SPACE AGENDA 2025

STRENGTHENING THE INDUSTRIAL BASE TO DELIVER PROLIFERATED DEFENSE SPACE SYSTEMS

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Executive Summary

The Department of Defense's (DOD's) plans to transition to a more proliferated space architecture will not be achieved without robust supply chains and a ready defense industrial base. Resourcing and executing this transition will be challenging, as the DOD seeks to use dozens to hundreds of satellites to support missions historically reserved for a few large satellites. Besides the greater numbers of satellites, these systems must be delivered on a shorter, more consistent schedule and at a scalable, sustainable unit-cost level. To be successful, the DOD will need to rebalance priorities to focus on resiliency over efficiency, taking steps to ensure that the United States has reliable and secure sources for raw materials, parts, and components. This chapter examines several issues at the intersection of proliferated DOD space systems, the defense industrial base, and supply chains, including:

- Factors motivating the DOD's transition to more proliferated space systems
- Implications of the transition for the defense industrial base and supply chains
- Challenges and early signs of stress resourcing and executing the transition

Given that proliferated space systems are a key component of the DOD's plans to improve resilience and deliver space warfighting capabilities, the DOD should reinvigorate its support to the defense industrial base. This should include steps across several categories: planning and visibility, stockpiling and using commercial technologies, and financial support. This chapter identifies a few specific actions the DOD, and industry in some cases, could pursue under each category:

- **Planning and visibility:** incorporating defense industrial base and supply chain assessments into the newly created Space Futures Command to better evaluate industry readiness to implement future force designs
- **Stockpiling and encouraging commercial technologies:** procuring and stockpiling certain long-lead items prior to contract award, reducing vendor risk and ensuring that parts are available to meet short acquisition timelines
- **Financial support:** continuing to identify opportunities to use Defense Production Act authorities and other mechanisms to invest in U.S. manufacturing capabilities for key components

The DOD should soon derive operational benefits from its initial proliferated space systems. If successful, these systems are likely to accelerate the department's plans to transition more of its missions and acquisitions to similar approaches. The DOD's actions over the next several years to support the defense industrial base will be critical to these efforts.

Introduction

The Department of Defense (DOD) plans to field multiple proliferated satellite constellations to improve resilience and more quickly field new technologies. These systems will employ dozens to hundreds of relatively small, highly networked satellites to support missions historically reserved for fewer large and less networked satellites. In the next several years, proliferated systems are expected to make significant contributions to critical missions, from missile warning and tracking to low-latency data transmission. If these early efforts prove successful, calls for expanding the number and types of missions that proliferated systems could support will likely grow louder.

Robust supply chains and a ready defense industrial base are essential to the DOD's success transitioning to a more proliferated space architecture. Resourcing and executing this transition will be challenging. The COVID-19 pandemic and Russia's further invasion of Ukraine have revealed a fragility within our most basic defense supply chains. Moreover, the defense industrial base must deliver greater numbers of satellites on a much faster timeline than traditional space system acquisitions while holding the cost of each satellite at a sustainable level. This will require careful planning as well as rebalancing the department's priorities to focus more on supply chain resilience over efficiency, including steps to ensure that the U.S. has reliable and secure sources for components, parts, and raw materials.[1]

Both the DOD (with broader U.S. government support) and industry are taking steps to advance the transition to more proliferated defense space architectures. These steps include efforts to improve planning and visibility, stockpiling key inputs, and financial supports and business practices. However, early signs of stress within the defense industrial base indicate that sustained attention and action to strengthen supply chains is vital, as these new types of space systems will increasingly support some of the DOD's most important warfighting capabilities. The department will also need to take steps to ensure warfighters are prepared to operate these systems and adapt to more frequent hardware and software refresh cycles. During this time of proliferated constellations, fast delivery, and stressed supply chains, a multipronged approach is needed, including improving planning and visibility, strategic stockpiling (upstream and downstream), and various levers for financial support. As a customer, the DOD can work to ensure transparent and fair mechanisms to achieve government mission success and commercial performance expectations.

Planning for Current and Future Missions

Several DOD acquisition efforts are underway to deliver proliferated satellite constellations to serve both existing and future space missions. These efforts vary in important ways, including constellation size, composition, and planned orbit, but they all borrow from commercial space innovations and practices. A number of other missions could also be served by proliferated constellations, including positioning, navigation, and timing; tactical communications; and weather services.[2]

The Space Development Agency (SDA), one of three Space Force acquisition organizations, is executing a series of acquisition programs, known as tranches, to field several layers of proliferated satellites. These efforts, organized under the SDA's Proliferated Warfighting Space Architecture (PWSA), are intended to support specific missions, including missile warning and tracking, as well as to provide a space-based data infrastructure that can serve a broad range of missions. As of August 2024, SDA has launched 27 satellites to low Earth orbit (LEO) for the initial demonstration of capability phase, Tranche 0. The operational PWSA capability of Tranche 1 and beyond is planned to total more than 500 satellites.[3] For the acquisition efforts under contract, Tranche 1 and Tranche 2, a total of 7 different vendors are building between 10 and 132 total satellites.[4] Once fully populated, the constellation will need to be regularly replenished with satellites to maintain coverage.[5]

Space Systems Command (SSC), another Space Force acquisition organization, is also pursuing a proliferated medium Earth orbit (MEO) constellation. The Resilient Missile Warning/Missile Tracking/Missile Defense program plans to field a constellation of about 27 satellites through a series of acquisition programs known as epochs.[6] This constellation will provide capabilities similar to some of SDA's satellites, but from a more distant altitude to provide additional resilience against some types of threats. Also, because these MEO satellites operate at a higher altitude than SDA's LEO satellites, fewer are needed to provide global coverage.[7] For the acquisition effort under Epoch 1, one contractor is building six satellites.[8] Space Force awarded another vendor a contract to continue maturing its design, strengthening competition within the program for future production contract awards.[9]

For all missions that will utilize proliferated space systems, there will likely be a learning curve for the warfighting community as they adjust to operating larger constellations. New technologies as well as changes to tactics, techniques, and procedures will likely be critical to fully utilizing these new space capabilities.[10]

Space Supply Chains and Implications for the Defense Industrial Base

Supply chains can be analyzed in a number of different ways, including viability, security, logistics, and quality, each of which can be further decomposed into subcategories. The demands of proliferated space systems will add pressure to supply chains across all these dimensions. However, in the early stage of the transition to more proliferated constellations, viability deserves careful consideration. The DOD cannot deliver and sustain its future defense architecture without diverse, resilient, and reliable supply chains. Traditional defense contractors will need to adjust their design and production processes to account for increased satellite quantities, smaller satellite sizes, and reduced timelines between contract award and delivery. While small satellites require many of the same raw materials, parts, and components as large satellites, there are important scale differences. For example, lithium-ion batteries designed for a several-ton satellite would overwhelm a several-hundred-kilogram satellite, yet both satellites may require the same material inputs or production lines.

Orbits and Quantities

The number of satellites required to populate a proliferated constellation is partly a function of the system's orbit. Historically, defense space systems have mostly operated in geosynchronous orbit, at an altitude of roughly 36,000 kilometers. At that distance, each satellite has line-of-sight access to up to a third of Earth's surface, such that a few satellites can provide global coverage for Earth observation, communications, or other missions. Proliferated satellites in lower orbits have line-of-sight access to a much smaller portion of Earth, so many more are needed to provide the same level of coverage.

As prior research has shown, practices used to effectively produce large quantities of goods in commercial markets, such as automobiles and consumer electronics, are relevant for space systems.[11] At the most basic level, success requires shifting the mission assurance focus from individual units to the overall process, applying proven commercial principles of high-volume production. Once the design and production processes are qualified, data analytics and statistical controls are used to evaluate each finished unit and ensure that it meets specifications.[12] In addition to supporting increased production quantities, this approach improves efficiency and timeliness by reducing unit-level reviews and rework.

The shift to more proliferated space systems is not just a matter of producing more satellites more quickly. These new systems also require different types of technologies and support infrastructures, in large part to enable many satellites to function as a coherent system. For example, proliferated constellations are now being designed with laser communications systems for both space-to-space (optical intersatellite links) and space-to-ground connections. Among other benefits, these systems are able to more securely and more quickly transmit large amounts of data compared to radio frequency communications systems. A single satellite may carry several laser communications terminals, allowing simultaneous connections to other satellites and facilitating a mesh network of efficient and resilient data routing throughout the constellation. The Space Force is investing in a number of vendors to advance laser communications terminals and related capabilities, including networking between different orbital altitudes.[13] These steps help enable multiple vendors to deliver interoperable systems, providing redundancy that strengthens acquisitions and capabilities. Maturing these technologies is vital for achieving the goal of robust, resilient space networks that use automation and advanced onboard processing capabilities to efficiently route data and recover from outages.

The DOD's future space systems also depend on hardware and software modularity, which are strategies that enable interoperability through the use of common interface and data standards. Modular designs are required for some types of DOD weapon system acquisition programs and are an increasing point of emphasis across all programs.[14] Among other things, modularity can help to lower costs for suppliers, since they can avoid building different versions of a system or subsystem to meet different customers' needs. The strategies also encourage resilience and strengthen competition, diversifying the number and range of subcontractors that can contribute to the overall system. At the architecture level, interoperability and modularity can take the form of constellations designed to operate with diverse generations or types of satellites, which can facilitate more rapid, smoother technology insertion, even when a constellation comprises several vendors' solutions.[15]

Benefits to the Industrial Base. More proliferated DOD space architectures offer several benefits for the defense industrial base. First, they provide industry a more consistent demand signal. Satellites in a proliferated LEO constellation are replaced more frequently, often on a predetermined schedule every few years. Vendors can have greater confidence in both how many satellites are needed to populate the constellation as well as the number and timing of replacement systems. This is contrasted against more irregular demand for traditional satellite systems, which involve longer periods of research and development with intermittent spikes in production demand. Among other things, companies are using the DOD's demand signal for proliferated systems to make capital investments that will increase production capacity, though there will, of course, be lags between investment and actual capacity.[16] Second, vendors do not have to do extensive development efforts, which can be both risky and costly under certain types of contracts, because proliferated systems are prioritizing relatively mature designs and components, in part to reduce the risk of schedule delays. Third, vendors are able to leverage their commercial product offerings for government customers and vice versa, reducing the number of distinct research efforts and production lines that must be maintained. This is because proliferated government systems are more often modeled after commercial space constellations and commercial technologies rather than government-unique requirements. This also benefits the government. Combined with the increased emphasis on hardware and software modularity, the DOD can more easily and quickly benefit from and integrate new commercial products.

Challenges for the Industrial Base. Proliferated national security systems also create challenges for the defense industrial base. First, they will compete more directly with commercial space systems for source materials, both domestically and internationally. In addition to SpaceX's Starlink system, which has more than 6,000 operational satellites on orbit as of September 2024.[17] Several other large commercial constellations will begin launching in the next few years, including Eutelsat OneWeb's combined GEO and LEO satellite constellation (France/United Kingdom) and Telesat's Lightspeed LEO constellation (Canada).[18] Second, a consistent DOD demand signal comes with an increased emphasis on timeliness. Traditionally, space acquisitions composed of a few large, exquisite satellites routinely missed scheduled delivery milestones.[19] Yet these delays could often be tolerated because fielded systems often outlasted their intended design lives by years. For proliferated constellations, delays to replacement systems will have a greater impact. Among other things, satellites in a proliferated constellation have much shorter lifespans, driven primarily by limited propellant capacity and the need to more frequently use thrust to maintain orbit. Third, vendors might be limited in the full benefits and efficiencies of high-volume production because the DOD's current demand for satellite quantities is fairly modest compared to similar commercial systems, and this demand is divided among several vendors to promote competition and diversity. In fact, only three of the vendors across the DOD's current proliferated space acquisitions have DOD contracts to produce close to or more than 100 satellites. While there is no defined threshold count that separates low and high production volumes, companies are more likely to benefit from production efficiencies as they approach 100 satellites.[20] The DOD's emphasis on fixed-price contracts for proliferated satellite acquisitions means that vendor profits will largely be driven by consistent awards of large numbers of satellites that drive production efficiencies. In other words, while the DOD is emphasizing competition and diversity, vendors have a strong incentive to capture as large a share of the satellite quantities as possible.

Prime Contractor Business Models

Vendors that have been awarded a prime contract under a proliferated space system acquisition appear to be adopting one of two business models. In the first model, the prime contractor subcontracts most of its major systems and components but relies on its own systems engineering, testing, and assembly expertise to deliver an integrated system. This is the approach taken by traditional defense contractors like Lockheed Martin, L3Harris, and Northrop Grumman. [21] In the second model, the prime contractor leverages an existing competitive advantage in satellite bus design and production, and then seeks to acquire other companies to establish direct control over much of its supply chain for critical subsystems and components. This vertical integration approach, championed in the sector by SpaceX, continues a trend among newer commercial space companies as well as defense contractors like Millenium Space Systems, Sierra Space, Rocket Lab, and York Space Systems.[22] Vertical integration is expensive, so not all companies can afford to pursue this approach, and to be successful, a vertically integrated company will still need to understand how to design and build its products at scale and cost-effectively. More broadly, vertical integration within the space sector may reduce competition and diversity if a vertically integrated company chooses not to make its components available to competitors.

One explanation for these diverging business models is that newer defense contractors are seeking to specialize in smaller satellites and proliferated systems, whereas traditional defense contractors have and will likely continue to build large, traditional defense satellites in addition to their other defense product lines. Because it is costly, vertical integration is more likely to deliver cost, performance, and schedule efficiencies when it is closely aligned to a company's core product lines. Vertical integration allows a company to set the standard for price, performance, availability, and delivery of key technologies. In announcing its SDA contract, Rocket Lab's chief technology officer explained that the contract " is the culmination of a thoughtful and deliberate investment in our space systems business. It's why we either acquire key space technologies or invest in them organically."[23] Jason Kim, at the time chief executive officer of Boeing's Millenium Space Systems, said that the company has vertically integrated about 80 percent of its supply chain, with the remaining 20 percent being commoditized parts and components that are widely available.[24] While it is not clear whether vertical integration in this market improves long-term profitability, it has enabled these nontraditional vendors to compete effectively for the DOD's proliferated space acquisition contracts.

In the past few years, traditional defense contractors have had mixed success with vertical integration. Raytheon recently announced that they would no longer pursue space prime government contracts and instead focus on opportunities supplying components.[25] This shift occurred despite the fact that only a few years ago the company acquired Blue Canyon Technologies, a small satellite manufacturer and mission services provider, in a move to vertically integrate its small satellite business.[26] In 2023, a senior Raytheon official explained that "being in a mission prime position hasn't yielded the results that we were looking for."[27] One important trend to watch is the extent to which the remaining traditional defense contractors active in proliferated space acquisitions—Northrop Grumman, L3Harris, and Lockheed Martin—continue to pursue prime contracts for proliferated system acquisitions or follow a strategy like Raytheon, more focused on acting as a key supplier, which likely reduces profit margins but also financial risk.

Whether both business models prove effective for these types of acquisitions will have important implications. If more vendors choose not to pursue prime contracts, there may be less competition for future awards, potentially resulting in less innovation and higher costs. Similarly, if vertically integrated vendors are successful at executing their acquisitions, it may be difficult for the DOD to select other, less proven, and less specialized vendors for prime contracts. Finally, vertical integration can raise concerns about diminished competitiveness and is part of the government's evaluation of whether mergers violate antitrust law.[28]

Early Signs of Stress

Even though the Space Force's proliferated space acquisitions are still relatively new and have not yet reached full production rates, there are concerns about the defense industrial base's ability to meet current and future demand. In particular, these concerns reflect the challenges both traditional and newer defense contractors will face securing necessary supply chain inputs and meeting both production and timeliness requirements. Recent examples of these challenges include:

- **Missed subcontractor deliveries.** One prime contractor, which has contracts with both the SDA and SSC to support proliferated space systems, did not finish satellite production in time to meet its launch window.[29] The company, which was able to launch its satellites several months later, blamed the delay on the subcontractor responsible for delivering satellite buses, claiming that it missed scheduled delivery dates and had defective hardware.

- **Backlogs.** A company that is a key subcontractor for several acquisition efforts is facing funding and production challenges as it tries to scale up to meet government and commercial demand.[30] While recording record revenues, the company has a significant production backlog, and it has not yet been able to realize efficiencies from investments to increase production capacity and drive down costs.

- **Shifting business models.** One contractor was a late addition to an SDA's acquisition program after Congress added $250 million to accelerate capability delivery. That contract now appears to have been cancelled, as the vendor has shifted its business model to no longer pursue prime contracts, despite the fact that in the last several years that vendor had taken steps to vertically integrate its supply chains to better compete for prime contracts.[31]

Beyond these specific examples, there have been many broad reports of space supply chain challenges. For example, attendees at the 2022 and 2023 State of the Space Industrial Base workshops—supported by the Space Force, the Air Force, Defense Innovation Unit, and the Air Force Research Laboratory—rated the space supply chain as one of the least healthy parts of the space industrial sector.[32] The fact that space supply chains are considered so fragile is concerning given the expected increased demand for proliferated space systems. For several years, just as the DOD's proliferated space acquisition programs were starting, supply chain disruptions were largely attributed to the COVID-19 pandemic. However, by early 2024, Frank Calvelli, Assistant Secretary of the Air Force for Space Acquisition and Integration, stated that supply chain disruptions and the pandemic were not valid reasons for missing schedule deadlines: "Buy your parts early, get your orders in, be organized, be effective."[33] Similarly, the SDA has encouraged its vendors to diversify their supply chains to avoid single points of failure.[34] However, diversification is only possible if there is more than one source available, and the trend toward vertical integration could limit the available supply of subcontractors for some components.

The DOD's shift toward more proliferated space systems may also contribute to other, long-standing challenges related to supply chain, such as cybersecurity and counterfeit parts. The increased emphasis on rapidly delivering space hardware and software must be counterbalanced with a strong security imperative emphasizing processes to guard against these risks.

Strategies for Addressing Supply Chain Risk

The DOD and industry have each taken steps to address risks to supply chain viability. However, across the following categories, more action is likely needed to deliver and support proliferated space systems. The DOD should reinvigorate its support to the defense industrial base, helping ensure production capacity and component availability to support future space missions. While the following strategies are largely independent of one another, a combined approach is likely to be most effective.

Planning and Visibility

Incorporate supply chain risk assessments into planning functions. Space supply chains would be improved if the Space Force fully incorporated supply chain assessments into its planning functions. Over the past several years, the Space Force has improved its long-term planning through force design exercises led by the Space Warfighting Analysis Center (SWAC). The SWAC's recommendations have had a discernable impact on the service's budget requests, shaping the future of missile warning and communications capabilities.[35] In 2024, the Air Force announced plans to move the SWAC under a newly established Space Futures Command that would "develop and validate concepts, conduct experimentation and wargames, and perform mission area design."[36] The command's new responsibilities should include risk assessments or other processes to assess the readiness of the defense industrial base to support the SWAC's force designs.

Improve understanding of supply chain strengths and constraints to support acquisition decisions. A persistent challenge to planning for and building supply chain resilience is the lack of reliable data to inform decisions and investments. Proposed approaches to this problem include systems for aggregating and dynamically updating supply chain information "to better understand component availability, cost adjustments, quality measures, and security risks."[37] For proliferated space system acquisitions, implementing such an approach or similar commercial tools would greatly improve the DOD's ability to get ahead of supply chain constraints. The DOD should consider more explicitly building supply chain visibility into its acquisition decisions and employing strategic sourcing principles to evaluate the strength of a vendor's supply chain before contract award.

Consolidate orders across programs. One way the Space Force could utilize more effective planning and supply chain visibility is to coordinate purchases across acquisition programs. This approach would be particularly useful for certain types of common, specialized parts, such as radiation-hardened electronics, for which the commercial market does not have a compelling need. Coordinating purchases would strengthen the DOD's purchasing power and help support a more viable market for these inputs. To avoid wasting resources, this activity would need to be guided by the other planning functions, including an understanding of commonalities between vendors' designs.

Stockpiling and Encouraging Commercial Technologies

Consider strategically stockpiling certain components downstream to meet the timelines for proliferated constellations. The DOD and industry can take steps to proactively address supply chain contracts by strategically stockpiling parts and components downstream in the supply chain. While acquisition programs often use various mechanisms to procure long-lead items, the short timelines between contract award and launch may require keeping some parts in inventory or procuring those long-lead items even before contract award. Such actions help buy down schedule risk, increasing the likelihood that a vendor can meet its development and production timelines. The head of one vendor for a government acquisition program told us that the company had chosen to pre-order some specialized parts prior to contract award, which enabled them to execute the contract more quickly.[38]

Third-party vendors may also play a role in strategic stockpiling. One company we spoke with analyzes space supply chains and assembles kits of critical satellite parts. The company can then contract with vendors to provide these kits as a way of accelerating schedule and reducing supply chain risk. The DOD can play a similar role. The Defense Logistics Agency could stockpile some critical long-lead components and then provide them directly to vendors that secure a contract. This would create some risk for the government but could help ensure a more competitive solicitation since no single contractor would have a stockpile, and thus schedule, advantage. Several other challenges to stockpiling will also need to be addressed. For example, if the DOD or industry choose to preorder a part of component rather than place orders as needed, the supplier of that part or component may experience large demand fluctuations rather than a smoother, more predictable demand. Government or third-party stockpiling also requires knowledge of a vendor's design in order to procure the correct parts or components in advance. Vendors may be reluctant to share this information.

The DOD should look for ways to stockpile materials upstream in the supply chain, such as critical minerals. Upstream in the supply chain, stockpiling can include critical minerals that are valuable for a range of industrial applications. For example, in April 2024, the DOD used Defense Production Act authority to strengthen the supply chain for germanium, a critical mineral used to produce space-qualified solar cells.[39] This and similar actions, including recycling efforts that preceded China's 2023 export controls, helped shore up the DOD's access to critical minerals, countering China's efforts to monopolize these minerals, including germanium.[40] Given the DOD's focus on China as a "pacing threat" in the context of an emerging great power competition, critical minerals deserve a central place in supply chain policy. Beyond stockpiling, industrial policy studies indicate the need for more expansive international partnerships, financial support, and other incentives to strengthen U.S. access to critical minerals that support the aerospace industry.[41]

Continue to emphasize the use of commercial off-the-shelf (COTS) parts where technically feasible. The use of COTS, or alternate-grade parts, holds the promise of significantly reducing costs and streamlining the cycle time for part qualification. Parts that come off commercial production lines, including specialized electronics, are less expensive than high-reliability parts made to meet military specifications. COTS parts also rely on statistical data when making determining qualification decisions, eliminating redundant qualification testing. In addition, specialized and lower-volume parts, and components, such as integrated circuits and field-programmable gate arrays, are two or three generations behind state-of-the-art commercially available parts that may allow for greater performance capability gains.

Financial Support

The third set of strategies to strengthen supply chains for proliferated space systems are various kinds of financial support. These may be particularly useful for nontraditional contractors that do not have access to significant capital, which inhibits their ability to take advantage of strategies like vertical integration and stockpiling.

Consider stabilizing a contractor's revenue stream by funding payments at regular intervals instead of performance-based payments. Both the DOD and industry can also utilize different reimbursement mechanisms to help vendors receive a more consistent cash flow. For the DOD, one such mechanism is the use of progress payments, whereby funding is released on a set time interval, rather than performance-based payments, which are tied to the accomplishment of contractual milestone. For fixed-price contracts, the total amount paid to the prime contractor is the same, but progress payments provide more consistent revenue. Similarly, at least one prime contractor used accelerated payments with its subcontractors during the COVID-19 pandemic to support small and at-risk businesses.[42]

Consider government direct payments that support key technologies or components in the space supply chain. The government's recent efforts to strengthen the U.S. manufacturing and industrial base provides another type of financial support through direct payments. For example, in June 2024, the Biden-Harris administration announced a nearly $24 million award to support expanded production of space-grade solar cells.[43] The DOD has used the Defense Production Act to make several similar investments.[44] As the DOD executes more proliferated space acquisitions and expands its understanding of the fragility within supply chains, it is likely to discover additional areas where such direct payments could increase defense industrial base resilience.

Conclusion

The DOD will soon derive operational benefits from its initial proliferated space systems. If successful, these systems are likely to accelerate the department's plans to transition more of its missions and acquisitions to similar approaches. Therefore, it is essential that the DOD and industry take steps to strengthen the supply chains that will be needed to resource this transition. Most importantly, this requires a more comprehensive and dynamic understanding of risks and fragility to guide solutions, including stockpiling and financial support.

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