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DOD Acquisitions for Space Depend on Prioritizing Warfighter Needs to Maintain Strategic Advantage

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Abstract

Congress has often expressed concerns about the DoD's ability to acquire innovative solutions that could serve the warfighter, particularly in software-intensive solutions, such as those that support the space domain. A further challenge is the DoD's adoption of Agile software development principles and its efforts to focus on warfighter needs. Our paper focuses on the GAO's work examining the DoD's approach to supplementing its space situational awareness (SSA) capabilities with commercial data; procuring the Space Command and Control (C2) system; and how the DoD's Software Acquisition Pathway focuses on warfighter engagement as well as outcome-based metrics to assess development progress.

Why This Matters

As the number of threats and objects in the space environment grows, timely and accurate data about these objects are crucial to understanding and managing commercial and military activities in space. The Department of Defense (DoD, 2020) has stated that space is vital to our nation's security, prosperity, and scientific achievement. The DoD also emphasizes that space is a contested environment due to the increasing number of threats to its satellites. For example, the DoD has reported that countries such as China and Russia have developed and demonstrated capabilities designed to contest or deny U.S. access to, and operations in, space.

With both the DoD and commercial companies growing their presence in space, the objects in space that can pose a threat to space assets is also growing rapidly. The DoD needs systems to help manage those objects—but struggles to build them. Since 2000, the number of cataloged space objects has jumped from about 10,000 to nearly 50,000. To command and control U.S. space assets, including maintaining the object catalog, the DoD needs supporting software-intensive systems. However, despite long-standing requirements and years of development work, the department still struggles to deliver effective systems that fully meet warfighters' needs and help them decommission legacy systems like the Space Defense Operations Center (SPADOC).



Background

Over the past 5 years, commercial and military activities in space have grown considerably, and continued growth is expected in the future. We reported in September 2022 that technological advancements allow for more affordable satellites and dramatic decreases in the cost to launch satellites, improving the potential to deploy large constellations of satellites that cover the entire globe (GAO, 2022d). We also reported that some experts cited the potential for 58,000 additional active satellites to be launched by 2030. Today, activities in xGEO are focused on scientific missions and exploration of the moon and other celestial bodies, but activity in xGEO is also expected to increase.

In addition, the amount of debris and other inactive objects in space is substantial. According to a Defense Intelligence Agency (2022) report, the primary risk to spacecraft in orbit is from the 600,000 to 900,000 space objects between 5 millimeters and 10 centimeters in size, many of which are not tracked in the DoD's Satellite Catalog (referred to in this paper as the catalog). The catalog is a database of information about specific space objects, including the objects' estimated size, location, and movements. Taken together, this information represents the DoD's current capability to archive, integrate, disseminate, and exploit SSA data obtained from detection, tracking, and identification.

Using such data enables DoD operations in space and helps mitigate risks to U.S. space assets, through command and control systems. Space command and control is the ability for military commanders to make timely, strategic decisions, take tactical actions to meet mission goals, and counter threats to U.S. space assets. Despite promising starts and some capabilities delivered, the Air Force's last three programs to improve space command and control capabilities over the past three decades have ended significantly over budget and behind schedule, with key capabilities going undelivered. The Department of the Air Force's current effort—Space Command and Control (Space C2)—is a software-intensive program that plans to deliver deferred requirements from past programs as well as to develop and field new advanced capabilities through an Agile strategy.

Our recent work found that the DoD has made efforts to modernize its software acquisition and development approaches for these systems over the past several years. However, we also highlighted that the DoD continues to face challenges in executing these approaches and rapidly delivering software to users (GAO, 2022c, 2022b, 2021b). The Defense Science Board and Defense Innovation Board, in 2018 and 2019 respectively, also found deficiencies in software development and acquisition practices within the DoD, such as outdated acquisition processes and challenges with rapidly delivering software to users. Their reports made 17 recommendations to the DoD to help address these deficiencies. Problems in software acquisition can result in DoD weapon programs delivering needed capabilities late, over-budget, or not at all.

SSA Key Takeaways: Prioritizing Warfighter Needs to Maintain Strategic Advantage

The GAO's prior and ongoing work in these areas point to a need to prioritize warfighters' requirements and continuously engage them in developing and acquiring space capabilities.

- 1. The DoD Faces SSA Challenges and Is Taking Steps to Address Them.** The DoD faces a number of challenges obtaining data needed for the SSA mission, a mission that Space Force identifies as foundational to all space operations. Specifically, Space Force and USSPACECOM officials identified current and anticipated challenges obtaining SSA data in the evolving space domain. These



include space becoming increasingly congested; ground-based sensor coverage varying by location, limiting SSA data collection; limits on sensor capability for xGEO objects; and the DoD’s ability to maintain SSA in light of adversary capabilities. The DoD is taking steps to mitigate these challenges, including incorporating additional sensors with primary missions other than SSA, developing new tactics, techniques, and procedures, reassessing SSA needs and updating requirements document, acquiring new SSA systems, and experimenting with commercial SSA data.

2. Space Force Has Not Fully Evaluated How Commercial SSA Data Could Meet Mission Needs.

- **Commercial companies provide a variety of SSA capabilities.**
Commercial SSA companies use sensors such as telescopes and radars to collect data on objects in space. The type of sensor used determines the type of data it can collect. Although the SSA companies we talked to are using similar sensing technologies as the DoD, they do offer some advantages to the DoD; some companies have deployed sensors across the globe, and in some cases, in locations that the DoD would not be able to do so because of political or security concerns. For example, one of the companies we interviewed has access to over 300 sensors on five continents, with many assets located in the southern hemisphere where the DoD has limited sensor coverage. In addition, most of the DoD’s ground-based radars can only track objects larger than 10 centimeters in diameter in LEO and objects about 1 meter in diameter in GEO.¹ However, one company’s commercial sensors can track objects as small as 2 centimeters in diameter, about the size of a marble.
- **DoD documents prioritize the use of commercial space capabilities when possible.** See Table 1 for a summary of DoD strategies establishing the department’s intent to use commercial capabilities.

Table 1: Department of Defense Strategies Related to the Integration of Commercial Space Capabilities (GAO Assessment of DOD Information, n.d.)

Document title and owner	Summary of guidance
2020 <i>Defense Space Strategy</i> , DoD	The 2020 <i>Defense Space Strategy</i> identifies commercial innovation as cornerstone enablers of the strategy’s lines of effort to outpace potential adversary threats. The strategy references commercial companies as an integral partner in achieving collective space security.
2022 <i>National Defense Strategy</i> , DoD	The 2022 <i>National Defense Strategy</i> places increased emphasis on commercial integration to leverage technological advancements and enable emerging capabilities. Further, the document directs the DoD to repurpose decision systems using innovations in both the commercial and military sectors to make smarter technology investments; leverage experimentation to solve problems; generate more flexible military capability requirements; and rapid experimentation, acquisition, and fielding.
2022 <i>Commercial Integration Strategy Overview</i> , USSPACECOM	The <i>Commercial Integration Strategy Overview</i> sets forth the framework for how USSPACECOM will collaborate, integrate, and partner with the U.S. commercial industry. The strategy sets priorities and synchronizes commercial integration efforts so that USSPACECOM can mitigate capability gaps, improve space architecture resiliency, and gain and maintain a technological and operational advantage over adversaries.

¹Apart from the other DoD sensors, the Space Fence is a ground-based radar that tracks objects as small as 1–2 centimeters in LEO.



In addition to the previously mentioned strategies, the DoD also updated its Space Policy Directive 3100.10 in 2022 to assign responsibility for DoD space-related activities in accordance with national and DoD policies (*Space Policy*, 2022). This Directive states that “consistent with national security requirements, commercial systems, services, and technologies will be used to the maximum practical extent, and commercial capabilities will be modified to meet those requirements when doing so is more cost-effective and timely for the US government.”

- **DoD acquisition and evaluation of commercial SSA data has been limited.** The DoD acquires a small amount of commercial SSA data primarily to meet its protect and defend mission through the JTF-SD Commercial Operations Cell (JCO).² This USSPACECOM initiative is focused on purchasing commercial SSA data in support of the command’s mission to protect and defend U.S. space assets. According to Space Force officials, as of May 2022, the JCO was buying commercial data for a few hundred objects of interest to the JTF-SD. According to company representatives we interviewed, Space Force purchases of SSA data for the JCO have been on an ad-hoc or monthly basis. However, the Space Force requested funding to buy commercial data in its budget request for the first times in fiscal years 2022 and 2023. According to a memorandum of understanding between Space Force and USSPACECOM, Space Force is planning to provide approximately \$20 million to the JCO for commercial SSA data purchases in fiscal year 2023 and a total of approximately \$110 million for fiscal years 2023 through 2027. According to a Space Force official, this funding covers a limited subset of SSA missions—namely, SSA for the protect and defend mission.
 - i. Although the commercial data purchased by the JCO is currently of limited use to the 18th and 19th Space Defense Squadrons for conducting their SSA mission, the Space Force is testing new capabilities in a few ways. For example, 18th Space Defense Squadron operators told us that they have browsed through the Unified Data Library (UDL) to see what type of commercial SSA data it contains and they have observed some of the Joint Task Force-Space Defense Commercial Operations Cell’s Sprint Advanced Concept Training events. Also, the 19th Space Defense Squadron is evaluating commercial and academic capabilities to improve SSA in xGEO.
 1. The Space C2 program is the Space Force’s latest effort to modernize a system that gathers data from sensors, transmits these data to a repository, and processes the data to enable commanders to make timely decisions, take action, and counter threats.³ However, we reported in December 2021 that the DoD has spent decades trying to modernize this system, and it is still trying to do so (GAO, 2021c). The 18th and 19th

²The government acquires licenses to use commercial SSA data in accordance with the Federal Acquisition Regulation, DFARS, and any specifically negotiated licenses, as mentioned above. Throughout this section, when we state that commercial data is acquired or purchased, what is being purchased is a license to use the commercial data, not the commercial data itself. See generally DFARS § 252.227.7013 (n.d.) and DFARS § 252.227-7014 (n.d.).

³Congress established the Space Force in 2019 as a military department within the Air Force. See National Defense Authorization Act for Fiscal Year 2020 (2019).



Space Defense Squadrons are waiting for the Space Command and Control program, discussed later, to deliver SSA capabilities.

3. Space Force Lacks a Plan on How to Use the Unified Data Library With SSA Systems.

- **Space Force has fielded the UDL and continues to develop new capabilities.** The Space Force began development of the UDL as a research and development effort in 2018 for \$150,000. In 2019, the Space Force awarded a contract to continue the UDL development and fielded an initial operational system in 2022.⁴ In April 2022, the UDL received a 3-year Authority to Operate by the Air Force, accrediting the system to be used operationally at the unclassified, secret, and top-secret levels. According to a contractor representative, agencies outside of the DoD and the Space Force are using the UDL to store other types of data; it is primarily a cloud-based repository of SSA data, with 85% of the data being SSA-related as of November 2022. In addition, the UDL can connect directly to sensors and store sensor data automatically. In April 2022, data from the Space Fence radar were directly uploaded and made available to the classified UDL, establishing the UDL's first direct sensor connection. This demonstrates the UDL's ability to connect to a sensor in the DoD Space Surveillance Network, which includes all of the DoD's SSA sensors.⁵ Since April, the UDL has connected to an additional sensor at the classified level and several other sensors at the unclassified level.
- **SSA systems are not using the UDL in operations, and Space Force does not have a plan to address existing challenges and determine how to use the UDL.** Although the UDL is used as a repository for commercial and DoD SSA data, the DoD's SSA C2 systems—SPADOC and the Correlation, Analysis, and the Verification of Ephemerides Network (CAVENet)—are largely not taking data from the UDL. The 18th and 19th Space Defense Squadrons rely on these SSA C2 systems to perform their mission functions, such as assessing potential collisions and maintaining custody of space objects. These systems use the DoD's SSA data in the catalog to carry out these functions, but not commercial SSA data from the UDL.
 - i. According to Space Force officials, the Space Force is currently testing ways to put commercial data into a common internal format for the UDL so that it can better integrate with existing C2 systems. This effort requires the ability to calibrate and monitor the quality of data from non-DoD sources to ensure they are safe and accurate for use in Space Force missions. Such a capability would mark a “paradigm shift,” according to the officials. Also, the Space Force recently began a trial period for the first full path using data from the UDL for integration with 18th and 19th Space Defense Squadrons. Specifically, this trial is incorporating data from four Air Force Research Laboratory sensors through the UDL that are not otherwise

⁴Development continues on the UDL, with total contract value exceeding \$280 million as of February 2023.

⁵The Space Surveillance Network is a collection of radars and ground- and space-based optical telescopes that tracks more than 27,000 satellites and pieces of orbital debris for the catalog.



able to connect with these C2 systems and are not part of the Space Surveillance Network. According to Space Force officials, the UDL connection to these non-traditional sensors, which are owned by the government, is intended to pave the way for eventual machine-to-machine commercial data integration into the DoD's SSA systems. The Space Force is using the data coming from these sensors to conduct SSA during the trial period, which began in January 2023 and was ongoing as of February 2023. While this is a good first step, the Space Force still needs to consider what further steps to take to determine how to use the UDL in SSA operations.

1. Creating a plan to integrate the UDL into Space Force operational systems, such as SSA and Space C2 missions, would better ensure operators had access to the full suite of DoD and commercial data to execute these critical national security missions.

Space Command and Control Key Takeaways: Addressing Challenges to Meet User Needs

The DoD intends for Space C2 to consolidate operational level command and control capabilities for DoD space assets into an integrated system for operators and decision makers. A consolidated set of capabilities will

- Allow operators to comprehensively identify and monitor threats to U.S. space assets,
- Identify possible courses of action to respond to threats,
- Communicate course of action to decision makers, and
- Direct action to respond to threats.

The overall design of the Space C2 program is for data to be gathered from sensors, placed into a data repository, and then be available for various applications to process and provide timely information to space operators and commanders. The program had been working to develop this design through Agile principles and by entering the Software Acquisition Pathway.

The GAO's prior work identified several challenge areas that have led to persistent delays in meeting key program requirements:

Management Challenges. In 2019, we identified three management challenges for Space C2: (1) absence of a formal acquisition strategy, (2) no formal system architecture, and (3) limited enterprise management authority (GAO, 2019). Of these, the lack of an approved acquisition strategy remains the most persistent challenge—the program continues to work from a draft strategy. We recommended Space C2 develop a comprehensive acquisition strategy and the program has not yet close that recommendation. Without an approved acquisition strategy, Space C2's plan to meet requirements and manage program risks does not have buy-in within the DoD and has not shown that it fully addresses all aspects of program development.

Technical Challenges. The primary challenge we identified in 2019 was the complexity of requirements Space C2 must meet (GAO, 2019). This complexity is two-fold: the program plans to develop systems that are technologically complex and then integrate those systems. This finding echoes years of prior GAO work on the DoD's efforts to replace SPADOC. In 1989, we found that the Air Force's attempts to modernize SPADOC were



highly complex and technically risky, resulting in acceptance of a system that was marginally useful (GAO, 1989). In 2006, we found the Combatant Commanders' Integrated Command and Control System deferred capabilities, resulting in risks to future operations if key systems like SPADOC were not replaced (GAO, 2006). In 2011, we reported that the Joint Space Operations Center Mission System faced multiple technical risks, including data and system integration resulting from the program's complexity, and technological maturity (GAO, 2011).

Workforce Challenges. In 2019, we highlighted workforce challenges that stem of the availability of staff with expertise in Agile software development (GAO, 2019). Given Space C2's planned Agile approach, that the DoD had not yet issued acquisition guidance on software-intensive programs, and that DoD officials pointed to a lack of qualified software developers in the department at that time, Space C2 was taking a risk.

Reporting Challenges. In our most recent report in December 2021, we found that annual reporting Space C2 provides to Congress is limited because it lacks contextual information that would highlight program changes (GAO, 2021c). For example, Space C2 changed its description of the capabilities it planned to provide without explaining why or how the program made this change. Including such detail would provide a more complete picture of the status of the Space C2 program.

The GAO has work ongoing to examine the program's annual report as well as the effects of the challenges we identified. At this point in time, questions remain regarding steps the DoD and the Space C2 program office may take to address some of these challenges. Space operators and commanders are still waiting on core Space C2 capabilities, particularly those that will help decommission SPADOC. We anticipate publishing our report later in 2023.

Software Acquisition Pathway Key Takeaways: Prioritizing Warfighter Needs to Maintain Strategic Advantage

In October 2020, the DoD released DoD Instruction 5000.87, *Operation of the Software Acquisition Pathway*. This pathway is for the timely acquisition of custom software capabilities developed for the DoD. The Software Acquisition Pathway emphasizes frequent, ongoing collaboration between the program office, software developers, and the software user community. To ensure collaboration among these communities, the Software Acquisition Pathway integrates modern software development practices—such as Agile—that rely on continuous feedback between these communities as well as regular assessments of new capabilities.

The Software Acquisition Pathway also requires key documents, including:

Capability Needs Statement. A high-level description of mission deficiencies that the development effort is to address and other attributes that provide information to define software solutions as they relate to the overall threat environment. The program office and end users or user community are responsible for drafting this statement, which the sponsor—the organization that identifies and advocates for needed end user capabilities and associated resources—approves. Programs should review the statement at least annually to determine if updates are warranted.

Product Roadmap. A high-level visual summary that maps out the vision and direction of software solutions over time. It describes the goals and features of each software delivery. The program office and sponsor develop and maintain the roadmap.



User Agreement. A commitment between the sponsor and program manager for continuous user involvement and assigned decision-making authority in the development and delivery of software capability releases. The program office is responsible for developing this document in coordination with the sponsor; the program and sponsor co-sign the agreement.

Value Assessment. An outcome-based assessment of mission improvements and efficiencies realized from the delivered software capabilities, and a determination of whether the outcomes have been worth the investment. The sponsor, program office, and user community are to perform Value Assessments at least annually to inform program decisions. The Value Assessment is the formal, recurring feedback mechanism for each program acquired through the Software Acquisition Pathway. The sponsor and program office should negotiate the timing and frequency of the Value Assessment and document that schedule in the User Agreement.

These elements of the Software Acquisition Pathway, especially the emphasis on frequent, collaborative software delivery and feedback relationships are, according to DoD policy and guidance, grounded in Agile and other modern practices for software development. According to Software Acquisition Pathway guidance, implementing these practices helps the DoD use technological innovation to sustain the U.S. military advantage.

Challenges With Outcome-Based Metrics and Incorporating User Perspectives

Our prior reporting on programs either on or using aspects of the software pathway found that identifying outcome-based metrics and incorporating user perspectives has been challenging for the DoD (GAO, 2021c, 2022a). Programs we reviewed have metrics to assess their own software development processes and performance but did not yet have metrics that describe if programs are achieving intended operational outcomes. Additionally, we identified that some program metrics and reporting could be enhanced by consistently incorporating user perspectives on the operational benefits associated with program efforts. DoD Instruction 5000.87 states that Value Assessments are to be outcome-based. In our March 2021 report on key terms in program evaluation, we defined outcomes as the desired results of a program; therefore, outcome-based metrics would measure those desired results (GAO, 2021a). Supporting guidance for the Software Acquisition Pathway also describes the importance of outcome-based metrics for programs to understand the mission improvements or efficiencies that newly developed capabilities provide and directs that programs use those results as the basis for the Value Assessment.

What the GAO Recommends

The GAO has made nine recommendations to the Air Force to establish a process and plan to ensure that it prioritize warfighter needs to maintain our strategic advantage. Recommendations from each of the reports we mention can be found at www.gao.gov by searching for the report number.

How the GAO Did This Study

The House Armed Services Committee's report 117-118 accompanying a bill for the National Defense Authorization Act for Fiscal Year 2022 contains a provision for the GAO to review planned procurement of commercial SSA data (H.R. No. 117-118 at 276, 2022). The provision also asked for an overview of the Unified Data Library (UDL), a DoD cloud-based, online data repository intended to improve the collection, sharing, and accessibility of SSA data. This report (1) describes the challenges the DoD faces in identifying and characterizing



objects in space, (2) assesses the extent to which the DoD uses commercial SSA data, and (3) assesses the development status of the UDL and how the DoD is using it.

To answer these objectives, we reviewed relevant documentation such as the DoD's 2022 *Defense Space Strategy*, the 2022 U.S. Space Command's (USSPACECOM) *Commercial Integration Strategy Overview*, an Air Force report to congressional committees entitled *Commercial Space Domain Awareness Services* and the RAND Corporation (2022) *Commercial Space Capabilities and Market Overview 2022* report (Department of the Air Force, 2021). Additionally, we interviewed officials from agencies with SSA responsibilities, including Space Force units and USSPACECOM. We also interviewed and collected information from a non-generalizable sample of 10 out of approximately 50 commercial companies. We selected these companies based on whether they had a contract with the DoD regarding SSA and the type of SSA data they provided the DoD.⁶ We also interviewed contractor representatives responsible for the UDL. Additional details on the report's methodology are in Appendix I.

To summarize our past work on Space C2 and the Software Pathway, we reviewed earlier reports, available publicly at www.gao.gov.

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⁶Results from non-generalizable samples cannot be used to make inferences about a population.





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