prime contractors.

Federal Supply Chain Activities

Since 2017, federal policymakers have taken an increased interest in strengthening America’s supply chains and industrial base, which have experienced longstanding challenges exacerbated by recent global events like the COVID-19 pandemic and the Russia-Ukraine conflict. Five major initiatives—three government-wide Executive Orders and two NASA-specific efforts—are described below.

- On July 21, 2017, President Trump signed Executive Order 13806, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States*, to focus on assessing manufacturing capacity; supply chains with single points of failure, especially third-tier suppliers and lower; and the availability of alternative sources.
- On January 25, 2021, President Biden signed Executive Order 14005, *Ensuring the Future is Made in All of America by All of America’s Workers*, a government-wide initiative to strengthen the use of federal procurement to support American manufacturing.
- On February 24, 2021, in response to the COVID-19 pandemic, President Biden signed Executive Order 14017, *America’s Supply Chains*, to focus on the United States’ need for a more resilient, diverse, and secure supply chain, particularly in the face of pandemics and geopolitical issues.

- On August 9, 2022, President Biden signed into law the 2022 NASA Authorization Act, which states, “Not later than 1 year after the enactment of this Act, and from time to time thereafter, the Administrator shall submit to the appropriate committees of Congress a report on the United States industrial base for NASA civil space missions and operations.” The report must provide, but is not limited to, a description of the status of NASA’s industrial base, a description of weaknesses in the supply chain, and a description of mechanisms and steps to mitigate supply chain weaknesses. The SCRF is currently tasked with meeting the reporting requirement.
- Most recently, on March 6, 2023, the Commerce Department’s Bureau of Industry and Security announced a joint effort with NASA and the National Oceanic and Atmospheric Administration to collect data from the civil space industrial base. The goal of this effort is to better understand the civil space supply chain network. The data will cover diminishing manufacturing sources and material shortages, foreign sourcing and dependencies, cybersecurity incidents, critical minerals and materials, COVID-19 pandemic impacts, and other challenges.

Prior NASA Study on Supply Chain Issues

In 2011, NASA contracted with the consultancy group Logistics Management Institute to assess NASA’s supply chain management and risks. While not specific to any individual program at the Agency, the study was based on research of industry best practices, surveys of relevant NASA personnel, and interviews with industry professionals involved in supply chain management. In December 2011, the Institute released a report titled *Strategies for Mitigating NASA’s Supplier Viability Risk*, which discussed several risk-identification techniques, including using all available data to identify risks before a supplier is selected, identifying and closely monitoring critical suppliers, using metrics to anticipate supplier warning signs, and utilizing reviews to continuously collect information on suppliers. The report also identified multiple proactive risk mitigation strategies that could be used to avoid certain risks before they occur. The report included several recommendations for NASA to implement these mitigation strategies, some of which include:

- *Establish an enterprise-level supplier risk team with a formal charter:* This group would be responsible for Mission Directorate-level supplier program management.
- *Integrate risk mitigation into NASA’s sourcing process:* Contractually require prime contractors to provide a description of their supplier risk management processes.
- *Use a supplier profile database for analysis and evaluation:* Enable program managers to evaluate potential suppliers during source selection and afterwards to track trends.
- *Incorporate contract language that requires reporting metrics:* Contractually require prime contractors to provide data regarding their subcontractors and suppliers.

Though the report was issued over a decade ago, as of May 2023 NASA has not fully implemented any of the recommendations. Some of the recommendations may be addressed as part of ongoing efforts within the SCRF and through development of the Insight Central database. In our view, because of continued supply chain issues with the Artemis programs and the long lead times needed to build certain components, these recommendations remain valid.

ARTEMIS SUPPLY CHAIN CHALLENGES PERSIST AS NASA'S EFFORTS TO IMPROVE MANAGEMENT OF ITS SUPPLIERS ARE EVOLVING

NASA and its prime contractors are experiencing challenges with availability of key components and other necessary supplies to meet Artemis goals, resulting in program cost increases and schedule delays. These challenges can be attributed to several factors including the Agency's limited visibility into the suppliers that support its major Artemis programs, geopolitical issues, workforce challenges, and competition with the Department of Defense (DoD) over a limited number of suppliers. Even though the Artemis programs and contractors use numerous techniques to mitigate supply chain issues, these methods are largely reactive and have resulted in varying degrees of success. As lessons learned from other agencies and industries have shown, proactive management could decrease costs and delays by allowing the Agency to make critical supply chain decisions earlier in the acquisition process.

Challenges Obtaining Key Components Have Resulted in Cost Increases and Schedule Disruptions to Artemis Programs

Ongoing supply chain challenges are affecting NASA and its prime contractors, leading to cost increases and schedule delays to the Artemis campaign goals. Specifically, critical components such as valves and EEE (electrical, electronic, and electromechanical) parts, and critical resources such as helium, are not consistently available when needed. For the SLS Program, program officials have identified \$18.5 million in increased costs because of supply chain impacts for Core Stage 2 related delays in obtaining materials such as helium, valves, and feedlines. For the Orion capsule being developed for Artemis III, issues with hardware suppliers and obtaining components in a timely manner have resulted in a projected cost increase of at least \$41 million. According to an Orion Program official, this represents about 50 percent of the total projected growth in direct costs for the Artemis III crew capsule. Furthermore, as of April 2023, the Artemis III Orion delivery has been delayed by 11 months due to the hardware suppliers' schedule performance. However, these cost and schedule increases do not reflect the total supply chain impact to the Artemis campaign. Many Artemis programs and projects do not separately track their prime contractors' supply chain impacts. Nonetheless, the majority of the Artemis prime contractors we interviewed stated that long-lead times and increased costs for raw materials and resources are major challenges in procuring critical parts.

Space-grade Valves



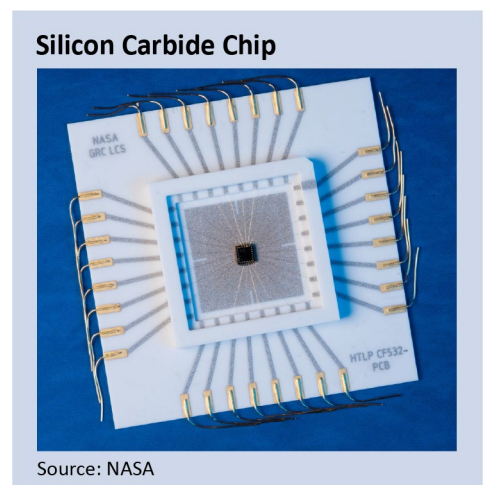
Source: NASA

Valves

Valves are a critical component to the Artemis campaign, supporting several different systems. They are highly specialized pieces of equipment that must withstand high pressure and temperatures. As such, only a few valve suppliers have the expertise to meet NASA's stringent requirements, leading to the longer lead times Artemis programs are experiencing in procuring valves. For example, Lockheed Martin, the prime contractor for the Orion Program, reported that the few suppliers it uses to obtain valves are also used by other NASA programs. Representatives from the SLS Program also indicated they are waiting for pre-valves from suppliers, and the delay in getting them could take months.¹² Without these pre-valves, further development of the core stage will be halted as they wait for the parts, resulting in continued schedule slips.

EEE Parts

EEE parts are mostly small components—such as microcircuits, capacitors, diodes, and transistors—that are the building blocks of a spacecraft. These components are critical to the Artemis campaign programs and projects and are subjected to harsh environmental and application stress. However, the suppliers for EEE parts are experiencing issues obtaining raw materials, challenges with their workforce, and technical failures during production. These challenges are creating longer than expected lead times and price increases of up to 300 percent. Further, as NASA relies on regions outside of the U.S. for these parts—such as Asia—U.S. government regulations and restrictions impact NASA's ability to procure these resources in a timely and cost-effective manner. Officials from both the Gateway Program and the Habitation and Logistics Outpost project mentioned difficulty obtaining EEE parts, stating that electronic parts may not be available to support their project milestone dates, which in turn could lead to significant schedule delays. Specifically, the Gateway Program reported lead times in obtaining EEE parts of at least 7 to 12 months. In addition, Habitation and Logistics Outpost project representatives stated they were having issues obtaining semiconductors, and their suppliers have been affected by supply and demand issues in obtaining the necessary raw materials and components.



¹² A pre-valve is a type of valve used in the SLS core stage main propulsion system that controls the supply of liquid oxygen and hydrogen to RS-25 engines.

Helium

Helium is a critical resource that has multiple aerospace purposes, such as cooling fiber-optic cables and semiconductor magnets, transferring heat away from computer chips during production, and as a

Helium Storage at Kennedy Space Center



Source: NASA

pressurizing agent for liquid fuel rockets. NASA also uses helium to keep hot gases and ultra-cold liquid fuel separated during a rocket launch. Over the past nearly 20 years, the helium market has experienced periods of global shortages, resulting in rising costs and long lead times. The helium shortage was exacerbated in September 2022 when the U.S. Bureau of Land Management ended the Federal Helium Program, which maintained a national helium reserve, enrichment plan, and pipeline. This resulted in federal users turning to the open market for helium. Due to its scarcity, the nationwide costs for liquid helium have more than doubled. As such, both NASA and Artemis prime contractors expressed concerns about obtaining helium

at reasonable costs and in a timely manner. Specifically, SLS Program officials stated they had a helium shortage for testing their thermal-protection foam on Core Stage 2, which impacted their schedule.

The difficulty in obtaining critical components and resources like valves, EEE parts, and helium highlights an ongoing challenge for the Artemis campaign. Both NASA programs and the prime contractors have expressed concerns about the supply chain that are impacting both cost and schedule across multiple programs and projects.

Challenges in NASA's Artemis Supply Chain Are Caused by a Variety of Factors

NASA Lacks Visibility into its Critical Suppliers for the Artemis Campaign

NASA lacks the data necessary to comprehensively identify all subcontractors and sub-tier suppliers supporting the Artemis campaign. Despite ongoing efforts, NASA currently does not maintain a single database that houses all known suppliers and any known performance challenges. During the audit we attempted to identify the universe of subcontractors for the Artemis campaign. This effort proved to be complex, and despite the aggregation and analysis of multiple data sources across NASA, we were unable to develop a complete list of subcontractors. However, we found that through the Agency's accounting system, the Agency tracks all contractors and suppliers that are directly funded by NASA, specifically those that are using a cost-reimbursement contract. Beyond those, the Agency has some insight into the subcontractors that the contracting officer has specifically identified through the consent to subcontract clause. However, this clause is only required in limited fixed-price situations, and we ultimately found NASA's insight into the subcontractors of the Artemis-related fixed-price contracts to be minimal. As the Agency attempts to move toward fixed-price and service-type contracts to mitigate cost and schedule risk, NASA's visibility into those primes' supplier chains will continue to diminish. This incomplete visibility into the supply chain leaves NASA further exposed to schedule risk and hinders NASA's strategic management of its supply chain.

Even when subcontractors and suppliers are known, their performance challenges are not broadly communicated across Artemis programs and projects to enable NASA to be better informed when making procurement decisions for other programs and projects. For example, according to Orion Program officials, one of Orion’s subcontractors has ongoing performance issues that may impact the Orion vehicles for future Artemis launches. However, these performance challenges were not shared across the Agency, and NASA ultimately selected the same subcontractor as a prime contractor for another Artemis-related system. According to Orion Program officials, if they had known this company was being considered for another NASA award, they would have shared their concerns with the appropriate officials. Over the past year, the subcontractor’s management, schedule, and performance for the Orion Program continues to decline, as does its performance as a prime contractor for the other system.

According to federal contracting guidance, prime contractors are responsible for managing their subcontractors.¹³ As such, the Artemis programs and projects rely on their prime contractors to track supplier challenges and mitigate issues as needed. The prime contractors are under no obligation to communicate known issues with their subcontractors or suppliers to NASA until there is a risk that the program’s schedule or costs will be impacted. However, this leaves NASA to address risks reactively rather than proactively. For example, both the Gateway and Orion Programs are experiencing schedule delays related to obtaining EEE parts that may impact launch dates. While NASA is developing mitigation plans with the contractor to address these issues, increased visibility of its subcontractors may allow the Agency to identify and address these challenges sooner and minimize potential schedule impact.

Space Industrial Base Hindered by Recent and Ongoing Global Events

Over the past several years, suppliers have been negatively impacted by COVID-19, inflation, and the Russia-Ukraine conflict, which in turn have affected the space industrial base—the total number of suppliers available to meet NASA’s needs. Overall, these major global events have caused significant fluctuations in the U.S. space market that are affecting the Artemis campaign. For example, the Mobile Launcher 2 (ML-2) project office reported a significant cost and schedule risk concerning volatile market pricing due to supply chain issues related and unrelated to COVID-19 and global labor shortages.

COVID-19 Impact. Several prime contractors for Artemis systems reported negative impacts of COVID-19. Lockheed Martin reported that its supply base was impacted by COVID-19 between 2020 and 2021, contributing to increased lead times. Some of its sub-tier suppliers shut down their facilities due to local restrictions, and employee exposure/sickness affected program plans as well. Lockheed Martin also noted that some suppliers requested equitable adjustments due to impacts from COVID-19. Bechtel, the prime contractor for the ML-2, cited staff attrition following the onset of COVID-19, with more people leaving the workforce or opting for positions that offer telework or remote work.

Inflation. According to the SLS Program, prime contractors have been affected by wage and material cost increases. Projected inflation in prices for labor and materials represent a risk to the program’s purchasing power, resulting in funding inefficiencies and cost and schedule growth. NASA’s Office of the Chief Financial Officer is tracking how global and U.S. inflation adversely impact NASA’s purchasing power and may jeopardize the Agency’s ability to complete all planned missions within current cost and

¹³ FAR 42.202(e)(2), *Assignment of Contract Administration*.

schedule estimates. Officials from Boeing, the SLS Program’s Stages prime contractor, also expressed concerns regarding inflation and its impact on procuring materials and parts at previously agreed-upon rates.

Russia-Ukraine Conflict. The conflict in Ukraine has exacerbated supply chain disruptions by impacting the movement of raw materials and industrial parts. Russia and Ukraine are responsible for approximately 25 to 30 percent of the global supply of the noble gases xenon and krypton and approximately 40 to 50 percent of the global supply of neon. Boeing officials explained that it has had difficulty procuring neon, which is used for the semiconductor wafer “printing” process. Similarly, the Power and Propulsion Element project under the Gateway Program reported slight impacts in efforts to obtain xenon, which is necessary for propulsion systems. However, according to NASA officials, as of August 2023, NASA’s primary contractor for the Power and Propulsion Element—Maxar—has successfully mitigated the risk and procured the xenon needed for this system.

Contractor Workforce Challenges Exacerbate Schedule Delays

Workforce challenges have been a long-standing issue for NASA that can result in major impacts on the supply chain for both prime contractors and their suppliers within the space industry. Several of NASA’s prime contractors reported that they are struggling to hire and retain a qualified workforce, an issue that can extend the time suppliers need to fulfill orders. As more contractors have entered the space industry, the competition for qualified engineers has grown. For government contractors, this has led to issues such as meeting the higher salary demands of the engineering workforce, resulting in difficulties hiring and retaining experienced engineers. Furthermore, during the COVID-19 pandemic many suppliers were forced to lay off workers and have since experienced trouble rebuilding their workforce with knowledgeable and trained employees. As the space industrial base struggles to hire and retain a qualified workforce, prolonged periods of understaffing contribute to parts delays and long lead times.

Underutilizing the Agency’s Logistics Management Division Hinders Mitigation of Supply Chain Risks

While NASA’s Logistics Management Division (LMD) is a useful resource for the Artemis programs and projects, we found it is not consistently utilized. LMD is composed of trained logisticians that analyze life-cycle management and supply chains by working jointly with suppliers and NASA programs. Logisticians work with the program and project officials to estimate material and supply requirements, along with funding needs, as the project progresses from formulation through completion. Using their expertise in logistics management, LMD logisticians can help the programs better understand their component and resource needs earlier in the purchasing process, thereby assisting them to acquire necessary supplies within a reasonable amount of time. In addition, they can provide support throughout a project’s life cycle, including supply sourcing, maintenance strategies, obsolescence planning for components, and diminishing manufacturing capabilities.

However, LMD officials stated that many of these logistician duties are assigned to others within the Artemis programs and projects, such as program engineers, program managers, and contractors, who may lack logistics expertise. Though NASA directives state the importance of having life-cycle support management from the start of a program, historically LMD officials are only included when there is an

identified issue, at which point it can be difficult to bring a program back on track.¹⁴ In contrast to NASA, internal DoD policy directs programs to embed life-cycle logisticians into their major programs.¹⁵ Looking forward, in our judgment, to help identify and mitigate some of the supply chain risks more quickly, LMD personnel should be embedded more fully into the Artemis programs. The logisticians have access to deficiency reporting systems and can forecast parts that may be outdated or becoming obsolete. With this level of supply chain detail, Artemis program officials, in conjunction with LMD, could make better informed decisions from the requirements establishment process through project completion to ensure project success.

National Security Projects Receive a Higher Priority than NASA in the Supplier Queue

NASA's Artemis programs and projects have encountered numerous schedule delays because they rank lower in the priority order compared to the DoD's national security projects for obtaining necessary parts and materials from suppliers. The priority rating system, known as the Defense Priorities and Allocations System (DPAS), is administered by the Department of Commerce and prioritizes national defense-related contracts and orders throughout the U.S. supply chain to support military, energy, homeland security, emergency preparedness, and critical infrastructure requirements. The DPAS regulation establishes two priority levels, DX and DO.¹⁶ A DX rating takes precedence over DO, is assigned to those programs of the highest national priority, and must be approved by the Secretary of Defense. While not all NASA contracts are assigned a DPAS rating, some Artemis contracts have received the second level rating of DO. Despite having this rating, order fulfillment is delayed if a supplier receives a DX-rated order, as all work on NASA and other DO-rated contracts stops until the DX-rated contract needs are met. Several Artemis prime contractors and Artemis-related programs expressed concerns about the schedule delays that result from this priority ratings system. For example, the SLS Program reported that work on Core Stage 2 will be delayed by 3 months because the supplier for feedlines needs to fulfill DX-rated contracts before SLS contracts.

NASA's Strategic Oversight of its Supply Chain Is Evolving as Efforts to Manage Disruptions Are Focused on Immediate Needs

NASA's Efforts to Strategically Oversee Its Supply Chain are Evolving

NASA has initiated several efforts to gain a more comprehensive understanding and improve cross-program visibility into its supply chain. NASA officials stated that improving visibility will better

¹⁴ NASA Policy Directive 7500.1D, *Program and Project Life-Cycle Logistics Support Policy* (March 2, 2015) states "Program Managers and Project Managers or their designated Life-Cycle Logistics Support Managers shall: (1) Integrate life-cycle logistics support considerations beginning with program/project conception, including: (a) Participation in the design process beginning at program/project conception to ensure that systems are supportable."

¹⁵ DoD guidance outlines the various life-cycle logistics responsibilities and procedures for product support managers, such as developing a Life Cycle Logistics Plan and providing input to design and contract development.

¹⁶ A DX rating is used for contracts and orders of highest national defense urgency. A DO rating is used for contracts and orders critical to national defense.

position them to strategically manage the array of supply chain challenges. Two internal databases—Insight Central and PrimeE—are attempting to provide increased awareness of the past, present, and future of NASA’s supply chains. Meanwhile, two collaboration efforts—the Supply Chain Resiliency Forum and Holistic Agency Study—seek to improve NASA’s understanding of and intra-agency communication about supply chain issues. While we commend NASA on its efforts to improve visibility into its supply chain, these efforts remain early in their implementation with no discernible results yet. Additionally, individual Artemis program and project offices are not yet directly involved in these efforts, raising the possibility that efforts to improve strategic oversight of the Agency’s supply chain may not be fully leveraged by the Artemis campaign.

Insight Central

Insight Central provides users with information about individual suppliers, such as the NASA programs and projects they serve, current contracts, and any detailed supplier reports performed by the Agency.¹⁷ The database has been operational since March 2021, less than 2 years after creation of the SCRM Program in October 2019. Currently, the database requires manual input from program personnel to remain up to date. However, program personnel across the Agency are not regularly inputting data, either by choice or because they are not aware the database exists. As a result, while some suppliers are in the database, there is little information about products they provide or if they have encountered past performance issues. The lack of complete and up-to-date data is particularly noticeable for Artemis programs and projects, with much of the existing information focused on smaller, uncrewed systems.

In addition, even when relevant information on Artemis suppliers is present, Artemis program officials do not consult the database. For example, Masten Space Systems, an aerospace manufacturer that was awarded a \$75.9 million Commercial Lunar Payload Services (CLPS) contract by NASA in 2020, filed for bankruptcy in July 2022.¹⁸ In 2021, a report uploaded to Insight Central noted Masten’s “vulnerability to economic conditions and risks as a small, privately held enterprise” and “lack of available information on the management of suppliers and overall supply chain.” Prior to announcing bankruptcy, Masten’s inaugural mission was delayed by a year due to supply chain issues. A more enterprise-wide and consistent use of Insight Central could have alerted NASA to this risk and enabled more proactive schedule management rather than noting it after it already occurred. Further, improved Agency insight prior to awarding the contract would have revealed the company’s financial risk, which could have been considered during the acquisition process.

In addition to NASA program personnel, we also found that the Agency’s contracting officials are not regularly utilizing this database to identify supplier issues or industrial base challenges before approving subcontract requests. Per federal guidance, the contracting officers are required to review proposals and provide their formal written consent or non-consent to the prime contractor to use a

¹⁷ The detailed supplier reports are Supplier Research and Analysis Reports, which provide a detailed view of a supplier’s business management; design, production, and technical risks; security issues; and any other concerns.

¹⁸ Initiated in 2018, NASA’s CLPS initiative is intended to allow rapid acquisition of lunar delivery services from American companies for payloads that advance science, exploration, and commercial development of the Moon. As part of the Lunar Discovery and Exploration Program in the Science Mission Directorate, CLPS awards cover end-to-end delivery services including integration, launch and landing, and mission operations. NASA OIG initiated an audit of the CLPS initiative in May 2023.

subcontractor.¹⁹ However, many NASA program officials noted that they do not provide input on who the prime contractors should select as subcontractors.

Insight Central is a key piece of NASA's efforts to increase supply chain visibility throughout the Agency. In general, the SCRM Program hopes the database will enable more proactive supply chain management across NASA through the identification of domestic sourcing challenges and associated alternatives or mitigations. Specific upcoming Insight Central developments include incorporation of data from several sources, including a database from the Defense Contract Management Agency (DCMA) that includes quality and delivery information; an extensive civil space industrial base survey; and a Supply Chain Visibility Data Requirement Description (DRD) document to obtain supplier data from prime contractors.

PrimeE

A similar but separate supply chain database is PrimeE, managed by NASA's LMD. PrimeE—drawing primarily from the System for Award Management and the Federal Procurement Data System—has multiple capabilities, including overlaying supply chain visualizations onto maps that display various types of risks.²⁰ An early version of PrimeE was developed 15 years ago to help simulate the economic impact from the retirement of the Space Shuttle Program. At the time, program officials were interested in learning more about the lower tiers of their supply chains: who the most critical suppliers were, which suppliers would be needed for the follow-on program, and who were the sole-source suppliers (i.e., companies that were the only ones manufacturing a particular product). After helping answer those questions, the database was shelved for the next several years.

Currently, PrimeE has several focus areas for its analysis and modeling capabilities, such as identifying sole- and alternate-source suppliers and mapping relationships between suppliers and NASA programs—visualizing a program's supply chain for multiple tiers. As a test case, LMD partially mapped the supply chain for RS-25 engines—four of which are used on each SLS flight—with overlaid risks. The tool can also run different economic resiliency simulations based on different scenarios (e.g., variability in demand, financial liquidity of a supplier) to measure the health of a segment of the industrial base. In this sense, PrimeE shows promise because it can identify future supply chain issues rather than only reporting issues that have already occurred. Moving forward, LMD plans for PrimeE to complement—not replace—existing supply chain tools such as Insight Central. While LMD officials stated they would be interested in ensuring PrimeE and Insight Central interact with one another, the SCRM Program has not currently agreed to this type of interface.

Supply Chain Resiliency Forum

Formed in March 2022, the SCRF serves as a discussion forum for representatives from across the Agency to coordinate, communicate, and gather information about supply chain-related activities. As of July 2023, the SCRF continues to develop its mission and goals and plans to establish a charter by the end of FY 2023. The group is composed of members with other full-time duties and therefore is often a secondary priority. Further, not all Centers or Mission Directorates are represented in the group (nor is anyone from the aerospace industry), though there have been a notable number of external

¹⁹ FAR Subpart 44.2, *Consent to Subcontracts*. Further, the NASA FAR Supplement 1844.202-1(b), *Consent to Subcontracts, Responsibilities*, requires contracting officers to document subcontract consent reviews using the Subcontract Consent Review template.

²⁰ The System for Award Management is a government-wide registry for vendors doing business with the federal government. The Federal Procurement Data System is the real-time database that serves the government acquisition community as the authoritative source of contract information.

engagements with other agencies and organizations to discuss supply chain efforts.²¹ In addition to sharing ongoing efforts and benchmarking supply chain management techniques against other federal agencies, the SCRF is working with NASA's Office of Procurement to develop the Supply Chain Visibility DRD for inclusion into prime contracts.

The Supply Chain Visibility DRD will contractually mandate that NASA's prime contractors provide supply chain information on the top three levels of a program's supply chain—the prime, the prime's subcontractors, and the subcontractors' suppliers. As of July 2023, the DRD was not yet finalized, though NASA plans to have this in place by the beginning of FY 2024. Contractors will submit the data to NASA, which will then house it within Insight Central. Once the data from the DRD is incorporated into Insight Central, anyone at NASA will be able to share issues they might have with a supplier, further increasing information sharing across programs and the Agency overall. The requirement will apply to procuring products and services for programs and projects on NASA's Agency Mission Program and Project List, which includes Artemis projects like the SLS Block 1B Development, ML-2, and the Gateway's Power and Propulsion Element. NASA will implement the DRD on new procurements that meet certain requirements, with the option to incorporate it into existing contracts.

The goal is for prime contractors to provide this information freely to NASA, though several Agency officials told us that major primes have indicated they are unwilling to do so, citing costs associated with gathering the information. While this data collection is a crucial first step, the database will only be helpful if NASA personnel use it. To that point, several program officials we interviewed doubted the usefulness of a comprehensive supply chain database, instead preferring that NASA's prime contractors manage the issue.

Holistic Agency Study

Another ongoing Agency effort to better understand its supply chains is the Holistic Agency Study. Led by representatives from NASA's Office of Technology, Policy and Strategy and Office of the Chief Engineer, the study was conducted from late 2021 to 2023. The study used a broad survey of NASA stakeholders to learn how supply chain management is handled across the Agency—in addition to specific issues they face—and will ultimately provide recommendations to NASA upon its release, expected during summer 2023. As of June 2023, preliminary results highlight NASA's siloed supply chain structure, with various groups working on their own issues, and the lack of a cohesive approach or awareness across Centers, programs, and projects. Further, initial results from the study show that supply chain issues are almost always a surprise to NASA, resulting in reactive "crisis management" by programs and projects. While solutions are usually found, NASA lacks an integrated approach or cross-project resolution to the problem. As of July 2023, the final report has not been released.

NASA and Contractor Efforts to Mitigate Supply Chain Disruptions Focus on Specific and Immediate Challenges

In addition to taking steps to increase visibility into the supply chain, the Artemis programs and their prime contractors are taking some measures to mitigate the numerous supply chain disruptions. While these efforts vary between NASA and its contractors, NASA's actions are primarily reactive whereas the

²¹ As of January 2023, SCRF membership included representatives from the following groups: Office of the Administrator; Common Exploration Systems Development Division; Science Mission Directorate; Space Technology Mission Directorate; Office of the Chief Engineer; Office of Technology, Policy and Strategy; Office of International and Interagency Relations; Office of Procurement; Office of the Chief Financial Officer; and Office of Safety and Mission Assurance. All representatives are located at NASA Headquarters.

contractors' actions include proactive strategies. Both of these approaches have experienced varying degrees of success.

When faced with supply chain challenges, NASA has taken action to rearrange resources from one project to another, authorized advance procurements, and coordinated with DoD for critical components:

- The Orion, SLS, and EGS programs have coordinated with other programs and projects to procure and share resources to mitigate schedule disruptions. When the Orion Program needed two valves, it coordinated with the SLS Program to purchase the valves on the existing SLS contract, eliminating a lengthy procurement process. Similarly, within the SLS Program, the Boosters project office provided batteries to the Stages project to be used for qualification testing purposes. Additionally, the ML-1 and ML-2 project offices, within the EGS Program, worked together to ensure tubing necessary for ML-1 repairs after the Artemis I launch would be available to meet Artemis II launch goals. The ML-2 project, which did not need the tubing at that time, was able to provide the tubing to ML-1, thereby avoiding a 12-week delay.
- Another step NASA is taking is to authorize the purchase of parts earlier in a project. After the Stages project office experienced schedule delays for propulsion parts with Core Stages 3 and 4, the office authorized the contractor to start purchasing the propulsion parts earlier than planned to mitigate those issues for Core Stages 5 and 6. This advanced purchasing is intended to prevent schedule slips resulting from late deliveries.
- Finally, NASA has developed partnerships through the Space Industrial Base Working Group, a multi-agency partnership focused on establishing and sustaining the U.S. space industrial base, to assist with supply chain issues.²² On one occasion, NASA noticed that a major supplier for reaction wheels was de-prioritizing Agency orders.²³ The Space Industrial Base Working Group provided NASA with funding to assist another supplier with producing reaction wheels, which alleviated some of the order backlog.

In contrast, NASA's prime contractors utilize a variety of tools, including bulk-buys, in-house manufacturing, and maintaining supplier databases, to proactively mitigate supply chain disruptions. For example, bulk ordering allows a contractor to build an internal inventory of common items instead of making an order for a component as needed. Similarly, in-house manufacturing allows the contractor to avoid long lead times from their suppliers. Another technique contractors use is managing supply chain dashboards and databases to maintain insight into their supply chains. These databases can store information about suppliers and be used to provide a supplier rating, which is determined by assessing supplier deliveries, technical performance, and adherence to deadlines. Table 2 outlines several other mitigation measures used by Artemis prime contractors.

²² The Space Industrial Base Working Group is composed of NASA and other U.S. spacefaring agencies and includes members from the Missile Defense Agency, Office of the Secretary of Defense, Defense Logistics Agency, and Air Force Research Laboratory. Part of the working group's focus is to establish and sustain sufficient demand in the U.S. market to support the U.S. space industrial base.

²³ Reaction wheels are used to provide attitude control—or orientation while in orbit—and stability on a spacecraft.

Table 2: Artemis Contractor Supply Chain Mitigation Techniques

| Techniques | Description/Intended Benefits |
|---|---|
| Bulk-buys for common parts | Saves money and increases stock of parts on hand to use across programs |
| Ongoing and direct communication with suppliers | Facilitates discussions of supply chain issues |
| Leverage company’s own financial resources | Allows for earlier ordering of parts and materials to lessen the risk of schedule slippage from delivery delays |
| In-house manufacturing | Streamlines acquisition processes and vertically integrates supply chain |
| Involving NASA to promote the mission directly to suppliers | Spotlights supplier’s role in unique and exciting space flight missions direct from the Agency |
| Seeking products internationally | Widens the industrial base when domestic suppliers cannot meet schedule/requirements |
| Internal dashboard/database | Tracks subcontractor and supplier performance |

Source: NASA OIG summary of interviews with Artemis contractors.

Other Agencies and Industries Offer Best Practices and Benchmarking Opportunities for NASA

As part of our review, we identified a variety of supply chain management best practices and benchmarking opportunities from other federal agencies, an international partner, and private sector companies. Specifically, we found that the Navy, Army, Air Force, and DCMA are each, to varying degrees, refining their insight into their supply chains. In addition, the European Space Agency (ESA)—one of NASA’s main international partners for the Artemis campaign—illustrates how NASA can improve its management of unique supply chains. Further, we researched best practices from private sector companies outside of the space flight sector—the automobile industry, in particular—that face similar supply chain difficulties to NASA.

Department of the Navy

In 2014, the Department of the Navy began developing a supply chain database that now allows it to identify its most critical suppliers based on several factors, including parts with long lead times, high dollar values, and those from single or sole sources. The main data sources for the database include shipyard purchase orders—which outline individual parts purchased, the cost of the part, and information about the supplier—as well as supplier quality and delivery data from the Navy’s Product Data Reporting and Evaluation Program (PDREP) database.²⁴ In recent years, the Navy began implementing Contract Data Requirement Lists (a required data submission from the contractor similar to NASA’s DRDs) into contracts to require shipbuilders to continue to provide this information. Codifying these requirements into major contracts allows the Navy to receive vast quantities of data it

²⁴ PDREP enables the reporting, collection, and use of supplier performance information. It supports the Navy’s oversight and management of the supply chain, ensuring first time quality and on-time delivery of materials. Information housed in the database includes material deficiencies, engineering reports, supplier audits, and surveys.

can use to maintain visibility into its supply chains. NASA is currently developing the Supply Chain Visibility DRD that would provide the Agency with similar supply chain information from its prime contractors.

Department of the Army

One office we spoke to within the Department of the Army gains extensive insight into its supply chains by utilizing an existing contract vehicle with a third-party service. While the service is costly, the capabilities are robust, and Army officials told us it is extremely useful.²⁵ Dashboards are populated with supplier data from bills of material from several Army programs and supplemented with open-source data and reports created using artificial intelligence. These dashboards, as well as specialized reports, provide more transparency and traceability of the Army's critical suppliers compared to NASA. For example, recent reports include one that provides a detailed assessment of a particular raw material and an evaluation of a key supplier based on several risk factors, including foreign influence, hardware, and financial solvency. Overall, this service allows for easier identification of, for example, program bottlenecks or suppliers with foreign ownership. In contrast, NASA has no such capability and must rely heavily on its prime contractors to maintain lower tier visibility into supply chains. As a result, NASA lacks early visibility into any challenges with or concerns about suppliers that may ultimately impact program costs and schedule.

Department of the Air Force

The Department of the Air Force is collaborating with NASA's Aeronautics Research Institute to lead a supply chain working group for NASA's Advanced Air Mobility mission. While the group is mostly an educational forum given the nascency of the drone market its members are studying, the working group actively engages with industry to establish relationships and discuss ideas. According to working group leadership, suppliers embraced the opportunity to meet with the Air Force and NASA to engage on these issues.

In comparison, NASA's SCRF does not have representation from each Agency Mission Directorate or any program-level personnel, let alone anyone from industry. Based on the amount of insight gleaned from our discussions with Artemis prime contractors, a fuller and more holistic membership for the SCRF would provide additional perspectives on important supply chain issues.

Defense Contract Management Agency

DCMA is taking several actions to improve its supply chain management. The agency is transitioning from two separate internal databases to the Navy's PDREP database to oversee its supply chain management and increase the fidelity of data on its suppliers.²⁶ Additionally, as a best practice, DCMA ensures a logistician or quality assurance individual is integrated on a contract from start to finish for better oversight and proactive resolution. As noted earlier, NASA does not fully utilize its logistics personnel for Artemis programs.

Separately, NASA could better utilize DCMA's contract administration capability to improve its overall supply chain management. Contract administration is an important component of supply chain

²⁵ According to General Service Administration representatives, the fee for the system is about \$90,000 per year, with the cost of individualized reports ranging from a few thousand to several hundred thousand dollars.

²⁶ NASA's SCRM Program is also working to leverage PDREP by connecting data from the PDREP into the Agency's Insight Central database.

management, given that supply chain management should occur throughout a program's life cycle. Effective contract administration can improve supply chain management by mitigating risks and improving relationships with suppliers. To this end, DCMA has extensive experience administering complex contracts on behalf of other agencies with defense suppliers, many of whom also supply to NASA. While both DCMA and NASA officials are often physically located in a contractor's facility, DCMA officials told us that the biggest advantage that DCMA has over NASA when it comes to contract administration is that, unlike NASA, DCMA is not the buying authority (e.g., Navy, Army, Air Force). According to DCMA officials, this lack of buying authority allows for a more independent assessment of a contractor's progress and performance, including its management of its subcontractors and suppliers.

Despite DCMA offering to perform full or partial contract management for NASA at a minimal cost, according to DCMA representatives, NASA does not utilize DCMA expertise as often as it could. To its credit, NASA has been working with DCMA since 2021 to develop a Memorandum of Understanding (MOU) to better align expectations and responsibilities between the two agencies with respect to contract administration services. The MOU is expected to be signed later this calendar year and would create an Executive Steering Group, co-led by representatives of each agency, with an aim to improve communication, planning, and resource-sharing between the agencies. One priority of the MOU is to increase leveraging of DCMA's capabilities, specifically in identifying supply chain risks. Overall, the agreement will allow NASA to take better advantage of what is currently an underutilized resource for its supply chain management.

European Space Agency

The European Space Agency (ESA) has several supply chain management methods from which NASA could learn. These include centralized Artemis project management support, periodic assessment of key suppliers, and contractual requirements for primes to report suppliers. ESA officials specifically noted that the close physical proximity of its Artemis program and project management personnel is beneficial for information sharing about supplier issues and a stark contrast to NASA's approach, in which Artemis programs are spread across multiple Centers.

Automobile Manufacturing Industry

U.S. automobile manufacturers use various techniques to proactively manage their supply chains. In response to the global microchip shortage and other pandemic-related disruptions, one automaker emphasized improved monitoring systems. This involved identifying the most important links in the supply chain, flagging issues in real time, and investing in digital tools to track signals, all of which was overseen by a newly created team with a codified governance structure and process. In the industry as a whole, enhanced visibility into lower tiers of supply chains to identify "bottleneck suppliers" was identified as a critical capability.

CONCLUSION

NASA relies on contractors to build key components of the ambitious Artemis campaign, such as the SLS, Orion, two mobile launchers, HLS, Gateway, and extravehicular spacesuits. As of March 2023, NASA has obligated approximately \$40 billion to 860 contractors in support of the Artemis campaign, and 59 of those contractors support five Artemis programs—SLS, Orion, EGS, HLS, and Gateway. Further, NASA’s contractors employ a network of subcontractors and suppliers to provide necessary hardware and services.

Numerous challenges to these supply chains have resulted in limited supplies and materials. These challenges are affecting both NASA and its prime contractors, leading to cost increases and schedule delays to meet the Artemis program and project goals. Critical components and resources, such as valves, EEE parts, and helium, are often not available when needed. Further, delivery of the Orion vehicle for Artemis III has been delayed by 11 months because of supply chain issues. Nonetheless, these cost and schedule increases do not reflect the total supply chain-related impact for the Artemis campaign as NASA does not track supply chain effects separately on its prime contracts. Currently, the Artemis program and project officials rely on the prime contractors to understand and track their supply chain issues, leaving NASA in a reactive mode to mitigate the effects.

NASA does not have comprehensive visibility into the Artemis campaign’s subcontractors or sub-tier suppliers, preventing NASA from strategically managing the numerous and ongoing challenges affecting the Artemis supply chain. Further, factors such as geopolitical issues, workforce challenges, failure to incorporate NASA’s logisticians throughout the contracts’ lifecycle, and competition with DoD over products from a limited number of suppliers all contribute to the Agency’s supply chain issues. NASA’s efforts to improve internal databases and encourage greater collaboration are ongoing and still evolving and have not yet produced the necessary visibility to increase NASA’s strategic management of the Artemis supply chain.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To improve NASA's management and visibility into its supply chain, we recommended the Executive for the Supply Chain Resiliency Forum:

1. Establish a charter for the existing Supply Chain Resiliency Forum, to include representation from the Moon to Mars Program Office and major Artemis prime contractors.
2. Complete the Supply Chain Visibility Data Requirement Description effort to gain supplier data from contractors.
3. Provide training to contracting officers on FAR Subpart 44.2 - Consent to Subcontracts, so that the contracting officers will utilize available supplier data to determine whether the contractor should enter a contract with a particular subcontractor.

To improve NASA's management of the Artemis supply chain, we recommended the Associate Administrator for Exploration Systems Development Mission Directorate:

4. Centralize supply chain management for the Artemis campaign within the Moon to Mars Program Office.
5. Ensure data is regularly entered into a supplier database (e.g., Insight Central) to track supplier data and ongoing challenges.
6. Incorporate a representative from the Logistics Management Division into each Artemis-related program and project at appropriate milestones, including at the onset of a contract and each life-cycle milestone.
7. Ensure an Artemis-specific study of the Agency's industrial base and supply chain is completed on a recurring basis.

We provided a draft of this report to NASA management who concurred with recommendations 1, 2, 3, 4, 5, and 7, and partially concurred with recommendation 6. We consider management's comments responsive to recommendations 1, 3, 4, 5, and 7, and therefore those recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions. However, we found the Agency's response to recommendations 2 and 6 unresponsive. Consequently, those recommendations will remain unresolved pending further discussions with the Agency.

NASA concurred with recommendation 2 to complete the Supply Chain Visibility Reporting DRD, which will provide the Agency with data for three tiers of suppliers to better understand its supply chains. While the Agency notes the DRD will be applied to new procurements under certain criteria, it does not mention if it will be applicable to NASA's many existing Artemis-related contracts. In our judgment, without including existing Artemis-related contracts in its reporting, the Agency will be missing key data necessary to comprehensively identify subcontractors and sub-tier suppliers supporting the Artemis campaign.

NASA partially concurred with recommendation 6 to incorporate a representative from the Logistics Management Division (LMD) into Artemis programs and projects at appropriate milestones, stating that the Agency will consider utilizing a representative for key program life-cycle reviews and assessments conducted at the Moon to Mars Program Office level. While we are encouraged that NASA will “consider utilizing” an LMD representative, in our judgment, embedding LMD personnel more fully into the Artemis programs will improve identification and mitigation of supply chain risks. As we note in our report, LMD personnel have access to deficiency reporting systems and can forecast parts that may be outdated or becoming obsolete. With this level of supply chain detail, Artemis campaign officials, in conjunction with LMD, could make better informed decisions from the requirements establishment process through project completion to ensure project success.

Management’s comments are reproduced in Appendix B. Technical comments provided by management and revisions to address them have been incorporated as appropriate.

Major contributors to this report include Ridge Bowman, Human Exploration Directorate Audits Director; Susan Bachle, Assistant Director; Victoria Adams; Areeba Hasan; Tyler Martin; Sarah McGrath; Courtney Daniels; Shari Bergstein; Jeremy Brown; Cody Bryant; Daniel Mills; Carlyle Webb; and Shani Dennis.

If you have questions about this report or wish to comment on the quality or usefulness of this report, contact Laurence Hawkins, Audit Operations and Quality Assurance Director, at 202-358-1543 or laurence.b.hawkins@nasa.gov.

Paul K. Martin
Inspector General

APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from August 2022 through September 2023 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.

In this audit, we assessed NASA's management of the Artemis campaign's supply chain to meet its human exploration goals, to include reviewing supply chain challenges and risks and processes to identify and mitigate supply chain issues. To assess NASA's supply chain management processes and NASA's visibility into the Artemis campaign supply chain, we conducted interviews with representatives from the SCRF, SCRM Program, LMD, Holistic Agency Study, Office of the Chief Engineer, and Artemis campaign program, project, and procurement officials. We also received access to the Insight Central database and independently analyzed the information included in the database.

To understand the challenges facing both NASA and the prime contractors we developed and sent detailed questionnaires to NASA program, project, and procurement representatives as well as the Artemis prime contractors. We sent detailed questionnaires to each of the Artemis programs and projects—EGS, Extravehicular Activity and Human Surface Mobility, Gateway, HLS, Orion, and SLS programs—to include 69 individuals. We received responses from 25 individuals, providing representation from each of the Artemis programs and projects. We also sent detailed questionnaires to nine Artemis prime contractors and received responses from all nine: Axiom, Bechtel, Boeing, Collins, Dynetics, Lockheed Martin, Maxar, Northrop Grumman, and SpaceX. The prime contractors that did not agree to a follow-up interview to discuss their responses included Bechtel and Boeing. All responses were received electronically. The results of these surveys, including follow-on interviews with select respondents, were incorporated throughout the report. We also reviewed federal and NASA requirements, including regulations on quality assurance and Executive Orders.

To identify critical suppliers to the Artemis campaign, we reviewed the NASA and prime contractor survey responses and conducted interviews with select Artemis program and project representatives, SCRM Program officials, and select prime contractors. We reviewed the CARITL, presentations concerning critical parts and suppliers, and supply chain risks affecting program costs and schedule. We also obtained a list of the subcontractors and suppliers from NASA for the Artemis campaign prime contracts, although the list was not comprehensive. We further obtained known subcontractor and supplier data from NASA's accounting system and from USA Spending. Utilizing Power BI, we developed an Artemis Supply Chain Dashboard of subcontractors and suppliers that NASA contracts with directly and are used by the prime contractors using those three data sources. We identified critical suppliers that are utilized by multiple Artemis programs and projects and by their prime contractors.

For benchmarking purposes, we conducted interviews with representatives from other government agencies, including the departments of the Navy, Air Force, and Army and DCMA. We also reviewed best practices from automobile manufacturing industries. We further developed and sent questionnaires to both the European Space Agency and Japanese Aerospace Exploration Agency. However, only the European Space Agency responded to the questionnaire.

Assessment of Data Reliability

We used computer-generated data while performing this audit. We reviewed and analyzed NASA obligation and funding data for FYs 2012 through 2022 in NASA's financial accounting system. The obligation and funding data were mainly derived from Artemis mission costs: EGS, SLS, Orion, HLS, and Gateway. We assessed the reliability of the financial data by (1) verifying the data with the NASA OIG's Office of Data Analytics, Artemis Supply Chain Dashboard, and Government Spending Open Data (<https://usaspending.gov>); (2) reviewing data provided by NASA's directorates and divisions, and the prime (if furnished); and (3) interviewing Agency officials knowledgeable about this data. We determined that the data was sufficiently reliable for the purposes of this report. As mentioned previously in the report, we concluded that the Insight Central database is a work in progress and incomplete. As a result, we did not use data from Insight Central for this report.

Review of Internal Controls

We reviewed and evaluated the internal controls associated with NASA's supply chain management of the Artemis campaign. We also reviewed appropriate policies, procedures, and regulations, and conducted interviews with responsible personnel. We concluded that the internal controls were adequate, but because our review was limited to these internal control components and underlying principles, it may not have captured all internal control deficiencies at the time of this audit. Our recommendations, if implemented, will correct the identified control weaknesses.

Prior Coverage

The NASA OIG and the Government Accountability Office have issued 23 reports containing significant relevance to the subject of this report. Unrestricted reports can be accessed at <https://oig.nasa.gov/audits/auditReports.html> and <https://www.gao.gov> respectively.

NASA Office of Inspector General

NASA's Management of the Space Launch System Booster and Engine Contracts ([IG-23-015](#), May 25, 2023)

NASA's Partnerships with International Space Agencies for the Artemis Campaign ([IG-23-004](#), January 17, 2023)

NASA's Management of the Mobile Launcher 2 Contract ([IG-22-012](#), June 9, 2022)

NASA's Management of the Artemis Missions ([IG-22-003](#), November 15, 2021)

NASA's Development of Next-Generation Spacesuits ([IG-21-025](#), August 10, 2021)

Artemis Status Update ([IG-21-018](#), April 19, 2021)

COVID-19 Impacts on NASA's Major Programs and Projects ([IG-21-016](#), March 31, 2021)

NASA's Management of the Gateway Program for Artemis Missions ([IG-21-004](#), November 10, 2020)

NASA's Management of the Orion Multi-Purpose Crew Vehicle Program ([IG-20-018](#), July 16, 2020)

NASA's Development of Ground and Flight Application Software for the Artemis Program ([IG-20-014](#), March 19, 2020)

Audit of NASA's Development of its Mobile Launchers ([IG-20-013](#), March 17, 2020)

NASA's Management of Space Launch System Program Costs and Contracts ([IG-20-012](#), March 10, 2020)

NASA's Management of the Space Launch System Stages Contract ([IG-19-001](#), October 10, 2018)

Audit of NASA's Information Technology Supply Chain Risk Management Efforts ([IG-18-019](#), May 24, 2018)

NASA's Management of Spare Parts for its Flight Projects ([IG-18-001](#), October 5, 2017)

NASA's Management and Development of Spacesuits ([IG-17-018](#), April 26, 2017)

NASA's Plans for Human Exploration Beyond Low Earth Orbit ([IG-17-017](#), April 13, 2017)

NASA's Parts Quality Control Process ([IG-17-016](#), March 29, 2017)

NASA's Management of the Orion Multi-Purpose Crew Vehicle Program ([IG-16-029](#), September 6, 2016)

Government Accountability Office

Space Launch System: Cost Transparency Needed to Monitor Program Affordability ([GAO-23-105609](#), September 7, 2023)

NASA: Assessments of Major Projects ([GAO-23-106021](#), May 31, 2023)

Supply Chain Resilience: Agencies Are Taking Steps to Expand Diplomatic Engagement and Coordinate with International Partners ([GAO-23-105534](#), February 2, 2023)

NASA: Assessments of Major Projects ([GAO-22-105212](#), June 23, 2022)

NASA Lunar Programs: Significant Work Remains, Underscoring Challenges to Achieving Moon Landing in 2024 ([GAO-21-330](#), May 26, 2021)

NASA Human Space Exploration: Significant Investments in Future Capabilities Require Strengthened Management ([GAO-21-105](#), December 15, 2020)

NASA Lunar Programs: Opportunities Exist to Strengthen Analyses and Plans for Moon Landing ([GAO-20-68](#), December 19, 2019)

APPENDIX B: MANAGEMENT'S COMMENTS

National Aeronautics and Space Administration

Mary W. Jackson NASA Headquarters
Washington, DC 20546-0001



Reply to Attn of: Exploration Systems Development Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Exploration Systems Development Mission
Directorate and Assistant Administrator for Procurement

SUBJECT: Agency Response to OIG Draft Report, "NASA's Management of the Artemis Supply Chain" (A-22-14-00-HED)

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "NASA's Management of the Artemis Supply Chain" (A-22-14-00-HED), dated September 6, 2023.

In the report, the OIG determined numerous challenges to these supply chains have resulted in limited supplies and materials. These challenges affected both NASA and its prime contractors, leading to cost increases and schedule delays to meet the Artemis program and project goals. The OIG opined that NASA does not have comprehensive visibility into the Artemis Campaign's subcontractors or sub-tier suppliers, preventing NASA from strategically managing the numerous and ongoing challenges affecting the Artemis supply chain.

Specifically, the OIG recommends the following:

Recommendation 1: Establish a charter for the existing Supply Chain Resiliency Forum, to include representation from the Moon to Mars Program Office and major Artemis prime contractors.

Management's Response: NASA concurs. The Agency-level Supply Chain Resiliency Board (SCRB) will be established in September 2023, in accordance with NASA policy and guidance. As set forth in the board's charter, "the SCRB supports the Acquisition Strategy Council (ASC) and the Chief Acquisition Officer (CAO) in advancing Agency strategy, policy, processes, capabilities, and organizational culture for (1) the pro-active assessment and management of supply chain and industrial base risks and opportunities to assure resilient NASA mission performance, and (2) the fulfillment of applicable U.S. Government policy and statutory requirements." The SCRB is a substantive evolution of the Supply Chain Resiliency Forum cited in the OIG report. The SCRB is designed to recommend courses of action and sustainable solutions to surmount the dynamic array of risks that threaten the provisioning of products and services required for NASA mission

success. SCRB membership consists of senior-level representatives of the member organizations, as follows:

- Office of the Administrator.
- Office of Technology, Policy, and Strategy.
- Office of International and Interagency Relations.
- Office of the Chief Engineer.
- Office of Procurement.
- Office of the Chief Financial Officer.
- Office of the Chief Information Officer.
- Office of Safety and Mission Assurance.
- Office of the General Counsel.
- Aeronautics Research Mission Directorate.
- Exploration Systems Development Mission Directorate.
- Science Mission Directorate.
- Space Operations Mission Directorate.
- Space Technology Mission Directorate.
- Mission Support Directorate.
- Other NASA organizations and/or subject-matter experts on a permanent or ad hoc basis as determined by the SCRB Chair in consultation with the ASC Chair as warranted.

NASA's engagement with prime contractors and suppliers under contract for Artemis programs and projects and other NASA programs and projects will continue in accordance with established programmatic responsibilities in conjunction with applicable procurement and contract management policies; thus, the SCRB charter does not provide for the representation of NASA prime contractors in the SCRB.

Estimated Completion Date: October 31, 2023.

Recommendation 2: Complete the Supply Chain Visibility Data Requirement Description effort to gain supplier data from contractors.

Management's Response: NASA concurs. It is planned to complete the Agency's review and approval of the proposed Data Requirements Description (DRD) for Supply Chain Visibility Reporting by prime contractors and an accompanying implementation plan via the Supply Chain Resiliency Board and the ASC and/or the CAO within the first quarter of fiscal year 2024. As currently formulated, the DRD will be applicable to new NASA procurements of products and services for programs and projects on the approved Agency Mission Program and Project List. The application and scope of the proposed DRD are further limited to supplier entities within the top three contractual tiers of NASA procurements (i.e., Tier 1: prime contractor to NASA; Tier 2: direct subcontractors to the prime contractor; Tier 3: direct suppliers to the direct subcontractors). The configuration of a secure application of the NASA Supply Chain Insight Central (SCIC) information services and analysis platform is under way to support the planned Supply Chain Visibility Reporting process and to provide integrated management of reported data and information for internal NASA planning, analysis, and

decision-making purposes. Initial and incremental implementation of the DRD for Supply Chain Visibility Reporting, as approved, is targeted for the second quarter of fiscal year 2024.

Estimated Completion Date: March 31, 2024.

Recommendation 3: Provide training to Contracting Officers on FAR Subpart 44.2 - Consent to Subcontracts, so that the Contracting Officers will utilize available supplier data to determine whether the contractor should enter a contract with a particular subcontractor.

Management's Response: NASA concurs. The Office of Procurement will provide refresher training to its contracting professionals on FAR Subpart 44.2, "Consent to Subcontracts." This training will include how to appropriately utilize supplier data when making consent to subcontract decisions.

Estimated Completion Date: September 30, 2024.

To improve NASA's management of the Artemis supply chain, we recommend the Associate Administrator for Exploration Systems Development Mission Directorate:

Recommendation 4: Centralize supply chain management for the Artemis campaign within the Moon to Mars Program Office.

Management's Response: NASA concurs. NASA recently incorporated a supply chain integration function within the Moon to Mars Program Office. The Artemis Integration Manager coordinates with Artemis programs and projects within the Moon to Mars Program Office to identify enterprise-wide supply chain issues and threats and works with the programs and other stakeholders on mitigation strategies. The Artemis Integration Manager also coordinates with other NASA organizations and internal stakeholders on supply chain assessments of Artemis programs and projects and Agency-level supply chain risk management initiatives. The Artemis Integration Manager is also responsible for providing regular status updates to Exploration Systems Development Mission Directorate (ESDMD) and Moon to Mars Program Office leadership on the Artemis supply chain, including issues, threats, and efforts under way, and serves as the ESDMD representative to the Supply Chain Resiliency Forum.

Estimated Completion Date: October 31, 2023.

Recommendation 5: Ensure data is regularly entered into a supplier database (e.g., Insight Central) to track supplier data and ongoing challenges.

Management's Response: NASA concurs. The NASA Supply Chain Insight Central (SCIC) information services and analysis platform, which was launched for Agency-wide, operational use in March 2021, serves as a key element of the Agency's evolving capabilities to build visibility and insight into the supply chains for NASA mission programs and projects and support the pro-active identification, analysis, and management of risks threatening the provisioning of products and services as required for mission performance. SCIC is managed and operated by the Office of Safety and

Mission Assurance (OSMA) Supply Chain Risk Management (SCRM) program in collaboration with other NASA organizations as a secure information system for internal NASA use. At present, SCIC contains records on 5,411 suppliers, including related supplier audit and assessment information and reports on 3,989 suppliers, and 184 supplier research and analysis reports.

Section 5.5 of the NASA Procedural Requirements (NPR) 8735.2C, Hardware Quality Assurance Program Requirements for Programs and Projects, includes a requirement for entering information on the scope and results of supplier audits and assessments into SCIC. Additional orientation and engagement activities are planned for FY 2024 to strengthen compliance with this requirement; however, ongoing fulfillment of this requirement alone is not sufficient for building and maintaining the supply chain visibility and insight necessary for proactive SCRM across the Agency. Accordingly, NASA, as described in the response to Recommendation #3, is planning to implement the DRD for Supply Chain Visibility Reporting by prime contractors using a new, SCIC application which will result in a robust flow of supplier information into SCIC for internal NASA planning and analysis purposes. In addition, in order to further boost visibility and insight into NASA supply chains, information, and data resulting from the U.S. Civil Space Industrial Base Survey currently under way will be incorporated into SCIC for use across the Agency. This ongoing survey, which is conducted by the Department of Commerce's Bureau of Industry and Security on behalf of NASA, will yield substantial data and information on about 2,000 current and potential suppliers of interest to NASA Mission Directorates, programs, and projects. Lastly, the OSMA SCRM program in conjunction with the Supply Chain Resiliency Board will continue to manage and assess the fulfillment of the activities described in this response and recommend follow-on actions as warranted to achieve the supply chain visibility and situational awareness necessary for the Agency's proactive mitigation of risks threatening NASA supply chains and the provisioning of products and services for NASA mission performance.

Estimated Completion Date: September 30, 2024.

Recommendation 6: Incorporate a representative from the Logistics Management Division into each Artemis-related program and project at appropriate milestones, including at the onset of a contract and each life-cycle milestone.

Management's Response: NASA partially concurs. The Moon to Mars Program Office acknowledges the benefit of logistics management expertise to large and complex programs and projects. NASA will consider utilizing a logistician from the Logistics Management Division for key program life-cycle reviews and assessments conducted at the Moon to Mars Program Office level.

Estimated Completion Date: June 30, 2024.

Recommendation 7: Ensure an Artemis-specific study of the Agency's industrial base and supply chain is completed on a recurring basis.

Management’s Response: NASA concurs. Artemis programs and projects participated in the Agency’s Holistic Supply Chain/Space Industrial Base Survey conducted in 2022. The Moon to Mars Program Office also engaged with the Aerospace Corporation in 2023 and obtained several reports reflecting recent Aerospace Corporation assessments that provide insight into trends and issues within the space industrial base that are relevant to the Artemis campaign. Artemis suppliers also participated in Wave 1 of the U.S. Civil Space Industrial Base Assessment conducted by the Department of Commerce in coordination with NASA, the National Oceanic and Atmospheric Administration, and the National Environmental Satellite, Data, and Information Service. Wave 1 surveys were issued by the Department of Commerce/Bureau of Industry and Security to suppliers in March 2023. The Moon to Mars Program Office is currently working with the Office of Technology, Policy, and Strategy (OTPS) and Artemis programs and projects to identify additional Artemis suppliers for participation in the next wave of surveys. The list of suppliers for participation in Wave 2 surveys will be provided to OTPS in September 2023. This action will be considered closed when the list of Artemis suppliers for inclusion in Wave 2 of the U.S. Civil Space Industrial Base Assessment is provided.

Estimated Completion Date: September 30, 2023.

We have reviewed the draft report for information that should not be publicly released. As a result of this review, we have not identified any information that should not be publicly released.

Once again, thank you for the opportunity to review and comment on the draft report. If you have any questions or require additional information regarding this response, please contact Ruth Siboni at (202) 358-4555.

Digitally signed by James Free
Date: 2023.10.10 11:44:49 -04'00'

James Free
Associate Administrator for
Exploration Systems Development
Mission Directorate

Digitally signed by Karla Jackson
Date: 2023.09.27 12:18:51 -04'00'

Karla Smith Jackson
Assistant Administrator for
Procurement

APPENDIX C: REPORT DISTRIBUTION

National Aeronautics and Space Administration

Administrator
Deputy Administrator
Associate Administrator
Chief of Staff
Director, Logistics Management Division
Assistant Administrator, Office of Procurement
Program Manager, Office of Safety and Mission Assurance Supply Chain Risk Management
Director, Kennedy Space Center
Director, Marshall Space Flight Center

Non-NASA Organizations and Individuals

Office of Management and Budget
Deputy Associate Director, Climate, Energy, Environment and Science Division

Government Accountability Office
Director, Contracting and National Security Acquisitions

European Space Agency (ESA)
Director General of ESA

Aerojet Rocketdyne
President

Axiom Space
Chief Executive Officer

Bechtel Corporation
Chief Executive Officer

Collins Aerospace
Chief Executive Officer

Dynetics
Chief Executive Officer

Lockheed Martin Corporation
Chief Executive Officer

Maxar Technologies Inc.
Chief Executive Officer

Northrop Grumman Corporation
Chief Executive Officer

Space Explorations Technology Corporation
Chief Executive Officer

The Boeing Company
Chief Executive Officer

Congressional Committees and Subcommittees, Chairman and Ranking Member

Senate Committee on Appropriations
Subcommittee on Commerce, Justice, Science, and Related Agencies

Senate Committee on Commerce, Science, and Transportation
Subcommittee on Space and Science

Senate Committee on Homeland Security and Governmental Affairs

House Committee on Appropriations
Subcommittee on Commerce, Justice, Science, and Related Agencies

House Committee on Oversight and Accountability
Subcommittee on Government Operations and the Federal Workforce

House Committee on Science, Space, and Technology
Subcommittee on Investigations and Oversight
Subcommittee on Space and Aeronautics

(Assignment No. A-22-014-00-HED)