



October 2019

# SPACE COMMAND AND CONTROL

Comprehensive  
Planning and  
Oversight Could Help  
DOD Acquire Critical  
Capabilities and  
Address Challenges

## Why GAO Did This Study

Since the early 1980s, the Air Force has been working to modernize and consolidate its space command and control systems into a single comprehensive platform. The past three programs to attempt this have ended up significantly behind schedule and over budget. They also left key capabilities undelivered, meeting the easier requirements first and deferring more difficult work to subsequent programs. At the same time, the need for a consolidated space command and control capability has been growing.

The House Armed Services Committee report accompanying a bill for the National Defense Authorization Act for Fiscal Year 2018 contained a provision for GAO to review DOD's newest efforts to develop space command and control capabilities. This report describes the status of these efforts and identifies challenges the Air Force faces in bringing them to fruition.

To conduct this work, GAO analyzed acquisition and strategy documentation, management directives, and lessons learned; and compared Air Force development plans with leading industry practices for software development, DOD guidelines, and best practices included in a draft GAO guide for assessing Agile software development programs.

## What GAO Recommends

GAO is making two recommendations, including that DOD should ensure the Air Force develops a comprehensive acquisition strategy for the Space C2 program. DOD concurred with the recommendations.

# SPACE COMMAND AND CONTROL

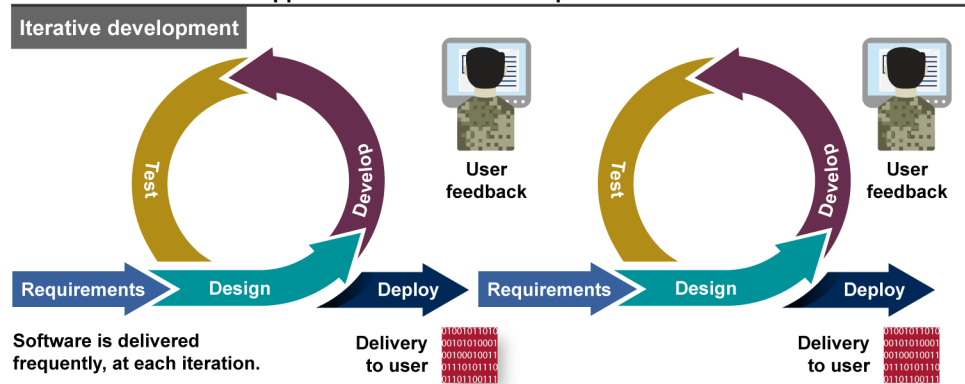
## Comprehensive Planning and Oversight Could Help DOD Acquire Critical Capabilities and Address Challenges

### What GAO Found

Given emerging and evolving threats in the space domain, as well as significant development problems in similar prior efforts, the Air Force is prioritizing the Space Command and Control (C2) program. Early prototype work on the program's software began in 2016. As of mid-2019, the program had delivered some initial capabilities; however, the capabilities delivered so far are not approved for use in operations. Because the program is still early in development, it has not yet established a time frame for certifying these capabilities for operational use. Further, the foundational elements of the program, including the infrastructure and software platform, are still being conceptualized. All Space C2 program capabilities will be significantly more automated than past development efforts and are being designed to allow operators to identify and monitor threats to U.S. space assets, identify courses of action to mitigate or eliminate those threats, communicate these actions to decision makers, and direct actions in response.

To develop Space C2's technologically complex software, the Air Force is following a modernized, iterative process called Agile development—a relatively new approach for Department of Defense (DOD) programs (see figure).

The Air Force's Iterative Approach to Software Development



Source: GAO analysis of Department of Defense (DOD) and industry documentation. | GAO-20-146

The Space C2 program is facing a number of challenges and unknowns, from management issues to technical complexity. Additionally, DOD officials have not yet determined what level of detail is appropriate for acquisition planning documentation for Agile software programs. They are also not certain about the best way to provide oversight of these programs but are considering using assessments by external experts. These knowledge gaps run counter to DOD and industry best practices for acquisition and put the program at risk of not meeting mission objectives. Additionally, software integration and cybersecurity challenges exist, further complicating program development. The Air Force has efforts underway to mitigate some of these challenges in the near term, but until the program develops a comprehensive acquisition strategy to more formally plan the program, it is too early to determine whether these efforts will help to ensure long-term program success.

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October 30, 2019

### Congressional Committees

The Department of Defense (DOD) plans to spend more than \$65 billion from fiscal years 2019 to 2023 to acquire space systems that provide essential capabilities for an array of functions and objectives, including U.S. national security, commerce and economic growth, transportation safety, and homeland security. For example, DOD's Global Positioning System provides positioning, navigation, and timing services worldwide, and its communications satellites provide secure communications critical for conducting military operations. These space systems are increasingly vulnerable to a variety of threats. Threats to orbiting space assets can be either intentional or unintentional—ranging from adversary attacks and signal jamming to electromagnetic radiation and collisions with space debris. Both types of threats have increased in recent years because foreign adversaries continue to pursue advanced capabilities and because the number of objects in space continues to grow. Given the high cost to acquire and field space systems and the increasing threats these systems face, the United States' ability to predict attacks and avoid collisions in space is more important than ever.

To help mitigate risks to U.S. space assets, the Air Force has been developing improved space 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 more than three decades have ended significantly over budget and schedule and with key capabilities going undelivered. The Air Force's newest effort—called Space Command and Control (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 a different approach to software acquisitions than DOD has used in the past.

Due to the importance of the new Space C2 program, the House Armed Services Committee report accompanying a bill for the National Defense Authorization Act for Fiscal Year 2018 contained a provision for us to review DOD's efforts to develop space command and control capabilities. This report (1) assesses the status of and plans for ongoing Air Force efforts to develop advanced command and control capabilities for space,

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and (2) identifies challenges the Air Force faces in developing these capabilities.

To address the objectives, we

- analyzed DOD test reports and program evaluations from prior software programs;
- reviewed DOD documentation of prior, current, and future plans to provide integrated command and control capabilities;
- reviewed draft DOD guidance for software development and a draft GAO guide for assessing modernized software development approaches;
- compared Air Force plans to leading industry practices for software development; and
- analyzed program office planning documents, including acquisition and strategy documents, management directives, lessons learned, and critical review reports.

We also interviewed DOD officials from offices and organizations that include the Office of the Under Secretary of Defense for Acquisition and Sustainment; Combined Space Operations Center; Air Force Space Command; National Space Defense Center; and Air Force Space and Missile Systems Center, among others. See appendix I for additional information on our objectives, scope, and methodology.

We conducted this performance audit from January 2018 to October 2019 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.

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## Background

Since the early 1980s, the Air Force has been working to modernize and consolidate its space command and control systems and improve its space situational awareness. Effective command and control systems are important because DOD space capabilities are globally distributed and operated from geographically diverse locations. With new threats against space assets, the ability to quickly respond or take action can mean the difference between mission success and failure. Space situational awareness is the current and predictive knowledge and characterization

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of space objects and the operational environment upon which space operations depend. Good space situational awareness data are the foundation of command and control systems because the data are critical for planning, operating, and protecting space assets and informing government and military operations.

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## Past Command and Control Efforts

The Air Force's last three space command and control programs over more than three decades have ended significantly over budget and schedule, and key capabilities have gone undelivered. Those programs were

- the Cheyenne Mountain Upgrade,
- the Combatant Commanders' Integrated Command and Control System, and
- the Joint Space Operations Center Mission System.

Some capabilities were deferred from one program to the next, making the true cost growth in each program significantly higher when compared to original program content. This deferral was due in part to the complicated nature of the planned work. Enabling a single system to command and control numerous assets in space and on the ground at multiple levels of information classification is a technically challenging task. In addition, as discussed below, we found that the Air Force made optimistic cost and schedule estimates for these programs, and thus did not assign adequate resources to their development.

## Cheyenne Mountain Upgrade

Begun in 1981, the Cheyenne Mountain Upgrade was intended to modernize systems that provide critical strategic surveillance and attack warning and assessment information. We issued 11 reports on the Cheyenne Mountain Upgrade program between 1988 and 1994. In 1991, we found that the program planned to complete only a portion of its requirements in an attempt to stay within budget and schedule constraints. We also found that the Air Force had adopted a strategy of deferring some requirements on the optimistic assumption that these requirements could be achieved during later stages of system development. We concluded that while such deferrals may have permitted the Air Force to meet revised short-term goals, they also masked the magnitude of problems the program experienced as it moved forward. We also found that DOD had not formally evaluated the performance risks related to deferring requirements and concluded that the strategy of deferral significantly raised the risk that system

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development would be more costly and take longer.<sup>1</sup> DOD declared the program operational in 1998; however, some critical capabilities were not delivered. At that time, the program was nearly \$1 billion over budget and 11 years late. That same year, DOD determined that some of the program's components were not well integrated and would be unresponsive to future mission needs.

Combatant Commanders' Integrated Command and Control System

DOD initiated the Combatant Commanders' Integrated Command and Control System program in 2000 to modernize and integrate the Cheyenne Mountain Upgrade computer systems and to replace a space situational awareness data computer system called the Space Defense Operations Center (SPADOC). At that time, the SPADOC system was significantly overtaxed and in need of replacement by a system that could handle larger volumes of data.<sup>2</sup> In 2006, we found that Combatant Commanders' Integrated Command and Control System program costs had increased by approximately \$240 million, 51 percent over initial estimates, and the program was at least 3 years behind schedule. In addition, we found that that some capabilities had been deferred indefinitely, resulting in increased risks to performing future operations.<sup>3</sup> Further, we found that the Air Force did not effectively assess the appropriateness of the program's requirements prior to initiating the program, leading to significant additions, deletions, and modifications to the program's initial requirements. Consequently—similar to what transpired within the Cheyenne Mountain Upgrade program—significant amounts of work were deferred to address the cost increases associated with requirements changes. Ultimately, the Combatant Commanders' Integrated Command and Control System program was not able to successfully replace SPADOC.

Joint Space Operations Center Mission System

Started in 2009, the Joint Space Operations Center Mission System (JMS) was the Air Force's most recent effort to meet command and control capability and space situational awareness data needs and

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<sup>1</sup>GAO, *Attack Warning: Cost to Modernize NORAD's Computer System Significantly Understated*, [GAO/IMTEC-91-23](#) (Washington, D.C.: Apr. 10, 1991).

<sup>2</sup>The Air Force developed SPADOC in the 1980s. It was designed to process space situational awareness data and maintain orbital information of space objects. SPADOC is now significantly beyond its estimated end-of-life, and is operating on an outdated computer mainframe—production of which was discontinued in 1998.

<sup>3</sup>GAO, *Defense Acquisitions: Further Management and Oversight Changes Needed for Efforts to Modernize Cheyenne Mountain Attack Warning System*, [GAO-06-666](#) (Washington, D.C.: July 6, 2006).



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replace the SPADOC system. JMS was a software-intensive system and was supposed to be delivered in three increments.<sup>4</sup>

- Increment 1 was to provide the foundational structure for the overall program.
- Increment 2 was to deliver numerous operational capabilities to users, including replacing SPADOC by the end of fiscal year 2014 with the ability to automatically determine if objects in space were likely to collide (called conjunction assessments), which was a key performance parameter for the program.<sup>5</sup>
- Increment 3 was to provide additional command and control capabilities and the ability to incorporate data from highly classified special access programs.<sup>6</sup>

Of the three planned increments, Increment 1 is the only one that is fully operational today. JMS Increment 2 encountered significant challenges during development, and in 2016 the program experienced a critical change because of significant schedule delays and cost increases.<sup>7</sup> Specifically, JMS Increment 2 planned to delay delivery by more than 1 year, in turn increasing total program costs by over 25 percent. According to the August 2016 JMS Critical Change Report, which the program office submitted to Congress in September 2016 as a result of the critical change, several issues contributed to Increment 2's challenges. These included an overly aggressive schedule, inadequate staffing, underestimating the amount of work required to integrate various pieces

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<sup>4</sup>For the purposes of this report, we use the international standard for software-intensive systems: any system in which software contributes essential influences to the design, construction, deployment, and evolution of the system as a whole. International Organization for Standardization / International Electrotechnical Commission/Institute of Electrical and Electronics Engineers (ISO/IEC/IEEE), International Standard, Systems and software engineering—Architecture description, 42010 (December 2011).

<sup>5</sup>Key performance parameters are critical system capabilities that must be met in order for a system to meet its stated operational goals.

<sup>6</sup>Special access programs are programs established for a specific class of classified information that impose safeguarding and access requirements that exceed those normally required for information at the same classification level.

<sup>7</sup>Under then existing law, Critical Change Reports (CCR) were required to be submitted to the congressional defense committees if there had been a program schedule change that would cause a delay of one year or more or if the estimated program development cost or full life-cycle cost for the Major Automated Information System program had increased by 25 percent or more over the program's original estimate. 10 U.S.C. § 2445c(d)(3) (repealed in Pub. L. No. 114-328, § 846 (2016)).

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of the system that were developed by different groups, and numerous concurrent development efforts. An independent program assessment team comprised of military, intelligence, and contractor staff determined that the JMS program had underestimated the complexity of developing the system. Further, the program reported that its organizational structure proved problematic. For example, the program reported that program-related contracts were awarded and administered outside the program office, which limited program flexibility and support and hampered effective oversight. As a result of the critical change, the program re-estimated its costs, established new schedule goals, and deferred a number of capabilities and requirements to Increment 3.

Even after these changes, JMS Increment 2 was not successful at delivering its planned capabilities. Air Force operational testing in 2018 revealed significant issues with JMS Increment 2 performance. The Air Force's test team determined that Increment 2 was not suitable for operations, as it was unable to provide conjunction assessments or maintain the catalog of space objects, another key performance parameter. In the wake of these findings and the numerous issues found in testing, the Air Force stopped further development on JMS Increment 2. When development ended, JMS was almost 3 years behind schedule and \$139 million (42 percent) over budget. Air Force leadership placed the JMS Increment 2 program in sustainment and transferred three of the 12 planned Increment 2 capabilities into operations; the remaining nine capabilities were to be used for planning and analytic purposes only, as they were not reliable enough for operational use. Key requirements from Increment 2, including automated conjunction assessments and the ability to maintain a high-accuracy space catalog, as well as all of the requirements from Increment 3, were deferred to a subsequent effort, called the Space C2 program.

#### SPADOC Replacement and Space C2

Because JMS was unable to replace SPADOC, the system is still in use today. Since 2000, the Air Force has been addressing unique space surveillance requirements for follow-on systems to SPADOC. Air Force officials we spoke with stated that the system's ability to continue operations is a growing concern. While work is underway to move SPADOC onto a more modernized platform and infrastructure, the Air Force has not established a schedule for that effort. In the meantime, Air Force officials told us that large amounts of data are going unprocessed as the volume of available sensor data today is greater than ever

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before—and is expected to increase exponentially in the next year as new DOD sensors come online.<sup>8</sup>

The Space C2 program is the Air Force's latest software-intensive program to develop capabilities to anticipate and respond to emerging threats in space and ensure the uninterrupted availability of capabilities to the warfighter. SPADOC is expected to be retired as Space C2 capabilities become operational. The Air Force expects to spend between \$72 million and \$108 million per year on the Space C2 program, which is managed by the Air Force's Space and Missile Systems Center, through fiscal year 2024.<sup>9</sup>

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## The Air Force's Space C2 Program Is in Its Early Planning Stages and Is Taking a New Approach to Software Development

While it is still early in the planning and development stages, the Air Force's Space C2 program office expects to deliver a consolidated space command and control system over the next few years using a new system design. The program also plans to use a modernized, iterative software development process called Agile development to more quickly and responsively provide capability to users. According to Air Force officials, this development approach is relatively new to DOD programs. Therefore, the Space C2 program and DOD officials are working to determine the appropriate level of detail needed for the program's planning documents as well as the best way to provide oversight of a non-traditional development approach.

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## The Space C2 Program Plans to Consolidate Capabilities Using a New System Design

The Space C2 program is intended to consolidate operational level command and control capabilities for DOD space assets into an integrated system, allowing operators and decision makers to have a single point of access to command and control space assets around the globe in a timely manner. A consolidated space command and control capability will:

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<sup>8</sup>The Air Force expects its newest space situational awareness sensor, Space Fence, to become operational in November 2019. The Air Force expects that Space Fence, once operational, will track about 200,000 objects, many of which have not been tracked before, and thus will add a significant amount of new data to space situational awareness systems.

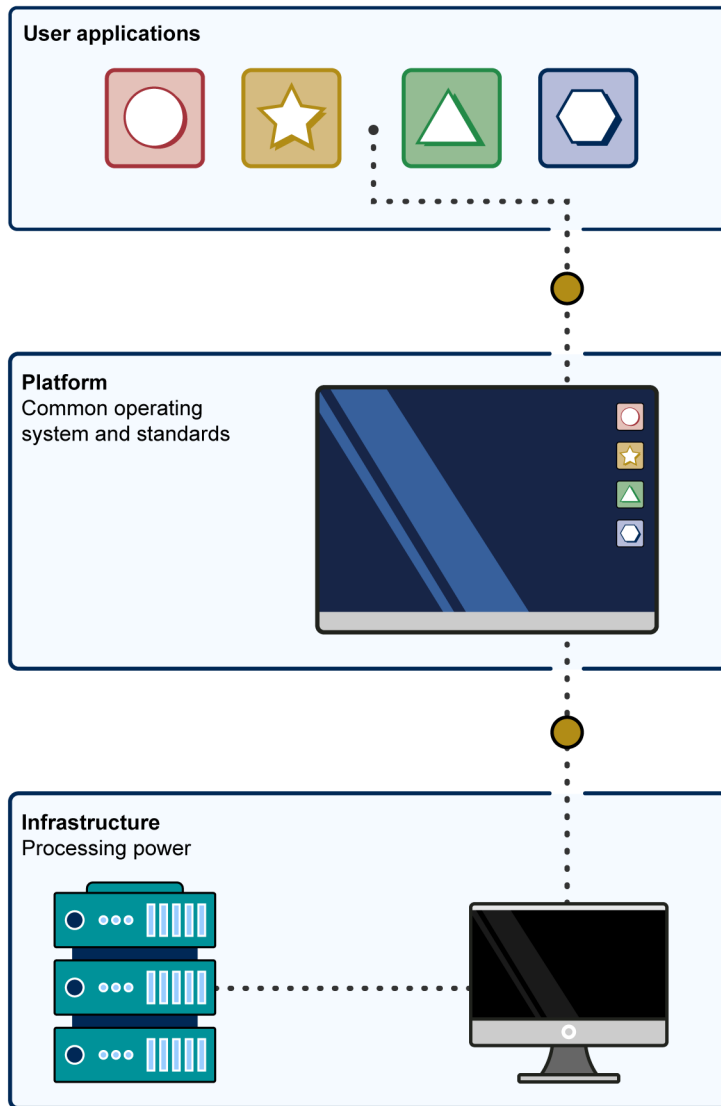
<sup>9</sup>DOD offices outside the Space C2 program are using additional funding for capabilities and efforts that will feed into the final Space C2 system. As some of this funding is classified, it is not provided here.

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- allow operators to comprehensively identify and monitor threats to U.S. space assets,
  - identify possible courses of action to mitigate or eliminate threats,
  - communicate courses of action to decision makers, and
  - direct action to respond to threats.

A consolidated space command and control capability is necessary, according to Air Force and DOD officials we met with, because the space domain has transitioned from a benign environment to one that—like ground, sea, and air domains—is contested by foreign adversaries. According to these officials, DOD needs the ability to respond to the increased threats to U.S. space assets in near real-time. Consequently, the Air Force is planning for Space C2 program capabilities to be significantly more automated than in the past, requiring high-quality software development and architecture planning.

As shown in figure 1, the Space C2 program itself will consist of multiple layers. Program officials explained that the foundational layer is the computing infrastructure, which must be secure from vulnerabilities and have adequate processing power to accommodate the complexity of the system. On this infrastructure will run the software platform, which forms the backbone of the operating system. The Space C2 program plans to procure the platform commercially. The software platform will contain standards that developers will need to comply with to create applications that will work on the platform. Some applications may be targeted to a broad number of users, and some may be more niche capabilities for a particular group of users. Space C2 program officials told us they believe this structure will allow them to be flexible in meeting multiple user needs more responsively than has been possible in past DOD programs. Users include, for example, space system operators responsible for predicting and avoiding space object collisions, and other operators responsible for responding to conflicts in space. The program also expects applications from a variety of developers, both commercial and government, to run on the platform, thus presenting opportunities for companies that do not regularly do business with DOD to participate in the program.

**Figure 1: Diagram of Space Command and Control Program System**



Source: GAO analysis of Air Force information. | GAO-20-146

The work being done for the Space C2 program is spread out among multiple Air Force groups. For example, the Air Force Research Laboratory has been developing applications for the Space C2 program both internally and with commercial partners since 2016. The Laboratory is also working on some battlespace awareness capabilities that may

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eventually run on the Space C2 program's platform.<sup>10</sup> Additionally, officials from the Air Force Rapid Capabilities Office stated that they have been working on common interface standards for applications, and this work will feed into the Space C2 program. As the Enterprise Manager, the Space C2 program manager is responsible for integrating all of the development work selected for use in the Space C2 program, irrespective of its origin.

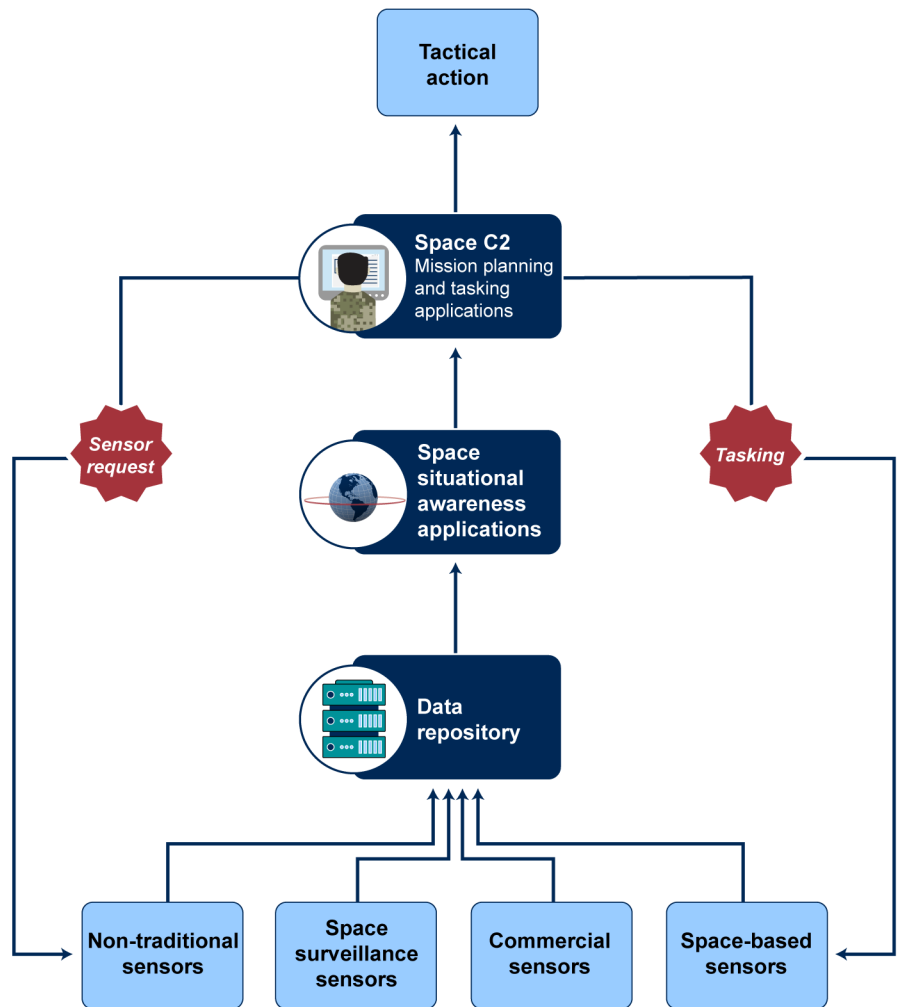
A principal component of the Space C2 program is a data repository that will be populated with data from a wide variety of commercial, civil, military, and intelligence space sensors. Eventually the program plans for operators using the Space C2 program's platform and applications to be able to retrieve data from the data repository. The data will be electronically tagged with its appropriate classification level and will be accessible to users according to their individual security clearances.

The overall design of the Space C2 program is for data to be gathered from sensors, placed into the data repository, and then be available for various applications to process and provide timely information to space operators and commanders on threats to space assets and anomalies in the space environment. Operators and commanders will then be able to promptly direct actions, such as tasking sensors to collect additional data or respond to threats. Figure 2 shows the proposed construct of the Space C2 program, including the various actions that can be taken in response to the data collected by the sensors.

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<sup>10</sup>Battlespace awareness is knowledge and understanding of the operational area's environment, factors, and conditions, to include the status of friendly and adversary forces, neutrals and noncombatants, weather and terrain, that enables timely, relevant, comprehensive, and accurate assessments in order to successfully apply combat power, protect the force, and/or compete the mission.

**Figure 2: Space Command and Control (C2) Program Planned Construct**



Source: GAO analysis of Air Force information. | GAO-20-146

### The Air Force Plans to Use an Agile Software Development Approach for Space C2 Development

The Space C2 program is planning to use an approach new to DOD in terms of software development, known as Agile. Agile development is a flexible, iterative way of developing software that delivers working capabilities to users earlier than the traditional, incremental DOD software development processes, known as the waterfall approach. Agile practices integrate planning, design, development, and testing into an iterative life cycle to deliver software early and often, such as every 60-90 days. The frequent iterations of Agile development are intended to effectively measure progress, reduce technical and programmatic risk, and be

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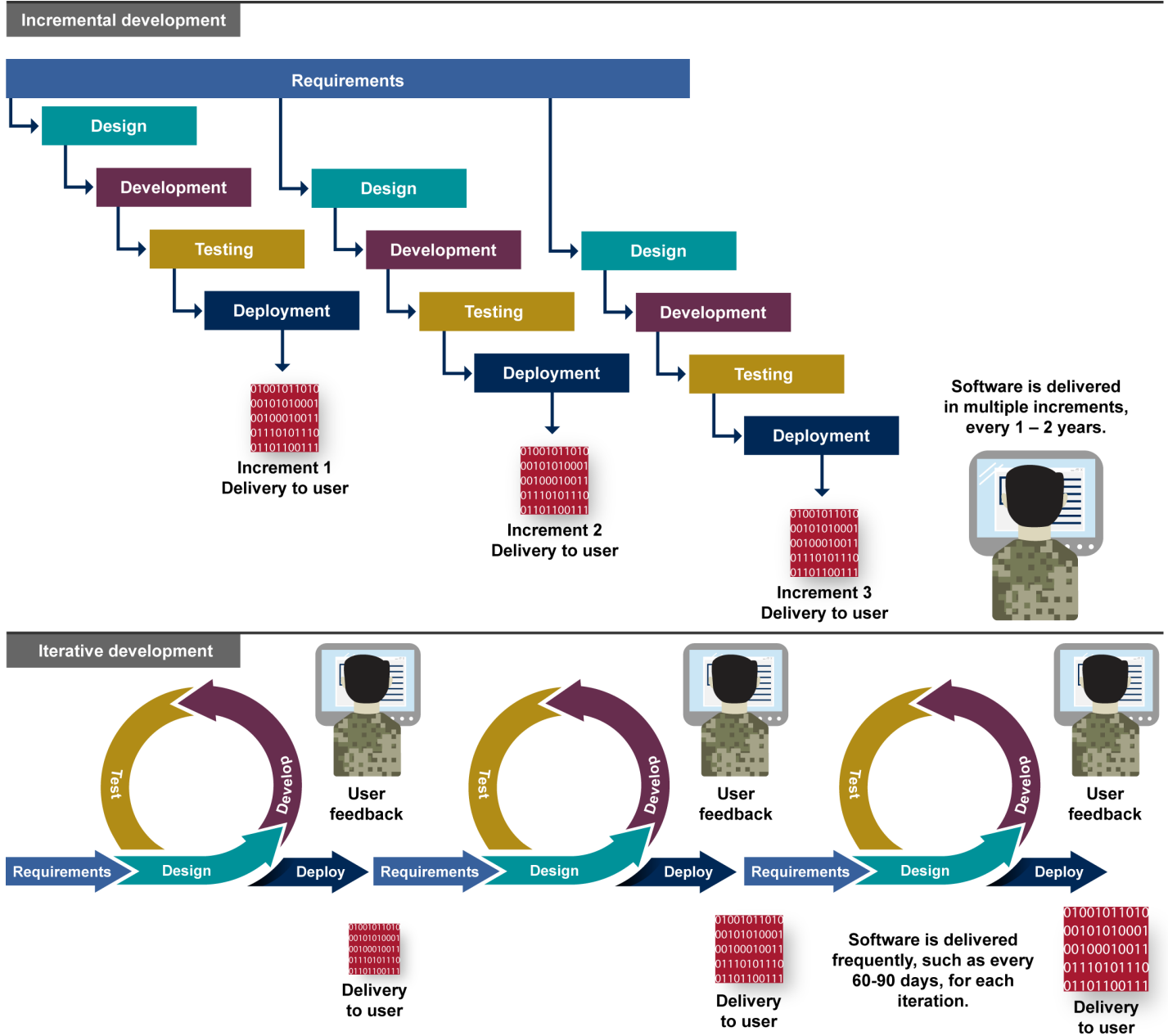
responsive to feedback from stakeholders and users. This is different from the way DOD has developed software in the past, in which requirements were solidified in advance of development and the software was delivered as a single completed program at the end of the development cycle—with no continual involvement or feedback from users or ability to modify requirements. Traditional software development mirrored the development of a hardware system. We have previously reported on past DOD software programs that experienced challenges due, in part, to that traditional development approach.<sup>11</sup> The differences between the two approaches are illustrated in figure 3.

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<sup>11</sup>GAO, *GPS: Actions Needed to Address Ground System Development Problems and User Equipment Production Readiness*, [GAO-15-657](#) (Washington, D.C.: Sept. 9, 2015); and *DOD Space Acquisitions: Including Users Early and Often in Software Development Could Benefit Programs*, [GAO-19-136](#) (Washington, D.C.: Mar. 18, 2019).



**Figure 3: Comparison of Incremental and Iterative Software Development**



Source: GAO analysis of Department of Defense (DOD) and industry documentation. | GAO-20-146

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The Space C2 program is one of the first DOD software-intensive programs to move away from the traditional approach and into the more modernized Agile development methodology. Program officials told us that many of the problems with JMS's development stemmed from its more traditional approach, and that with the Space C2 program they wanted to avoid circumstances that did not lead to program success. Considering that past software development problems were caused, at least in part, by the traditional method of software development, utilizing a different approach could be a positive step. However, the current DOD acquisition instruction does not include guidance for Agile software programs. According to DOD officials, new software guidance is in development, and this guidance is expected to offer pathways for developing Agile programs. DOD has also developed a draft template to assist Agile programs with developing their acquisition strategies, though the template and associated software guidance are in the early stages of development. In the meantime, however, Space C2 program officials confirmed that they are currently operating without specific software acquisition guidance. Space C2 officials also clarified that while official Agile software acquisition guidance has not yet been formally published, the program office has been actively engaged with the Office of the Under Secretary of Defense for Acquisition and Sustainment on refining draft policy and guidance. The program office noted that its program activities over the past year have been informed by and are consistent with this draft guidance.

The Space C2 program has submitted preliminary planning documents to the Under Secretary of Defense for Acquisition and Sustainment for approval.<sup>12</sup> While officials in the Under Secretary's office expect these documents to be modified and expanded upon in late 2019, the Under Secretary gave the program approval to begin its development under an Agile process, signifying her support for using alternative approaches. In addition, Air Force officials told us that the Commander of Air Force Space Command has requested frequent briefings on the program's development process, and while he does not have approval authority over the program, he is monitoring the program closely. Plans show that the

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<sup>12</sup>The Under Secretary of Defense for Acquisition and Sustainment, as the Milestone Decision Authority for the Space C2 program, has oversight and approval authority over the program's plans. The Milestone Decision Authority is the designated individual with overall responsibility for a program. This individual has the authority to approve entry of an acquisition program into the next phase of the acquisition process and is accountable for cost, schedule, and performance reporting to higher authority, including congressional reporting.

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program is conducting 90-day development iterations with the goal of providing working software at the end of each cycle.

As of August 2019, the program had completed three program development iterations, and reported delivering capabilities which included: expanding the commercial data available in the data repository; tasking various sensors; and providing a tool for visualization and analytics. The Air Force noted that these capabilities were deployed in a relatively short time; however, most capabilities delivered so far are considered to be available for use “at your own risk,” since they have not yet been fully approved for use in operations. Though the Air Force has not yet published a time frame for certifying these capabilities for operational use, the new development approach is underway and delivering some early capabilities. DOD officials noted that the foundational elements of the Space C2 system, including the infrastructure and software platform, should be completed prior to significant application development; however, at this early stage of the program, the schedule indicating the time frame in which these elements will be completed appears to be still in development.

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## DOD Is Establishing Agile Software Development Expertise

For government programs, some level of insight and oversight is essential when using public funds to develop a system. According to DOD officials, DOD is embracing Agile development because software can be delivered quickly and can be more responsive to user needs. However, according to GAO’s upcoming guide for assessing Agile development programs, known as the Agile Assessment Guide, sound engineering principles are still beneficial when employing this approach.<sup>13</sup> For example, continuous attention to technical excellence and good design requires the developers to consider security requirements throughout development. This is particularly true with complex programs that process sensitive data with complex security requirements. In past work, we have found that teams overlooking security requirements may end up developing systems that do not comply with current federal requirements (for example cybersecurity requirements for information technology programs), resulting in the software not becoming operational until these components

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<sup>13</sup>Draft *GAO Agile Assessment Guide*, Version 13. To develop the draft Agile guide, we have worked closely with Agile experts in the public and private sector and some chapters of the guide, including the one we used, are considered more mature because they were reviewed by the expert panel. The guide is expected to be published in 2020.

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are addressed.<sup>14</sup> In addition, the Agile Assessment Guide notes that transitioning to Agile software development can be challenging because Agile methods require organizations to do more than implement new tools, practices, or processes. Agile requires a re-evaluation of existing organizational structures, planning practices, business and program governance, and business measures, in addition to technical practices and tools. However, Agile does not mean eliminating the need for documentation, planning, oversight, architecture, risk analysis, or baseline schedule, for example.

Leading practices for Agile software development—as described in GAO’s upcoming Agile Assessment Guide—state that, among other things, programs should have the following characteristics:

- a product owner who manages the requirements prioritization, communicates operational concepts, and provides continual feedback to the development team;<sup>15</sup>
- staff who are appropriately trained in Agile methods;
- management that has established an Agile supportive environment;
- a program strategy that reflects the mission, architectural, safety-critical components, and dependencies;
- organization’s acquisition policy and guidance that require the contract type and the acquisition strategy to be aligned to support Agile implementation;
- an architecture that is planned upfront to enable flexibility and to provide support to Agile methods; and
- mission goals that drive the prioritization of the most advantageous requirements (e.g., security and privacy) that are well understood and reviewed throughout development.

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<sup>14</sup>See, for example, the *Federal Information Security Modernization Act of 2014*, 44 U.S.C. § 3551 et. seq., or National Institute of Standards and Technology *Standards for Security Categorization of Federal Information and Information Systems*, FIPS Publication 199 (Gaithersburg, Md.: Feb. 2004). Also see [GAO-15-657](#) and GAO, *Weapon Systems Cybersecurity: DOD Just Beginning to Grapple with Scale of Vulnerabilities*, [GAO-19-128](#) (Washington, D.C.: Oct. 9, 2018).

<sup>15</sup>Product owner is defined as the “voice of the customer”, accountable for ensuring business value is delivered by creating customer-centric items, ordering them, and maintaining them in the backlog.

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Recognizing the need to change traditional processes to accommodate more iterative software development, both the Air Force and Under Secretary of Defense for Acquisition and Sustainment have created software advisor positions. The Air Force Chief Software Officer and the Special Assistant for Software Acquisition are working to improve and modernize the way DOD acquires software. In addition, DOD is looking into how to use industry practices to modernize the way it develops software. For example, the Office of the Secretary of Defense has a Development Security Operations (DevSecOps) pathfinder program for software, which helps programs define and develop a technical digital roadmap and leverages industry and Office of the Secretary of Defense expertise in developing appropriate infrastructure for software programs. The DevSecOps concept emphasizes rapid prototyping, security, and continuous integration and delivery of software products. In a May 2019 Acquisition Decision Memorandum, the Under Secretary of Defense for Acquisition and Sustainment directed the Space C2 program to become a pathfinder program. This is a positive step, because it should increase input into the program's acquisition planning by the Office of the Secretary of Defense software development experts.

The Office of the Secretary of Defense has other groups that draw on private-sector software development expertise to help DOD programs, including the Defense Digital Service and the Defense Innovation Board.<sup>16</sup> These groups' missions include improving DOD's technology and innovation, and the groups can be valuable DOD resources for helping the Space C2 program develop its plans and Agile processes. The Defense Innovation Board conducted a review of some of the Space C2 program's software acquisition plans in December 2018. According to the Office of the Secretary of Defense officials we spoke with, this informal review was beneficial and resulted in real-time feedback on the approach the program was taking, as well as suggestions for areas to focus on. In the May 2019 memorandum, the Under Secretary of Defense for Acquisition and Sustainment noted that in October 2019 she will determine if an independent technical assessment of the Space C2 program is necessary. Considering the stated benefits of the prior

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<sup>16</sup>The Defense Digital Service (DDS) is an agency team of the U.S. Digital Service. DDS hires top technologists on term-limited assignments to help DOD build, buy, and deploy technology and digital services. The Defense Innovation Board (DIB) is to provide the Secretary of Defense, Deputy Secretary of Defense, and other senior leaders across DOD with independent advice and recommendations on innovative means to address future challenges through the prism of three focus areas: people and culture, technology and capabilities, and practices and operations.

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Defense Innovation Board review of the Space C2 program, as well as the fact that using Agile processes for a DOD program is relatively new and includes many unknowns, independent reviews could help ensure the program is on a successful path.

As the Office of the Secretary of Defense and the Air Force have made an effort to increase in-house Agile software development expertise, programs like the Space C2 program—especially in light of its early stage of development—could benefit from periodic attention from the experts at its disposal, including input from independent, external reviews to help ensure the necessary software development steps are taken to set programs up for success. DOD programs following traditional acquisition processes conduct internal reviews at major milestones, and GAO best practices for knowledge-based acquisitions also include conducting independent program reviews at these milestones. The draft GAO Agile Assessment Guide notes that while traditional DOD program milestone reviews are not used for Agile programs, Agile programs rely on other review methods such as stakeholder demonstrations and retrospective program reviews during each iteration of work. In addition, the GAO Schedule Assessment Guide, which identifies best practices for managing a program’s schedule, states that programs should conduct periodic reevaluations of risks, and that an independent view in this is valuable.<sup>17</sup> Such reviews offer greater objectivity, as the reviewers are not responsible for the activities being evaluated, and programs benefit from the wide variety of expertise and experience represented by the external review team. In addition, in many cases, having these external reviews periodically can prove useful.

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<sup>17</sup>GAO, *Schedule Assessment Guide: Best Practices for Project Schedules*, [GAO-16-89G](#) (Washington, D.C.: December 2015).

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## The Air Force's Space C2 Program Faces Challenges in Multiple Areas and Plans Are Underway to Address Some, but Not All of Them

The Space C2 program faces a number of management, technical, and workforce challenges. Some of these challenges may ultimately be overcome by time and experience, and the Air Force has efforts underway to mitigate others in the near-term. But it is too early to determine whether these efforts will be sufficient to achieve program success.

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### Management Challenges

The Space C2 program faces several management challenges. The Air Force has been working on developing various parts of the Space C2 program since 2016, but as previously noted, the program is working from a draft acquisition strategy and does not yet have an overall program architecture. These plans are important for providing direction for a program and facilitating effective oversight by establishing a business case for the effort. A business case establishes that the program is necessary and that it can be developed with the resources available, and typically includes: a requirements document, an acquisition strategy, sound cost estimates based on independent assessments, and a realistic assessment of risks, including those relating to technology and schedule.

In addition, according to Air Force officials, the Space C2 Enterprise Manager has management responsibility—but not authority—over multiple development efforts included in the Space C2 enterprise. For example, technology maturation and risk reduction activities are divided across three program offices, managed by two program executive officers, and reliant upon multiple sources of information.<sup>18</sup> This division of work is being done in part because the various organizations have areas of expertise that the program was hoping to leverage. However, such distribution of activities among many organizations can result in synchronization and coordination challenges. JMS's development was hampered by similarly-split responsibilities for development contracts for various efforts.<sup>19</sup> Because space is becoming an increasingly contested

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<sup>18</sup>A program executive officer is the main stakeholder responsible for cost, schedule and performance in a DOD acquisition program or a portfolio of similar programs.

<sup>19</sup>The Joint Space Operations Center (JSpOC) Mission System (JMS) Increment 2 Major Automated Information System (MAIS) Critical Change Report, August 2016.

domain, DOD has noted that its ability to effectively respond to space threats has increased the importance of focused leadership in national security space, to include Space C2. See table 1 for additional details of management challenges facing the Space C2 program.

**Table 1: Management Challenges to Space Command and Control Program and Corresponding Department of Defense Mitigation Plans**

Challenge area	Description of challenge	DOD mitigation plans
No formal acquisition strategy	An acquisition strategy is a comprehensive plan that describes how a program will manage program risks and meet program objectives, and that establishes metrics to help ensure oversight is consistent and any development issues are identified early. Program officials submitted a draft Space Command and Control (C2) acquisition strategy to stakeholders in the Office of the Secretary of Defense in late 2018, but the stakeholders rejected the draft as it lacked key attributes. In part, Office of the Secretary of Defense stakeholders said the strategy lacked detail on the program’s management structure, requirements definition and prioritization, system architecture and infrastructure definition, plans to incorporate lessons learned from the Joint Space Operations Center Mission System development problems, intellectual property and data rights strategy, and the program’s cost estimating methodology. Without an acquisition strategy there is no plan in place that describes the approach a program will follow to manage program risks and meet program objectives.	In May 2019, the Under Secretary of Defense for Acquisition and Sustainment directed the Space C2 program to submit for approval a revised acquisition strategy, consistent with the Department of Defense’s (DOD) draft Agile software acquisition strategy template, in November 2019. The interim DOD guidance outlines numerous details that should be included, some of which mirror details sought by Office of the Secretary of Defense stakeholders. For example, the software acquisition template states that the program should specify program metrics, contracting strategy, and funding levels by year.
No formal system architecture	System architectures provide a basis for planning and guiding development to ensure interoperability and compatibility between and among subsystems. An architecture is an essential tool for effectively and efficiently engineering business operations (e.g., processes, work locations, and information needs and flows) and defining, implementing, and evolving information technology systems in a way that best supports these operations. Without a system architecture to guide development, the Space C2 program may experience ineffective program management and integration.	In May 2019, the Under Secretary of Defense for Acquisitions and Sustainment directed the Space C2 program to submit for review Space C2 system infrastructure /architecture designs by October 31, 2019.



Challenge area	Description of challenge	DOD mitigation plans
Limited Space C2 Enterprise Manager authority	<p>Although the Space C2 Enterprise Manager retains integration authority over the Space C2 system and platform, this position does not have authority to direct the numerous efforts underway throughout DOD that will eventually feed into Space C2. According to the program's Critical Change Report, similar lack of oversight and control over the award and administration of related contracts was a central issue in the Joint Space Operations Center Mission System program's development problems. For example, the Space C2 program plans to employ common standards and interfaces that are currently being developed by another Air Force office to support integration of commercial innovation, but these contracts are managed outside the Air Force Space and Missile Systems Center where the Space C2 program and Enterprise Manager are located. Additionally, the Space C2 program intends to incorporate prototypes that are being developed by the Air Force Research Laboratory, but the Space C2 Enterprise Manager at Space and Missile Systems Center does not have direct control over transitioning these technologies into the program. We have previously reported that empowering program managers to make decisions and manage resources was a best practice in industry program management.<sup>a</sup> Without a manager that has authority to direct the numerous efforts, the program may experience ineffective collaboration, synchronization, and integration.</p>	<p>In May 2019, the Under Secretary of Defense for Acquisition and Sustainment directed the Space C2 program to submit a plan that will help enable effective collaboration, synchronization, and integration of activities across multiple organizations. The plan is to be completed in September 2019 in coordination with the Office of the Under Secretary of Defense for Acquisition and Sustainment.</p>

Source: GAO analysis of DOD and Air Force documents. | GAO-20-146

<sup>a</sup>GAO, *Best Practices: Better Support of Weapon System Program Managers Needed to Improve Outcomes*, [GAO-06-110](#) (Washington, D.C.: Nov. 20, 2005).

According to officials from the Space C2 program and the Office of the Secretary of Defense, the Space C2 program was allowed to begin development work without an acquisition strategy, due to the program's urgency. In May 2019, the Under Secretary of Defense for Acquisition and Sustainment tasked the Space C2 program office with revising its preliminary acquisition strategy to be consistent with DOD's draft template for software acquisition. DOD's draft template contains specific elements for ongoing planning and evaluation that are to be included in DOD software acquisition strategies moving forward, including

- acquisition and contracting approach;
- program management structure, including authorities and oversight responsibilities;
- plans for platform and infrastructure development;
- requirements management and development approach, and plans for prioritization;
- risk management plans, including how the program will identify and mitigate risks;

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- metrics for measuring quality of software, and how those results will be shared with external stakeholders;
  - manpower assessment identifying program workforce needs and state of expertise in Agile methods;
  - requirements for reporting program progress to decision makers; and
  - yearly funding levels.

We have also noted these factors in our previous reports that identify the need to develop a sound, executable business case at the outset of a program, and the importance of using knowledge-based decision making in DOD acquisition programs.<sup>20</sup> In addition, our work on best practices for knowledge-based acquisitions has emphasized that the success of any effort to develop a new product hinges on having the right knowledge at the right time, and that a better opportunity exists to meet program goals when the knowledge is available early.<sup>21</sup> However, given that DOD's draft template is still subject to change, including these elements in the finalized acquisition strategy would help position the program for success.

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## Technical Challenges

The Space C2 program also faces significant technical challenges, as described in table 2. For example, the program is planning to meet previously deferred requirements that proved too complex for prior programs to achieve. It also plans to address new and emerging threats to space assets, for which requirements are not yet defined. In addition, the program plans to use an Agile software development approach, the processes of which DOD has yet to show proficiency in applying, as discussed above. Integration of the multiple types of software planned for Space C2 is also likely to present considerable technical challenges. Further, cybersecurity is a growing concern for DOD space programs, including Space C2.

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<sup>20</sup>See for example, GAO, *DOD Acquisition Reform: DOD Should Streamline Its Decision-Making Process for Weapon Systems to Reduce Inefficiencies*, [GAO-15-192](#) (Washington, D.C.: Feb. 24, 2015); and *DOD Acquisition Reform: Leadership Attention Needed to Effectively Implement Changes to Acquisition Oversight*, [GAO-19-439](#) (Washington D.C.: June 5, 2019).

<sup>21</sup>GAO, *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, [GAO-02-701](#) (Washington, D.C.: July 14, 2002).

**Table 2: Technical Challenges to Space Command and Control Program and Corresponding Department of Defense Mitigation Plans**

Challenge area	Description of challenge	DOD mitigation plans
Requirements are complex, difficult to address, and some have yet to be defined	The Air Force has not yet articulated how the Space Command and Control (C2) program plans to prioritize meeting the Joint Space Operations Center Mission System (JMS) Increment 2 and 3 deferred requirements. These requirements were validated in 2012 and 2015, respectively. The Defense Innovation Board recently reported on the JMS program and pointed out that any software program in which a set of software requirements was established more than 5 years ago should be stopped and restarted with a description of the desired end state (including a list of features with specifications) and a prioritization of features that should be targeted for simplest usable functionality. In addition, program officials have stated that they plan to be able to address future requirements as they arise. Designing a program to meet as-yet-undefined requirements poses a challenge because it is difficult to plan a system's foundation without knowing all it will be asked to do.	As Space C2 requirements are still in development, risk mitigation plans have not been developed. The Space C2 program noted, however, that it has implemented an agile requirements process that allows capabilities to be continuously evaluated and prioritized based on user feedback.
Undemonstrated proficiency in Agile software development	Although the Development Security Operations (DevSecOps) concept is promising, the Department of Defense (DOD) has previously had difficulty implementing this approach. In March 2019, we found that four major DOD software-intensive space programs, including JMS, struggled to effectively engage system users and efforts to involve users and obtain and incorporate feedback were often unsuccessful. Three of the four programs were Air Force programs. In addition, the programs reviewed also faced software-specific challenges related to using commercial software, applying outdated software tools, and having limited knowledge and training in newer software development techniques. <sup>a</sup> As we reported in March 2019, JMS tried to implement elements of Agile software development, by emphasizing smaller, frequent deliveries of software to users, but ultimately struggled to move away from its long delivery schedules. <sup>b</sup>	DOD has a software development expert leading the DevSecOps effort to help implement DevSecOps for multiple DOD pathfinder programs. Space C2 is one of the pathfinder programs.
Four different types of software are to be integrated	The Air Force plans to deliver Space C2 capabilities using at least four different methods for acquiring software: commercial off-the-shelf, industry developed, government developed, or military service developed, all of which will need to be integrated to some degree. We also found in March 2019 that other programs that have done similar work indicated that integrating the multiple layers of the Space C2 system will be challenging. <sup>c</sup> Further, at this time, the Space C2 software platform has yet to be designed and built, so applications currently in development will need to be adapted to run on the platform's final design. This approach adds technical risk to the program, and DOD officials cited this as a major challenge that led to development problems for the JMS program.	As of August 2019, the Air Force had not developed plans that will mitigate challenges to software integration.

Challenge area	Description of challenge	DOD mitigation plans
Cybersecurity measures early in development	Cybersecurity aims to reduce the likelihood that attackers can access DOD systems, and to limit the damage if they do. <sup>d</sup> Space C2 is early in its development and the Air Force has not yet determined how the Space C2 program will design and incorporate cybersecurity. Software development industry leading practices encourage programs to develop robust cybersecurity measures early in development of a program. We reported in October 2018 that adding cybersecurity measures after a program is underway is ineffective in securing systems and networks. Although JMS had cybersecurity requirements, it experienced cybersecurity certification challenges. We also reported in October 2018 that DOD faced mounting challenges in protecting its weapon systems from increasingly sophisticated cyber threats due to the computerized nature of weapon systems; DOD's late start in prioritizing weapon systems cybersecurity; and DOD's nascent understanding of how to develop more secure weapon systems. <sup>e</sup>	DOD has recently taken steps to improve overall weapon systems cybersecurity, including issuing and revising policies and guidance to better incorporate cybersecurity considerations. In addition, DOD is developing an Enterprise DevSecOps initiative to provide an overarching roadmap to DOD's cybersecurity effort. In addition, the Space C2 program stated that it is implementing DevSecOps practices to address cybersecurity concerns in the program's design. The program also noted that it received authority to operate for its platform layer in September 2019.

Source: GAO analysis of DOD and Air Force documents. | GAO-20-146

<sup>a</sup>GAO, *DOD Space Acquisitions: Including Users Early and Often in Software Development Could Benefit Programs*, GAO-19-136 (Washington, D.C.: Mar. 18, 2019).

<sup>b</sup>GAO-19-136

<sup>c</sup>GAO-19-136

<sup>d</sup>Definition adapted from National Institute of Standards and Technology, *Framework for Improving Critical Infrastructure Cybersecurity*, Version 1.1 (Apr. 16, 2018).

<sup>e</sup>GAO, *Weapon Systems Cybersecurity: DOD Just Beginning to Grapple with Scale of Vulnerabilities*, GAO-19-128 (Washington, D.C.: Oct. 9, 2018).

## Workforce Challenges

In addition to the management and technical risks we identified, limited availability of staff with expertise in Agile software development poses a challenge to the Space C2 program and to DOD in general. The Space C2 program manager stated that the program is undertaking an effort that is fast-paced in nature and needs to be rapidly fielded, and she expressed confidence in her staff's abilities to meet the development demands. However, various DOD officials told us that a lack of qualified software developers within DOD, and within the Space C2 program, is an issue. Agile software development methods are different from the traditional approaches used by DOD, and according to DOD officials, proficiency in Agile methods requires specific training. Software developers with this training are in high demand in the private sector, and according to DOD officials, sufficient numbers may not be immediately available for the Space C2 program.

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One industry best practice for software development states that to be successful, programs should ensure that each development team has immediate access to people with specialized skills including contracting, architecture, database administration, development, quality assurance, operations (if applicable), information security, risk analysis, and business systems analysis.<sup>22</sup> As early as March 2009, DOD acknowledged it had a top priority to establish a cadre of trained information technology professionals, and that the lack thereof was a significant impediment to successful implementation of any future software development process.<sup>23</sup> Furthermore, a 2018 Defense Science Board report highlights the lack of Agile software expertise in DOD, citing no modern software expertise in program offices or the broader acquisition workforce.<sup>24</sup> Moreover, the report states that DOD defense prime contractors need to build their own internal competencies in modern software methodologies. Similarly, we found in March 2019 that DOD faces several challenges related to hiring, assigning, and retaining qualified personnel to work on space acquisition programs, similar to the challenges it faces more generally with the acquisition workforce. We also noted that DOD is taking steps to address these challenges where possible.<sup>25</sup>

In May 2019, the DOD's Defense Innovation Board issued a congressionally mandated study on software acquisition and practices.<sup>26</sup> The report stated that numerous past studies have recognized the deficiencies in software acquisition and practices within DOD. The report also noted the importance of digital talent and stated that DOD's current personnel processes and culture will not allow its military and civilian software capabilities to grow fast or deep enough to meet its mission needs. In addition, the report stated that new mechanisms are needed for

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<sup>22</sup>GAO Draft Agile Assessment Guide, Chapter 3.

<sup>23</sup>Defense Science Board, "Defense Science Board Task Force on Department of Defense Policies and Procedures for the Acquisition of Information Technology," *U.S. Department of Defense*, March 2009.

<sup>24</sup>Defense Science Board, *Design and Acquisition of Software for Defense Systems*, (Washington, D.C., Feb. 14, 2018).

<sup>25</sup>GAO, *Defense Space Systems: DOD Should Collect and Maintain Data on Its Space Acquisition Workforce*, [GAO-19-240](#) (Washington, D.C.: Mar. 14, 2019).

<sup>26</sup>Section 872 of the National Defense Authorization Act for Fiscal Year 2018 required the Secretary of Defense to direct the Defense Innovation Board to study how to streamline software development and acquisition regulations. Defense Innovation Board, *Software is Never Done: Refactoring the Acquisition Code for Competitive Advantage*, May 3, 2019.

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attracting, educating, retaining, and promoting digital talent and for supporting the workforce to follow modern practices, including developing software in close coordination with users. Finally, the report emphasized that the military services and Office of the Secretary of Defense will need to create new paths for digital talent (especially internal DOD talent) by establishing software development as a high-visibility, high-priority career track and increasing the level of understanding of modern software within the acquisition workforce. This is the case for all DOD space programs, including Space C2.

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## Conclusions

DOD's ability to command and control U.S. space assets, as well as anticipate and respond to the threats these assets face, is critical. However, over more than three decades, DOD's efforts to improve its space command and control capabilities—commensurate with the space threats that have continued to grow in frequency and type—have been fraught with development problems. The Air Force has again undertaken a program to meet the nation's ongoing and future consolidated command and control needs, while trying to overcome past problems with a modern software development process. The Space C2 program is making a concerted effort to learn from past software development mistakes while forging a new path for Agile development. Though DOD is taking steps to ensure that the Space C2 program has a comprehensive approach in place for managing, identifying, and mitigating challenges associated with this approach, key program plans and agency-wide guidance are still in draft form, leaving uncertainty as to how program development and oversight will ultimately proceed. Finalizing a robust acquisition strategy containing the key elements for ongoing planning and evaluation would position the program for success.

Striking the right balance between trying new development methods and working within DOD's knowledge-based framework will be essential for meeting cost, schedule, and performance goals. Periodic assessments of the program's approach to developing software, done by independent software development experts, could not only help ensure the reviews are balanced, but would also help ensure the Space C2 program effectively addresses the challenges it faces and is situated for success. Such reviews would also help the Space C2 program to identify potential roadblocks, and ultimately, potential solutions. Effectively addressing the challenges facing the Space C2 program will help ensure that needed space command and control capabilities are no longer deferred, but actually delivered.

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## Recommendations for Executive Action

We are making two recommendations to the Department of Defense.

The Under Secretary of Defense for Acquisition and Sustainment should ensure that the Air Force's finalized Space C2 program's acquisition strategy includes, at a minimum, the following elements:

- acquisition and contracting approach;
- program management structure, including authorities and oversight responsibilities;
- plans for platform and infrastructure development;
- requirements management and development approach, and plans for prioritization;
- risk management plans, including how the program will identify and mitigate risks;
- metrics for measuring quality of software, and how those results will be shared with external stakeholders;
- manpower assessment identifying program workforce needs and state of expertise in Agile methods;
- requirements for reporting program progress to decision makers; and
- yearly funding levels. (Recommendation 1)

The Under Secretary of Defense for Acquisition and Sustainment should ensure that the Air Force's Space C2 program conducts periodic independent reviews to assess the program's approach to developing software and provide, as needed, advice to the program and recommendations for improving the program's development and progress. Participants could include, but are not limited to, officials from the Defense Innovation Board, the Defense Digital Service, the office of the Air Force Chief Software Advisor, and the Under Secretary of Defense for Acquisition and Sustainment's Special Assistant for Software Acquisition. (Recommendation 2)

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## Agency Comments and Our Evaluation

We provided a draft of this product to the Department of Defense for comment. In its comments, reproduced in appendix II, DOD concurred with our recommendations. DOD also provided technical comments, which we incorporated as appropriate.

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We are sending copies of this report to the appropriate congressional committees, the Secretary of Defense, the Secretary of the Air Force, and the Under Secretary of Defense for Acquisition and Sustainment. In addition, the report will be available at no charge on GAO's website at <http://www.gao.gov>.

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



Cristina T. Chaplain  
Director, Contracting and National Security Acquisitions



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*List of Committees*

The Honorable James M. Inhofe  
Chairman  
The Honorable Jack Reed  
Ranking Member  
Committee on Armed Services  
United States Senate

The Honorable Richard C. Shelby  
Chairman  
The Honorable Richard Durbin  
Ranking Member  
Subcommittee on Defense  
Committee on Appropriations  
United States Senate

The Honorable Adam Smith  
Chairman  
The Honorable Mac Thornberry  
Ranking Member  
Committee on Armed Services  
House of Representatives

The Honorable Peter J. Visclosky  
Chairman  
The Honorable Ken Calvert  
Ranking Member  
Subcommittee on Defense  
Committee on Appropriations  
House of Representatives

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# Appendix I: Objectives, Scope, and Methodology

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The House Armed Services Committee report accompanying a bill for the National Defense Authorization Act for Fiscal Year 2018 contained a provision for us to review the Department of Defense's (DOD) efforts to develop space command and control capabilities. This report (1) assesses the status of and plans for ongoing Air Force efforts to develop advanced command and control capabilities for space, and (2) identifies challenges the Air Force faces in developing these capabilities.

To assess the status of and plans for ongoing Air Force efforts to develop advanced command and control capabilities for space, we analyzed Air Force Space Command and Control (C2) Program Increment Demonstration and Planning Retrospective reports for the first three increments and examined acquisition strategies for relevant programs, including acquisition strategies and addenda for Joint Space Operations center (JSPOC) Mission System (JMS) Increments 1 and 2. We also examined the Air Force's draft acquisition strategy for Space C2 and DOD's draft acquisition strategy for Major Agile Software Programs; reviewed Space C2 document mapping planned capabilities to the specific requirements that will be met by program deliveries; and analyzed status updates from the Space C2 program and the Combined Space Operations Center and program update briefings prepared for congressional staff by the JMS and Space C2 programs and the National Space Defense Center. In addition, we analyzed Space C2 program plans in conjunction with interim DOD guidance for Agile Software Acquisition, the Joint Chiefs of Staff Cyber Survivability Endorsement Implementation Guide, the Office of the Secretary of Defense guidance on cybersecurity operational test and evaluation procedures in acquisition programs and DOD Enterprise Development, Security and Operations (DevSecOps) processes; and examined the Principal DOD Space Advisor's Capabilities Based Assessment which included issues relating to Space C2. We also reviewed Air Force Broad Agency Announcements and Requests for Information for Space Battle Management Command and Control and Space Situational Awareness capability development. In addition, we obtained information from 12 of the 16 companies with whom the Air Force is working to obtain their perspectives of the Air Force's approach to developing Space C2 capabilities.

To identify challenges the Air Force faces as it develops advanced command and control capabilities for space, we analyzed the JMS Critical Change Certification; examined Joint Requirements Oversight Council memoranda pertaining to the JMS critical change management and certification; reviewed the Air Force's Space and Missile Systems Center evaluation of commercial capability gaps and capabilities; reviewed the

JMS Program Manager briefing on lessons learned; and examined the DOD test and evaluation report on JMS Increment 2 (Service Pack 9). We also reviewed a selected chapter of GAO's draft Agile Assessment Guide (Version 13), which is intended to establish a consistent framework based on best practices that can be used across the federal government for developing, implementing, managing, and evaluating agencies' information technology investments that rely on Agile methods.<sup>1</sup> To develop this guide, GAO worked closely with Agile experts in the public and private sector; some chapters of the guide are considered more mature because they have been reviewed by the expert panel. We reviewed this chapter to ensure that our expectations for how the Air Force should apply best practices for development of software capabilities for space command and control are appropriate for an Agile program and are consistent with the draft guidance that is under development, and we compared Space C2 program plans to the practices outlined in the guide. Additionally, since Agile development programs may use different terminology to describe their software development processes, the Agile terms used in this report are specific to the Space C2 program. We also compared Air Force development plans with interim and established DOD guidelines for software development, and GAO best practices for knowledge-based decision-making in weapons system development. We also reviewed prior GAO reports on the Cheyenne Mountain Upgrade, the Combatant Commanders' Integrated Command and Control System, software acquisition, and cybersecurity.<sup>2</sup>

Additionally, we interviewed DOD officials from the Office of the Under Secretary of Defense for Acquisition and Sustainment; Joint Chiefs of Staff, Force Structure, Resources, and Assessment Directorate; U.S. Strategic Command; Air Force Combined Space Operations Center; Defense Advanced Research Projects Agency; Missile Defense Agency; Office of the former Principal DOD Space Advisor; Air Force Space Command; Air Force Research Laboratory; Defense Digital Service;

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<sup>1</sup>GAO's Agile Assessment Guide is expected to be published in 2020.

<sup>2</sup>GAO, *Attack Warning: Lack of System Architecture Contributes to Major Development Problems*, [GAO/IMTEC-92-52](#) (Washington, D.C.: June 11, 1992); *Defense Acquisitions: Further Management and Oversight Changes Needed for Efforts to Modernize Cheyenne Mountain Attack Warning System*, [GAO-06-666](#) (Washington, D.C.: July 6, 2006); *DOD Space Acquisitions: Including Users Early and Often in Software Development Could Benefit Programs*, [GAO-19-136](#) (Washington, D.C.: Mar. 18, 2019); and *Weapon Systems Cybersecurity: DOD Just Beginning to Grapple with Scale of Vulnerabilities*, [GAO-19-128](#) (Washington, D.C.: Oct. 9, 2018).

Office of Cost Assessment and Program Evaluation; Air Force Rapid Capabilities Office; National Space Defense Center; and Air Force Space and Missile Systems Center. Finally, we interviewed officials from commercial companies that are known in the space community to have potential input into the development of space command and control capabilities to understand how the Space C2 program plans to integrate commercial capabilities into the program.

We conducted this performance audit from January 2018 to October 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

# Appendix II: Comments from the Department of Defense



ASSISTANT SECRETARY OF DEFENSE  
3600 DEFENSE PENTAGON  
WASHINGTON, DC 20301-3600

ACQUISITION

OCT 10 2019

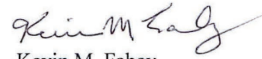
Ms. Christina Chaplain  
Director, Acquisition and Sourcing Management  
U.S. Government Accountability Office  
441 G Street, N.W.  
Washington, DC 20548

Dear Ms. Chaplain:

Enclosed is the Department of Defense (DoD) response to the GAO Draft Report, GAO-19-677SU, "Space Command and Control: Comprehensive Planning and Oversight Could Help DOD Acquire Critical Capabilities and Address Challenges," dated October 2019 (GAO Code 102540).

The Department appreciates the effort of the GAO and the opportunity to comment on the draft report.

Sincerely,

  
Kevin M. Fahey

Enclosure:  
As stated

GAO DRAFT REPORT DATED OCTOBER 1, 2019  
GAO-19-677SU (GAO CODE 102540)

“SPACE COMMAND AND CONTROL: COMPREHENSIVE PLANNING AND  
OVERSIGHT COULD HELP DOD ACQUIRE CRITICAL CAPABILITIES AND  
ADDRESS CHALLENGES”

DEPARTMENT OF DEFENSE COMMENTS  
TO THE GAO RECOMMENDATION

**RECOMMENDATION 1:** The GAO recommends that The Under Secretary of Defense for Acquisition and Sustainment should ensure that the Air Force's finalized Space C2 program's acquisition strategy includes, at a minimum, the following elements:

- Acquisition and contracting approach;
- Program management structure, including authorities and oversight responsibilities;
- Plans for platform and infrastructure development;
- Requirements management and development approach, and plans for prioritization;
- Risk management plans, including how the program will identify and mitigate risks;
- Metrics for measuring quality of software, and how those results will be shared with external stakeholders;
- Manpower assessment identifying program workforce needs and state of expertise in Agile methods;
- Requirements for reporting program progress to decision makers; and
- Yearly funding levels. (Recommendation 1)

**DoD RESPONSE:** The DoD concurs with this recommendation. The Under Secretary of Defense for Acquisition and Sustainment, in an Acquisition Decision Memorandum signed on May 20, 2019, directed the Air Force provide an Acquisition Strategy for approval in November 2019. An acquisition strategy template provided to the Air Force includes the elements identified by the GAO.

**RECOMMENDATION 2:** The GAO recommends that The Under Secretary of Defense for Acquisition and Sustainment should ensure that the Air Force's Space C2 program conducts periodic independent reviews to assess the program's approach to developing software and provide, as needed, advice to the program and recommendations for improving the program's development and progress. Participants could include, but are not limited to, officials from the Defense Innovation Board, the Defense Digital Service, the office of the Air Force Chief Software Advisor, and the Under Secretary of Defense

for Acquisition and Sustainment's Special Assistant for Software Acquisition.  
(Recommendation 2)

**DoD RESPONSE:** The DoD concurs with this recommendation. The Under Secretary of Defense for Acquisition and Sustainment, in an Acquisition Decision Memorandum signed on May 20, 2019, has directed the Air Force return for an In-Process Review to discuss program execution. At the In-Process Review, the Under Secretary will assess the need for future periodic and independent reviews of the program.

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# Appendix III: GAO Contact and Staff Acknowledgments

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## GAO Contact

Cristina T. Chaplain (202) 512-4841 or [ChaplainC@gao.gov](mailto:ChaplainC@gao.gov)

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## Staff Acknowledgments

In addition to the contact named above, Rich Horiuchi, Assistant Director, Emily Bond, Claire Buck, Maricela Cherveney, Burns Eckert, Laura Hook, and Roxanna Sun made key contributions to this report. Assistance was also provided by Pamela Davidson, Kurt Gurka, Jennifer Leotta, Harold Podell, Marc Schwartz, James Tallon, Eric Winter, and Alyssa Weir.



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