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SATELLITE COMMUNICATIONS

DOD Should Develop a Plan for Implementing Its Recommendations on a Future Wideband Architecture

GAO-20-80

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GAO Highlights

Highlights of GAO-20-80, a report to congressional committees

Why GAO Did This Study

DOD officials estimate spending an average of $4 billion each year to acquire and sustain wideband satellite communications that provide fast and reliable voice, video, and data transmissions critical to military operations. DOD is considering how to meet its future wideband needs across many different operating environments and scenarios. The National Defense Authorization Act for Fiscal Year 2016 required DOD to conduct a Wideband Communications Services AOA to identify ways to replace current systems as the satellites reach the end of their service lives.

The National Defense Authorization Act for Fiscal Year 2017 contained a provision for GAO to assess DOD's analysis. This report addresses (1) whether the Wideband AOA was comprehensive, (2) how DOD solicited input from stakeholders, and (3) the conclusions DOD reached through the Wideband AOA.

GAO reviewed the Wideband AOA along with DOD policies, documentation, and analyses; interviewed DOD officials and commercial stakeholders; and assessed the AOA against best practices for a comprehensive AOA process.

What GAO Recommends

GAO is recommending that DOD develop a plan to guide implementation of the Wideband AOA recommendations. DOD provided technical comments on a draft of this report, which GAO incorporated as appropriate.

View GAO-20-80. For more information, contact Cristina T. Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

The Department of Defense (DOD) conducted a comprehensive analysis of alternatives (AOA) process for wideband satellite communications, as determined through an assessment of the AOA against relevant GAO best practices. A comprehensive analysis of alternatives process indicates that the analysis team thoroughly addressed a wide range of possible satellite system alternatives.

DOD used multiple methods to obtain stakeholder input, in accordance with its Wideband AOA study plan. For example, the study team incorporated input from across the military services and operational users, among others. Moreover, the Air Force and Defense Information Systems Agency conducted interrelated studies to provide additional information to the Wideband study team.

DOD's analysis concluded that integrating military and commercial systems into a hybrid architecture would be more cost effective and capable than either acquisition approach alone. However, DOD also found that it needs more information to select its next satellite communications architecture and made recommendations for further study. Examples of these recommendations include:

- **Develop an enterprise satellite communications terminal strategy** – DOD found the magnitude of replacing user terminals to work with new systems was challenging and that more information on emerging technology and possible changes to terminal acquisition approaches would help DOD address this challenge.
- **Invest in commercial technologies** – DOD found that it lacked detailed technical information on commercial systems' cyber protections and that additional information on such protections would help DOD determine the extent to which they would meet DOD's needs.

Such recommendations align with GAO's acquisition best practices for knowledge-based decision-making and have the potential to improve the department's satellite communications acquisitions. However, DOD stakeholders said there is no formal plan to guide and coordinate implementation of the AOA recommendations. Without such a plan, DOD is at increased risk of not having the information it needs to make timely, knowledge-based decisions on future systems to provide critical communications for military operations.

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U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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Department of Defense (DOD) officials estimate spending an average of $4 billion each year to acquire and sustain wideband satellite communications capabilities, including developing and fielding military satellite systems, contracting for commercial satellite communications services, and acquiring and operating satellite ground terminals. Wideband satellite communication capabilities provide fast and reliable voice, video, and data communications on a global scale to support critical military operations. For example, wideband satellite communications provide military leaders information on their operational environment and allow commanders to communicate with geographically dispersed units to help ensure coordinated, successful operations.

DOD is considering how best to meet its future wideband communication needs. Several factors shape these needs, including an expected increase in military systems that depend on satellite-provided data; many changing operating environments and scenarios; and growing threats to DOD space systems. For example, in recent years, threats to DOD space systems that provide communications have increased, including anti-satellite weapons, communications jamming, cybersecurity risks, and environmental hazards in space, such as orbital debris.

Congress, in the National Defense Authorization Act for Fiscal Year 2016, required DOD to conduct an analysis of alternatives (AOA) for a follow-on wideband communications system to the Wideband Global SATCOM system that includes space, air, and ground layer communications capabilities for DOD.[1] DOD conducted a Wideband Communications Services (Wideband) AOA from December 2016 to June 2018. The National Defense Authorization Act for Fiscal Year 2017 required DOD to submit its analysis to us for review and assessment.[2] DOD provided the AOA to us in June 2019, after the Office of the Secretary of Defense finished its reviews. This report addresses (1) whether DOD conducted a

[1]National Defense Authorization Act for Fiscal Year 2016, Pub. L. No. 114-92, § 1611 (2015).

[2]National Defense Authorization Act for Fiscal Year 2017, Pub. L. No. 114-328, § 1605 (2016).

comprehensive analysis of satellite communications alternatives in accordance with GAO best practices; (2) how DOD solicited and incorporated input from military and commercial stakeholder communities during the Wideband AOA; and (3) the conclusions DOD reached through the Wideband AOA.

To conduct this work, we reviewed the Wideband AOA report and all supporting documents, such as AOA working group appendixes on technologies and alternatives, cost analysis, and ground terminals that communicate with satellites, among others. We also reviewed detailed cost models, schedules, and other Wideband AOA supporting documentation. We compared the Wideband AOA against DOD's Wideband Communication Services AOA Study Plan. We reviewed related reports on an Air Force pilot program and documents the Navy and Army prepared to support the AOA. We also reviewed DOD documentation related to wideband communication including the Wideband MILSATCOM Roadmap Report, the National Security Satellite Communications Systems Synchronization Roadmap, the 2017 Commercial Satellite Communications Expenditures and Usage Report, and the Chairman of the Joint Chiefs of Staff Instruction on Department of Defense Satellite Communications. Using information from these documents, combined with information from interviews with DOD officials who led or participated in the AOA, we assessed the Wideband AOA against the six criteria from our Analysis of Alternatives Best Practices that assess the comprehensiveness of the AOA process. Appendix I contains additional details on our AOA Best Practices.

In addition to materials from the Wideband AOA appendixes, we reviewed DOD requests for information from industry to examine how the department incorporated input from commercial stakeholders. To support our work across all reporting objectives, we interviewed officials from the Office of the Undersecretary of Defense for Acquisition and Sustainment; Office of the Secretary of Defense-Cost Assessment and Program Evaluation; DOD Chief Information Officer; the Defense Information Systems Agency; the Joint Chiefs of Staff-Force Structure, Resource and Assessment; Air Force Space Command Space and Missile Systems Center; Army Space and Missile Defense Command and the Program Executive Office Command Control Communications-Tactical; Office of the Chief of Naval Operations; and Marine Corps Systems Command. Finally, we interviewed a broad range of commercial industry stakeholders, including satellite communications providers.

We conducted this performance audit from October 2018 to December 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.

Background

DOD uses military and commercial satellite communications (SATCOM) to meet its global communications requirements. DOD acquires wideband capacity through two methods:

- **DOD purpose-built**: DOD obtains some of its SATCOM through its purpose-built systems, which include Wideband Global SATCOM (WGS) satellites. While DOD awards contracts to commercial companies to build these systems, the department is responsible for the systems' procurement, operations and sustainment; therefore, they are considered purpose-built.
- **Commercial contracts**: DOD also purchases commercial SATCOM services to supplement its purpose-built systems, such as for satisfying users who have needs beyond available military satellite resources, supporting training on ground systems, or meeting the needs of unique users. In these cases, DOD acquires commercial SATCOM bandwidth through several competitively selected vendors, who are responsible for operating and sustaining their own systems.

Military SATCOM architectures fall into three types:

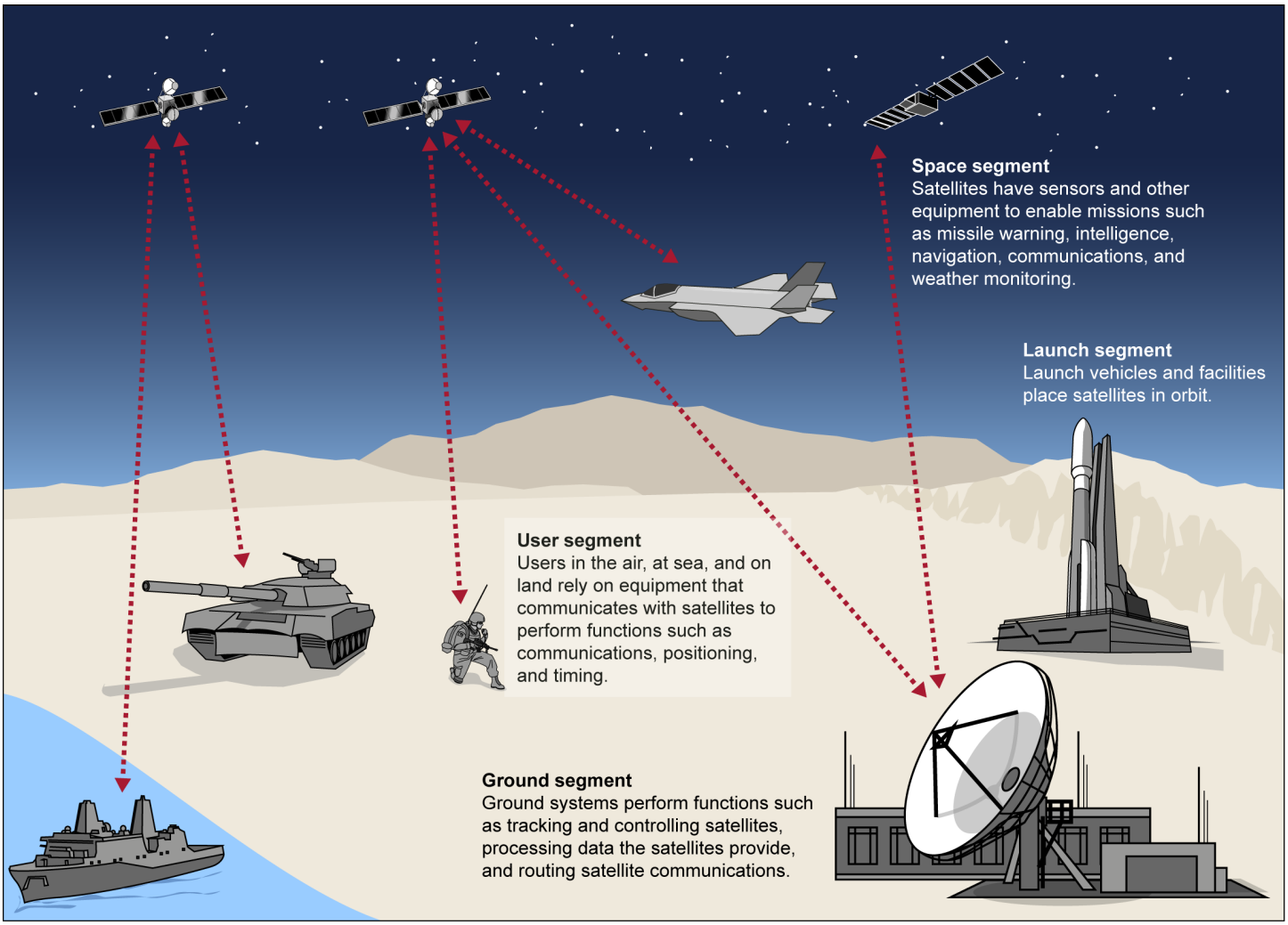
- protected, which provides secure, assured communications;
- wideband, which supports worldwide capacity for high data rate communications, including high-quality voice and imagery; and
- narrowband, which provides reliable and secure communications less vulnerable to adverse weather conditions or other physical limitations, such as distance, dense foliage, and terrain.

DOD's primary wideband satellite communications system, WGS, currently provides a portion of DOD's required SATCOM bandwidth, but the Air Force estimates its satellite constellation's capabilities will begin to degrade in the late 2020s. The Air Force is adding at least one more satellite to the WGS constellation and plans for an enhanced WGS-11 to provide the capacity of two satellites. During the Wideband AOA, DOD estimated that adding this satellite to the constellation would extend the

availability of wideband communications to 2031. According to the Air Force, there is potential for adding a 12th WGS satellite to the constellation.

Like other types of space systems, DOD's wideband SATCOM systems generally involve four types of interrelated segments that make a space capability fully functional. As illustrated in figure 1, they include (1) the space segment—namely the satellites; (2) the ground segment, with network services and also including satellite and payload control systems and data processing subsystems and facilities; (3) user equipment, such as radios, terminals, and routers needed by the warfighter to use the capability; and (4) launch vehicles and facilities.

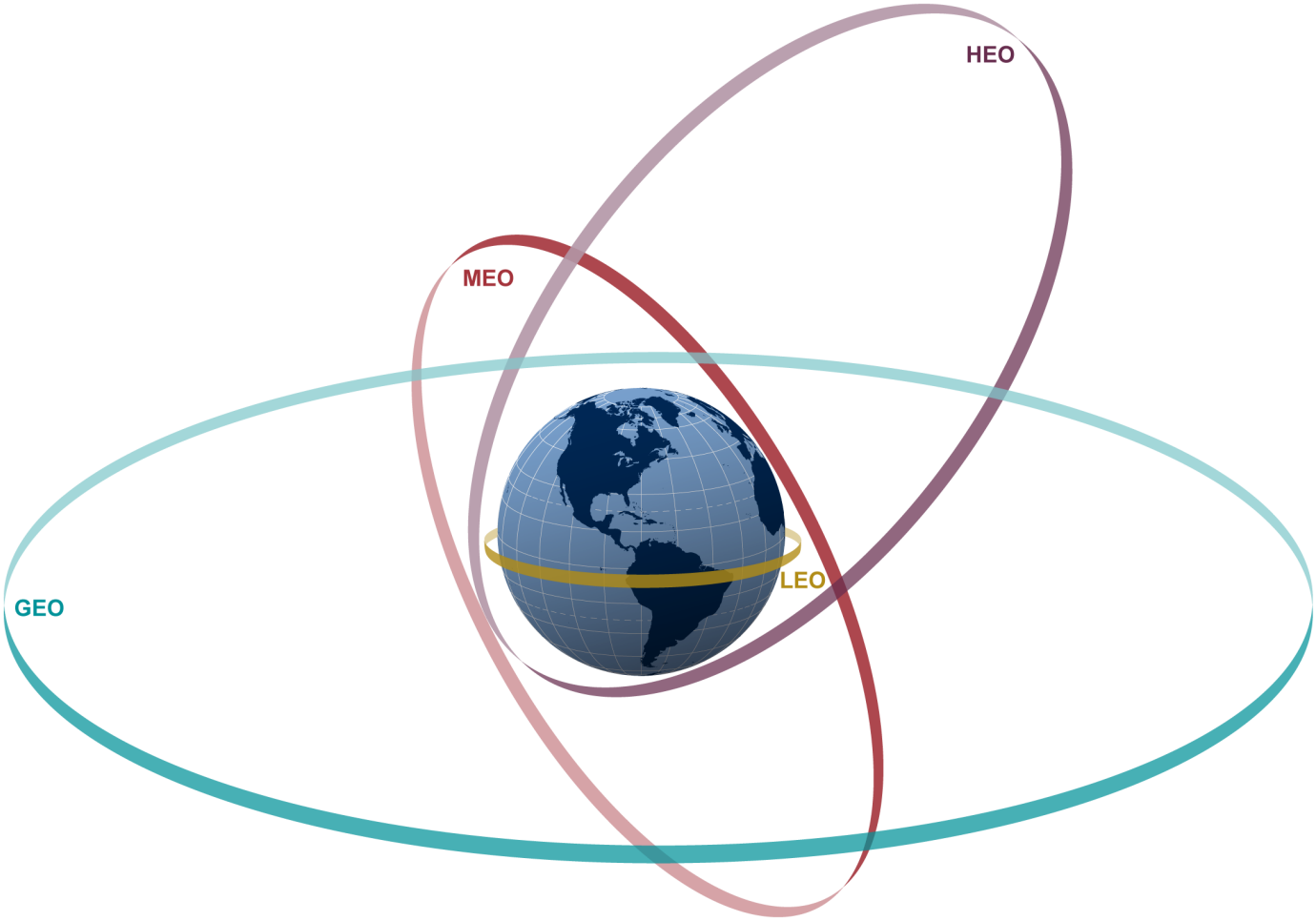
Figure 1: Segments of DOD Space Capabilities



Source: GAO analysis of Department of Defense (DOD) documentation. | GAO-20-80

Within the space segment, satellites operate in several different types of orbits to meet different communication and mission needs, as shown in figure 2. The orbital location of a satellite can affect its capacity to transmit data, or what parts of the Earth can receive its signal. For example, highly elliptical orbits are necessary for providing long dwell times over northern latitudes due to the curvature of the Earth, while other orbits cover remaining latitudes.

Figure 2: Examples of Different Types of Earth Orbits



Orbit types	Altitude (miles)	Uses
Low Earth Orbit (LEO)	Up to approximately 1,200	• Communications • Intelligence, Surveillance, and Reconnaissance • Human spaceflight
Medium Earth Orbit (MEO)	Approximately 1,200 to 22,000	• Communications • Position, navigation, and timing
Highly Elliptical Orbit (HEO)	Approximately 25,000 at apogee	• Communications • Intelligence, Surveillance, and Reconnaissance • Missile warning
Geosynchronous Earth Orbit (GEO)	Approximately 22,000	• Communications • Intelligence, Surveillance, and Reconnaissance • Missile warning

Source: Department of Defense. | GAO-20-80

Wideband satellites operate in different radio frequency spectrum bands. DOD typically relies on C, X, Ku, and Ka-bands to provide wideband connectivity, determined by where and how users are operating. Each of these frequency bands has advantages and disadvantages for various applications. Satellite transponders operating at the lower C-band frequencies are less susceptible to degradation from rain than other bands.[3] In the United States, the X-band is specifically designated for use by the U.S. government and the North Atlantic Treaty Organization. The Ku-band operates at higher frequencies and can communicate with smaller antennas and offer more flexibility. The still-higher-frequency Ka-band satellites can transmit more data than C, X, and Ku-band satellites, but their signals are more susceptible to degradation from water vapor and rain than satellites in lower frequency bands.[4] Commercial satellite communication providers have historically operated primarily in the Ku-band but are now expanding services in the Ka-band to offer higher data rates.

AOA Process and Best Practices

An AOA is a key first step in DOD's acquisition process and assesses alternative solutions for addressing future needs. DOD acquisition guidance provides the purpose and procedures associated with conducting an AOA to support decision making.[5] DOD experts in areas such as cost estimating, technological analysis, and acquisitions, along with military and commercial stakeholders, comprise the AOA study team. The study team is involved in the day-to-day work of the AOA process and conducts the analyses that form the foundation of the assessment. During the AOA study period, the study team develops alternatives to satisfy capability gaps that they assess against pre-established performance requirements.

[3]A transponder aboard a communications satellite receives the uplink signal sent from the ground, shifts its frequency for the downlink frequency, amplifies it, and transmits it to the ground.

[4]See GAO, *Telecommunications: Competition, Capacity, and Costs in the Fixed Satellite Services Industry*, GAO-11-777 (Washington, D.C.: Sept. 7, 2011).

[5]DOD Instruction 5000.02, Operation of the Defense Acquisition System, Enclosure 9, Analysis of Alternatives.

We have identified 22 best practices for an AOA process.[6] Of these, 6 best practices are associated with a "comprehensive" AOA. Comprehensive means that the AOA process ensures that the mission need is defined in a way to allow for a robust set of alternatives, that no alternatives are omitted, and that each alternative is examined thoroughly for the project's entire life cycle. Without a clearly defined mission need and comprehensive list of alternatives, the AOA process could overlook the alternative that best meets the mission need. Furthermore, without considering the complete life cycle of each alternative, decision makers will not have a comprehensive picture of the alternatives analyzed.

DOD Conducted a Comprehensive Analysis of Wideband SATCOM Alternatives

DOD completed its analysis of wideband SATCOM alternatives in June 2018 and identified 11 alternatives that represent several possible approaches to SATCOM acquisitions. We found the Wideband AOA to be a comprehensive assessment.

[6]GAO developed the AOA process best practices with input from program management experts in the public and private sector and published them in GAO report, *Amphibious Combat Vehicle: Some Acquisition Activities Demonstrate Best Practices; Attainment of Amphibious Capability to be Determined*, GAO-16-22 (Washington, D.C.: Oct. 28, 2015). For our assessment, we used the updated version of the AOA best practices that will appear in our planned update to the GAO Cost Guide: *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: Mar. 2009), which we anticipate issuing in early 2020.

DOD Developed Alternatives to Inform Future SATCOM Decisions

The Office of the Secretary for Defense for Acquisition and Sustainment completed the Wideband AOA in June 2018 to support decision making for future wideband architectures.[7] Several subsystems comprise a SATCOM architecture and can include the number, type, orbital location, and capacity of satellites and associated ground or user segments.[8] WGS constellation satellites will begin reaching their end of life in the early 2030s, which means DOD will need to begin launching replacement system satellites in the late 2020s. DOD satellite systems take, on average, over 7 years to develop and launch the first satellite of a purpose-built system. Given these time frames, the Wideband AOA study team focused on possible alternatives DOD could begin developing as early as 2019. In October 2016, the Office of the Secretary of Defense-Cost Assessment and Program Evaluation developed the Wideband Communications Services Analysis of Alternatives Study Plan. This Study Plan provided the schedule and tasks to be conducted for the Wideband AOA. These tasks included identifying study questions to be addressed and listing measures of performance and effectiveness. The Study Plan also described the organizational structure and methodology for executing the Wideband AOA.

The Wideband AOA study team developed 11 alternatives that broadly represented three different acquisition approaches: legacy DOD SATCOM procurement focused on purpose-built systems with some commercially-contracted services; commercial-focused SATCOM procurement; and a strategy that would transition from a mainly purpose-built system to a more commercial SATCOM-oriented model. Historically, DOD has bought purpose-built SATCOM assets, including satellites and supporting ground systems, while contracting for supplemental

[7]The Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)) is responsible for establishing polices on and supervising all matters relating to acquisition. The Office of USD(A&S) has certain oversight responsibilities for major defense acquisition programs throughout the acquisition process, such as collecting and distributing performance data. The Under Secretary is the Defense Acquisition Executive and serves as the milestone decision authority for certain major defense acquisition programs.

[8]In December 2016, the Under Secretary of Defense for Acquisition, Training, and Logistics (USD (AT&L)) approved initiating the Wideband AOA in accordance with the study guidance and study plan approved by the Director, Cost Assessment and Program Evaluation. Initially, USD(AT&L) designated itself and the Principal DOD Space Advisor to co-lead the AOA, but after the Wideband AOA began, DOD reorganized and these functions transferred to USD (A&S) and the Secretary for the Air Force for Space Policy.

commercial bandwidth. Table 1 summarizes the architectures and these approaches.

Table 1: Summary of Final Wideband Satellite Communications Alternatives

Legacy Purpose-Built with Commercial Contracting Approach	Commercial with Limited Purpose-Built Approach	Transitional Step to Commercial Approach
4 architectures	6 architectures	1 architecture
Choices considered: • Replenish Wideband Global SATCOM to maintain current performance • Maintain current level of commercial contracting • Procure purpose-built, modernized X-band and Ka-band wideband satellite communication capability	Choices Considered: • Commercially-managed services[a] • Low-Earth orbit satellite constellation with new terminals • Medium-Earth orbit satellites	Choices Considered: • Long-term transition to a primary low-Earth orbit commercial constellation from a legacy acquisition approach of a purpose-built system • Flexible multi-band/multi-system terminals

Source: GAO summary of Wideband Analysis of Alternatives | GAO-20-80

[a]A managed service delivers SATCOM data to the user, similar to cellular phone service. The user's data must flow through commercially owned and operated networks and systems, for example satellites and user terminals.

The Wideband AOA Process Was Comprehensive

Our assessment of the Wideband AOA found that it met our criteria for a comprehensive AOA process. Table 2 shows our determinations of how fully the Wideband AOA met each of our six best practices. Appendix I provides more detail on our AOA best practices.

Table 2: Results of GAO's Best Practices Assessment of DOD's Wideband Analysis of Alternatives (AOA)

AOA Best Practices for a Comprehensive Process	Assessment of the Wideband AOA (Numerical Rating)
Define mission need – The customer identifies a credible gap between current capabilities and those required to meet the customer's goals to avoid favoring any solution. The AOA takes place before any solution design and development. The customer decides at what level of design completion to perform an AOA.	**Fully met (5)** According to AOA documentation and stakeholders we met with, the AOA study team established increased user demand as the credible gap in military satellite communications and users validated this need. DOD conducted its AOA before selecting a solution and relied on existing or planned designs.
Define functional requirements – The customer identifies the general parameters that the selected alternative must address, including the capabilities the AOA process seeks to review. Functional requirements are realistic, organized, clear, prioritized, and traceable. They should be set early in the AOA process and agreed upon by stakeholders.	**Fully met (5)** Wideband AOA documentation identified the parameters for assessing possible alternatives, such as cost and resiliency, which also act as functional requirements. Documentation also shows that the AOA study team developed these functional requirements early in the AOA process.

AOA Best Practices for a Comprehensive Process	Assessment of the Wideband AOA (Numerical Rating)
Develop AOA time frame – The customer provides the study team enough time to complete the AOA to ensure a robust and complete analysis. A detailed schedule is developed prior to beginning the AOA. The duration of the AOA process depends on the number of viable alternatives and availability of the team members. The time frame is tailored for the type of systems to analyze and ensures adequate time to accomplish the AOA.	**Fully met (5)** DOD conducted this AOA over a period of 19 months, from December 2016 through June 2018. Study team leaders shared detailed schedules and told us they had sufficient time overall to conduct their analysis, including a detailed review of user terminal costs and replacement schedules.
Develop list of alternatives – The AOA study team identifies and considers a diverse range of alternatives to meet the mission need. Market research and surveillance should inform the alternatives, which should also be mutually exclusive.	**Fully met (5)** The AOA study team initially identified over 40 satellite communications architectural subcomponents, such as frequency band or satellite mass, then developed these subcomponents into unique alternatives. We also reviewed evidence of market research and found that the alternatives were mutually exclusive.
Assess alternatives' viability – The AOA team screens the list of alternatives to eliminate those alternatives that are not viable and documents its rationale. All alternatives are examined using predetermined qualitative technical and operational factors. Only those alternatives found viable are fully examined in the AOA process.	**Substantially met (4)** AOA documentation outlined the identification of the final 11 alternatives, based on a larger number of architectural subcomponents and the previously-determined functional requirements. AOA documentation did not clearly show how the study team finalized its list of subcomponents before developing the final alternatives. Officials explained that after that point, they did not assess any alternative as non-viable.
Develop life-cycle cost estimates – The AOA team develops a life-cycle cost estimate for each alternative, including all costs from inception of the project through design, development, deployment, operation, maintenance, and disposal. The AOA team includes a cost expert who is responsible for the development of a comprehensive, well-documented, accurate, and credible cost estimate.	**Partially met (3)** A review of the cost estimates for the various alternatives under consideration indicates that the AOA team used a consistent estimating structure for all alternatives. However, the cost estimating relationships in the model to calculate costs for the space components were used differently in the cost model than in the documented relationship between the technical input and cost. Modeling should demonstrate that the cost-to-non-cost estimating relationships are logical and that the data used for modeling can be verified and traced back to source documentation. Further, the documentation did not establish how DOD developed the cost model for certain ground infrastructure elements and the cost estimates did not use discount rates to adjust the present values to account for the time value of money. Applying a discount rate is an important step in cost estimating because all cost data must be expressed in like terms for comparison.
	Averaged overall assessment: Fully met (4.5)

Source: GAO analysis of Department of Defense information and updated AOA best practices from GAO's forthcoming revised Cost Guide.| GAO-20-80

Note: We determined the overall assessment rating by assigning each individual rating a number: Not Met = 1, Minimally Met = 2, Partially Met = 3, Substantially Met = 4, and Fully Met = 5. The resulting average becomes the overall assessment as follows: Not Met = 1.0 to 1.4, Minimally Met = 1.5 to 2.4, Partially Met = 2.5 to 3.4, Substantially Met = 3.5 to 4.4, and Fully Met = 4.5 to 5.0.

Based on our analysis, we found that the Wideband AOA study team thoroughly addressed a wide range of possible satellite system alternatives. Moreover, the Wideband AOA study examined the ground segment systems—including user terminals—which will communicate

with the satellite system DOD chooses to replace WGS. Although user terminals were not the primary focus of this AOA, DOD officials told us this effort was the first time DOD has studied and consolidated department-wide costs for these terminals, which they said provided valuable context to decision-makers. We discuss this new information on terminals in further detail later in this report.

In Accordance with Its Study Plan, DOD Used Multiple Methods to Obtain Stakeholder Input

As set forth in the AOA Study Plan, the Wideband AOA study team solicited and incorporated input from across DOD stakeholders, such as the military services, operational users, and SATCOM partner nations. The study team also solicited and incorporated information from commercial SATCOM vendors to inform its alternatives. Additionally, the Wideband AOA study team incorporated information from interrelated studies, referred to as pilots and pathfinders, that the Air Force and Defense Information Systems Agency conducted. These studies recommended ongoing experimentation and adaptation to identify, incorporate, and guide future commercial SATCOM development, as well as changes to DOD's approach to SATCOM acquisitions.

Military and Commercial Stakeholders Provided Input to the AOA

As set forth in its Study Plan, the Wideband AOA study team obtained military input from across DOD and information from commercial SATCOM vendors to inform its alternatives. AOA working groups were one of several mechanisms DOD used to obtain stakeholder input. The AOA study plan directed the establishment of eight working groups to consolidate subject matter experts for relevant SATCOM topics, as shown in table 3. Each working group, task force, and team conducted its analysis and wrote an appendix to the AOA report summarizing its methodology, inputs, and results. Each team also provided its own conclusions or recommendations, which contributed to the overall findings and recommendations of the AOA report.

Table 3: Wideband Analysis of Alternatives (AOA) Working Groups

Working Group	Purpose
Integration Working Group • Resiliency Task Force – led by the Office of the Under Secretary of Defense for Acquisition and Sustainment • Doctrine, Training, materiel, Leadership and Education, Personnel, Facilities, Policy Task Force – led by the Principal DOD Space Advisor Staff	Responsible for facilitating communications across the working groups, synthesizing results, developing the Wideband AOA final report, and providing briefings. The Resiliency Task Force assessed alternatives for their ability to withstand adversary threats. The Doctrine, Training, materiel, Leadership and Education, Personnel, Facilities, Policy Task Force reviewed all non-materiel concerns the alternatives presented.
Technology and Alternatives Working Group – led by Air Force Space and Missile Systems Center	Tasked to identify satellite communications architectural components and develop them into alternatives for assessment.
Cost Analysis Working Group – led by the Office of the Secretary of Defense-Cost Assessment and Program Evaluation	Developed the life-cycle cost estimates for the final set of alternatives.
Performance Effectiveness Analysis Working Group – led by U.S. Army Space and Missile Defense Command	Assessed alternatives against pre-established performance criteria to determine their viability.
Commercial Working Group – led by Air Force Space and Missile Systems Center	Conducted roundtable sessions and reported awarding six study contracts to satellite communications industry vendors to obtain information on current and emerging commercial satellite communications capabilities.
Cyber Working Group – led by the Johns Hopkins University, Applied Research Laboratory	Assessed alternatives for cybersecurity risks. This is the first Department of Defense (DOD) AOA to include a Cyber Working Group.
Enterprise Working Group – led by DOD's Office of the Chief Information Officer • Terminal Team • Ground Infrastructure Team	Responsible for assessing the ground segment of satellite communications, in the context of the AOA alternatives. This group examined the cost and magnitude of satellite communications user terminals and ground stations in use across DOD.
Threats and Scenarios Working Group – led by Air Force Space Command	Worked with the Intelligence Community to develop threat scenarios the Resiliency Task Force used to assess the alternatives.

Source: GAO summary of Wideband AOA Study Plan and AOA Appendices. | GAO-20-80

Military service representatives who participated in the Wideband AOA described to us how their personnel were involved in many or all of the working groups. AOA study leaders also emphasized the quality of the input from the working groups and were confident the AOA successfully captured the perspectives of acquisition, operational, and user communities—personnel responsible for buying, controlling, and using wideband SATCOM.

In addition to the working groups, the Wideband AOA study team developed functional requirements for the alternatives by requesting SATCOM user demand data from the services, and invited SATCOM

partner nations to participate in the AOA—a portion of which accepted.[9] These efforts provided additional information from user communities. Wideband AOA study team leaders described how they relied on a formal Joint Chiefs of Staff process to obtain inputs from the military services on their current and projected bandwidth demands. Through this process, the department obtained SATCOM user demand data from combatant commands, military services, and their sub-commands. The AOA study team then used these results to develop an aggregate user demand projection that was foundational to the AOA. Any viable alternative had to provide sufficient bandwidth to meet future user demand.

DOD requested inputs from commercial SATCOM vendors and the Commercial Working Group used these to identify the space system subcomponents, namely technical characteristics, including frequency bands, orbit, and satellite mass that the Technologies and Alternatives Working Group eventually combined into the 11 final alternatives. The Commercial Working Group's intent in identifying these subcomponents was to represent capabilities the SATCOM industry will have on-orbit by 2023, without depicting any single vendor's potential system. The Commercial Working Group also incorporated results from DOD pilot and pathfinder efforts (discussed below) to develop a roadmap for DOD to implement an enterprise management approach to SATCOM procurement and operations.

DOD Pilot and Pathfinder Efforts Provided Additional Information to the Wideband AOA Study Team

The Air Force and Defense Information Systems Agency conducted interrelated pilot and pathfinder studies before and during the Wideband AOA that provided information on SATCOM business arrangements, user terminal prototyping, and acquisition efficiencies. In 2014 and 2015, Congress authorized, and then directed, DOD to carry out a pilot program on the acquisition of commercial satellite communication services.[10] As part of this pilot, DOD initiated pathfinder projects to test the feasibility of these new business arrangements. The Air Force and Defense Information Systems Agency studied and prototyped methods to improve

[9]The AOA study team extended offers to Australia, Canada, France, Germany, Italy, New Zealand, United Kingdom, Belgium, Norway, Czech Republic, South Korea, Denmark, Spain, Japan, Netherlands, Luxembourg, and North Atlantic Treaty Organization Headquarters.

[10]Carl Levin and Howard P. "Buck" McKeon National Defense Authorization Act for Fiscal Year 2015. Pub. L. No. 113-291, § 1605 (2014) (authorizing a pilot program) and Pub. L. No. 114-92, § 1612 (2015) (directing DOD to develop and carry out a pilot program).

commercial SATCOM acquisition and provide more flexible satellite connections for mobile SATCOM users. The agencies did so by contracting with commercial SATCOM providers for the following:

- **Air Force Pilot** – define and demonstrate prototyping to improve access to commercial SATCOM. The Air Force completed phases 1 and 2 of this 3-phase pilot program, studying preferential purchasing approaches that incentivize industry and the types of SATCOM architectures that enable such purchasing, such as a managed services approach that consolidates commercial SATCOM procurement for DOD users. Phase 1 studied commercial satellite communication architecture and business structures. The Wideband AOA's Commercial Working Group used the phase 1 results in its modeling of SATCOM enterprise management. Phase 2 demonstrated a flexible modem-to-terminal interface to allow a terminal to "roam" or switch between different manufacturers' satellite constellations. Phase 3 is ongoing and focuses on network integration risk reduction efforts.
- **Air Force Pathfinders** – prove that innovative business arrangements can meet DOD requirements and reduce costs. Through the pathfinder research efforts, the Air Force purchased an on-orbit transponder as well as pre-launch transponder to demonstrate different strategies for buying SATCOM. The final pathfinder effort is ongoing and is to demonstrate how access to shared bandwidth and more flexible ground systems can improve SATCOM access for warfighters. These types of capabilities help users to move more quickly and easily, with a reliable SATCOM connection.
- **Defense Information Systems Agency Pathfinders** – examine how acquisition efficiencies improve SATCOM services. The pathfinders' findings provided observations on market trends for SATCOM contracting, namely that pricing will continue to decrease. The pathfinders also showed that DOD's typical SATCOM requirements are not stable from year to year, meaning DOD cannot accurately predict when or where it will need surge SATCOM capacity. The pathfinders also identified management challenges to aggregating SATCOM requirements.

The pilot and pathfinder efforts recommended ongoing experimentation and adaptation to identify, incorporate, and guide developing commercial SATCOM capabilities, as well as changes to DOD's traditional approach to SATCOM acquisitions. In particular, both the Air Force and Defense Information Systems Agency recommended that DOD adapt to changing

business models, especially for managed services in commercial SATCOM, in which DOD would purchase SATCOM services but would not own or manage the systems and data rates. Changing business models could also include greater coordination with the SATCOM industry, so DOD can better incorporate commercial technology into future systems. The Defense Information Systems Agency also recommended that DOD pursue an alignment of common types of user terminals and SATCOM architectures. For example, many programs use a different approach to procuring terminals and SATCOM architectures, which prevents DOD from taking advantage of commonalities that could save resources. Such commonalities include users in the same geographic area. These Air Force and Defense Information Systems Agency recommendations overlap with half of the findings and recommendations of the Wideband AOA.

DOD Concluded That Future Wideband SATCOM Requires a Hybrid Approach and More Knowledge, but It Lacks a Plan to Implement AOA Recommendations

DOD concluded in the Wideband AOA that integrating purpose-built satellite systems and commercially-provided systems into a hybrid architecture would be more cost effective and capable than any single purpose-built or commercial system alone. The AOA study team recommended actions to obtain more information on transitioning to a more integrated architecture of purpose-built and commercial systems and reducing risk. However, DOD does not have a plan to implement these recommendations and inform timely decision-making.

DOD Concluded That Future Wideband Communications Require a Hybrid Approach

During the AOA, DOD found that integrating purpose-built satellites and commercially-provided systems into a hybrid architecture would save costs and provide more capability than any single purpose-built or commercial system alone. The department currently uses a mix of purpose-built and commercial SATCOM contracts, but DOD has not historically managed these systems in coordination, or with an enterprise approach. DOD considered 11 architectures in its final analysis and all were to some extent hybrids of purpose-built and commercial systems because the AOA study team found that DOD requires a combination of military and commercial system capabilities. The Wideband AOA report identified three of the 11 potential architectures that would best meet DOD's wideband SATCOM needs:

- **Legacy Purpose-Built and Commercial Contracting Architecture** - Procure and field a new purpose-built constellation for X and Ka-band capabilities with anti-jam technologies and upgraded antennas. DOD would continue to contract for commercial SATCOM as needed.
- **Commercial-Oriented Architecture** - Pursue advanced commercial high capacity satellites with steerable beams over the Ka-band. Also procure 10 purpose-built satellites to meet the military's requirement for X-band communications.
- **Transitional Step to Commercial Architecture** - Transition to commercially-managed services architecture in low-Earth orbit for approximately 5,000 users over the long term. DOD would procure and field the modernized, purpose-built legacy architecture described above, then modify its suite of user terminals to align with the new low-Earth orbit satellites, emphasizing a cost-effective strategy to do so. For users who do not transition to the new commercial satellites, the purpose-built constellation provides continued X and Ka-band capability.

During the Wideband AOA, DOD found that any post-WGS solution must continue to provide purpose-built SATCOM capabilities. For example, some users require X-band communications and identified this as the single most important capability to maintain. However, commercial constellations provide limited X-band communications due to this band's historical use for military communications.[11] The companies and international partners that do offer X-band communications provide fragmented coverage that does not fully meet DOD's needs. In addition, commercial satellite constellations do not offer services in all of the areas DOD operates, such as over oceans and in polar regions.

At the same time, because purpose-built systems alone cannot meet all military requirements, DOD found it will need to rely on commercial capabilities as part of a future architecture. Consequently, the AOA study team assessed alternatives that would expand DOD's use of emerging commercial technologies. For example, DOD expects certain operations, like aerial vehicle flights that rely on wideband SATCOM, to increase and drive demand for commercial SATCOM capabilities. Moreover, the AOA study team found that emerging commercial capabilities could meet routine military needs, such as training, at a competitive cost. The AOA

[11]X-band is designated for military use by the North Atlantic Treaty Organization. There are a limited number of commercial X-band providers.

study team concluded integrating these capabilities into a future architecture would be beneficial.

AOA Recommendations Focus on Gaining Additional Knowledge for Decision-Making and Reducing Risk

In its Wideband AOA report, the AOA study team made a series of recommendations focused on maintaining current wideband capabilities and overcoming near-term information gaps in transitioning to new SATCOM acquisition and management approaches. All of the recommendations focused on gaining information needed to transition to a hybrid architecture of purpose-built and commercial systems in the long term. Table 4 provides examples of DOD's recommendations and the additional knowledge DOD needs to obtain as it pursues a post-WGS solution.[12]

Table 4: Examples of Wideband Analysis of Alternatives (AOA) Recommendations and Additional Information Needed

AOA Recommendation: Maintain the legacy Wideband Global SATCOM (WGS) system. • Immediately assess incorporating anti-jamming and cybersecurity features. • Examine ground infrastructure needs for the 11th and 12th WGS satellites.	
Rationale and context for the recommendation:	**Additional Information Needed:**
Threats to space assets are increasing as space becomes more congested and foreign adversaries continue to pursue advanced capabilities. For example, a February 2019 Defense Intelligence Agency Report found Russia and China are developing cyberspace capabilities to target satellite systems. The Department of Defense (DOD) expects the 11th WGS satellite to provide twice the capacity of any other WGS satellites on orbit today.	DOD officials we spoke with said the scope of the AOA did not include analyzing the ground infrastructure upgrades necessary for handling increased capacity. DOD currently has a study underway to obtain more information on possible ground infrastructure changes.
AOA Recommendation: Fund a purpose-built capability post-WGS. • Cost-effectively meet user demands, including all-weather capabilities. • Recommended capability development start in fiscal year 2020. • Consider alternative orbits.	
Rationale and context for the recommendation:	**Additional Information Needed:**
According to DOD, funding a post-WGS purpose-built capability will ensure DOD users have access to satellite communications resources that meet their requirements, including when a new commercial system is delayed or does not perform as anticipated. With the addition of the 11th WGS satellite, the legacy system is expected to provide capability to 2031.	DOD found it needs more information on systems located in alternative orbits, such as low-Earth orbit. The Space Development Agency is focused on a low-Earth orbit constellation to provide communications and other satellite-based operational support for DOD. The agency is exploring new technical concepts for such an architecture and its efforts could provide information on alternative orbits.

[12]For the full set of Wideband AOA recommendations, see app. II.

AOA Recommendation: Develop an Enterprise Satellite Communications Terminal Strategy.

- Reduce complexity of terminal diversity and governance.
- Facilitate rapid modernization through flexible terminals that can use new waveforms.
- Optimize cost, schedule, performance, and interoperability.

Rationale and context for the recommendation:	Additional Information Needed:
The AOA study team found the magnitude of replacing terminals to work with legacy and new systems was challenging: • DOD has approximately 17,000 wideband user terminals, managed across 135 designs. • User terminals operate across a diverse set of platforms—such as ships, backpacks, vehicles, all with differing system requirements. The study team found new terminals required to work with commercial systems drive the cost of replacing DOD's current terminal suite due to development and integration costs. Procuring the actual terminal unit may be relatively inexpensive; however, any required redesign to integrate new terminals into the platform can be costly. For example, antenna and radio frequency interface-related costs drive 40 to 70 percent of the overall cost to develop and field a new terminal. At the same time, a supporting study to the Wideband AOA found that some terminals can be modified to operate with more types of satellites by adding new modems or software, reducing replacement costs. This capability, aligned with regular terminal recapitalization schedules, can help improve terminal affordability, according to officials. Moreover, the addition of WGS satellites extends the expected life of the constellation to 2031. This will require that upgraded or new terminals maintain compatibility with the WGS constellation and associated waveforms and modems.	Given the breadth of issues related to replacing or upgrading terminals, the AOA study team found it needs more information on commercial technology as well as the potential effects of reorganizing approaches to terminal development and procurement.

AOA Recommendation: Evaluate hybrid military/commercial constellations.

- Expand pilot efforts to develop architectural standards and interface controls for enterprise management to adopt a managed services approach.
- Design a prototype of a wideband enterprise satellite communications management and control capability.

Rationale and context for the recommendation:	Additional Information Needed:
DOD found that commercial providers are moving toward managed service models and this is a new concept within DOD, which has not yet established the benefits and costs of such an approach. However, commercial providers are also ending their support of legacy service models, adding pressure on DOD to adopt managed services.	DOD found that it needs more information on the feasibility of managing military- and commercial-provided satellite communications services through one organization, also known as Enterprise Management and Control.

AOA Recommendation: Invest in Commercial Technologies.

- Shape commercial capabilities to support future DOD needs.
- Invest in, pursue pilot efforts, and shape commercial industry development focused on cybersecurity, terminal integration, technology and assessment, and spectrum access.

Rationale and context for the recommendation:	Additional Information Needed:
During the AOA, DOD lacked detailed technical information about cyber protection, deterrence, and survivability techniques adopted by commercial providers. For example, the AOA found that commercial satellite communications providers are motivated by business strategies and priorities that create a return on investment. These entities may employ cybersecurity methods only to the extent that they ensure a return on the required investment.	DOD found it needs more information on the specifics of commercial system cyber protections and technology maturity.

Source: GAO analysis of DOD information | GAO-20-80

The Wideband AOA recommendations also addressed risks associated with any new SATCOM architecture, which the study team found include: (1) the uncertain stability and maturity of emergent commercial SATCOM systems and (2) the magnitude of replacing or modifying SATCOM user terminals.

- **Commercial Technology Stability and Maturity**: DOD found in the Wideband AOA that the commercial SATCOM market needs time to grow and stabilize as industry seeks to build a consumer base, especially for low-Earth-orbit-based internet services. The AOA study team found that if commercial companies cannot close their businesses cases around proposed solutions, DOD investments or programs that rely on those proposed solutions may fail. Further, many commercial systems, especially those based in low-Earth orbit, are still maturing. SATCOM providers have not yet worked closely with DOD to see how they would need to modify such constellations to operate with future DOD systems, including ground systems. Wideband AOA stakeholders—military and commercial—also described their struggle to share information on technical requirements, new capabilities, and pricing. For example, military stakeholders wanted more detailed engineering data on emerging commercial capabilities while commercial stakeholders wanted additional information on proposed alternatives for providing cost data. Commercial stakeholders also sought to protect their proprietary information. DOD's recommendation to invest in and shape commercial SATCOM development is aimed at reducing this risk and improving information sharing between DOD and the SATCOM industry.
- **Replacing or Modifying User Terminals**: Managing user terminal development and upgrades is complex and, according to DOD officials, is one of the largest challenges the department faces in selecting a post-WGS architecture. In its analysis, DOD found that managing upgrades or replacement costs and schedules for over

17,000 terminals of approximately 135 different designs was a major challenge. The AOA's analysis showed that out-of-cycle terminal replacement would drive significant costs and affect DOD operations. For example, vehicles like Humvees or ships have maintenance periods that are scheduled years in advance. Changing terminals could require unscheduled maintenance, potentially disrupt personnel planning, and cost more than if the terminals were upgraded on their planned refresh cycles.

Certain users also cannot transition to commercial SATCOM and still meet operational requirements. For example, Navy stakeholders told us their terminals were not considered for transition to commercial systems during the Wideband AOA due to a number of issues, including Ku-band radio frequency interference, all-weather availability, open ocean coverage, and network constraints. Both our past work and the Wideband AOA found that DOD faces ongoing risks in aligning its satellite and ground control systems. We have reported that these risks have arisen, in part, because user terminal development programs are typically managed by different military acquisition organizations than those managing the satellites and ground control systems.[13] The AOA recommendation to develop an enterprise SATCOM terminal strategy is aimed at reducing the risk user terminals present to DOD's post-WGS SATCOM architecture.

DOD Does Not Have a Formal Plan to Implement AOA Recommendations

DOD's recommendations that focus on gaining additional knowledge align with GAO's acquisition best practices for knowledge-based decision-making and risk reduction, but DOD lacks a formal plan to implement these recommendations. More specifically, DOD's recommendation to gain knowledge about the viability and maturity of commercial SATCOM system technologies corresponds with our best practices that outline the importance of ensuring needed technologies are proven to work as intended before programs begin.[14] According to officials we spoke with from various DOD organizations involved in the Wideband AOA and

[13]GAO, *Defense Acquisitions: Challenges in Aligning Space System Components*, GAO-10-55 (Washington, D.C.: Oct. 29, 2009).

[14]For example, see GAO, *Acquisition Reform: DOD Should Streamline Its Decision-Making Process for Weapon Systems to Reduce Inefficiencies*, GAO-15-192 (Washington, D.C.: Feb. 24, 2015). GAO, *DOD Acquisition Reform: Leadership Attention Needed to Effectively Implement Changes to Acquisition Oversight*, GAO-19-439 (Washington, D.C.: June 5, 2019). GAO, *Weapon Systems Annual Assessment: Limited Use of Knowledge-Based Practices Continues to Undercut DOD's Investments*, GAO-19-336SP (Washington, D.C.: May 7, 2019).

SATCOM acquisitions, they have work ongoing that provides relevant information, including Air Force pathfinders and a study of ground infrastructure supporting WGS. However, these officials told us that there is no formal plan to guide post-AOA efforts including coordinating and providing the knowledge DOD needs to mitigate risks and inform timely decisions on DOD's next wideband communications architecture. If DOD does not develop and implement a plan—including roles, responsibilities, and time frames—for building knowledge, then DOD risks not having enough information to make timely, knowledge-based decisions on systems that provide critical communications for military operations. For example, the Wideband AOA recommended developing an enterprise terminal strategy to centralize user terminal procurement. Without a plan to guide such an effort, it is unclear what organization within DOD would begin working with the military services to develop this strategy and potentially adjust the services' acquisition approach to terminals.

At the same time, it is important to note that DOD space acquisition is facing a changing leadership environment, and developing and implementing a plan for post-AOA efforts would need to take place in the midst of such changes. In 2016, we reported that for over 2 decades, fragmentation and overlap in DOD space acquisition management and oversight had led to ineffective and untimely decision-making, leading to delays in space system development and increasing the risk of capability gaps across critical weapons systems.[15] DOD and Congress are taking steps designed to ultimately streamline decision-making and clarify authorities for space; however, it will likely take several years to implement such changes. Moreover, it is unclear the extent to which these changes will affect acquisition of user terminals—a long-standing challenge for DOD because the organizations responsible for buying terminals are not the same organizations that buy satellites. The changes being instituted include:

- **Re-established United States Space Command.** In August 2019, the President re-established the U.S. Space Command as a unified combatant command. DOD will form today's Space Command with some offices from Strategic Command responsible for space operations, with the mission to protect and defend space assets. Although U.S. Space Command does not conduct space acquisitions,

[15]GAO, *Defense Space Acquisitions: Too Early to Determine If Recent Changes Will Resolve Persistent Fragmentation in Management and Oversight,* GAO-16-592R (Washington, D.C.: July 27, 2016).

it is responsible for the satellite operators who help systems like WGS function—stakeholders in a post-WGS decision.

- **Transferred commercial SATCOM procurement to Air Force Space Command.** At the direction of the National Defense Authorization Act for Fiscal Year 2018, Air Force Space Command assumed responsibility for procuring commercial satellite communications for DOD in December 2018.[16] The Defense Information Systems Agency previously managed most commercial SATCOM acquisitions and is still responsible for other types of ground segment systems.
- **Proposed Establishment of a United States Space Force.** Early in 2019, the President and DOD proposed the establishment of a U.S. Space Force as a sixth branch of the U.S. Armed Forces within the Department of the Air Force. The Space Force would include the uniformed and civilian personnel conducting and directly supporting space operations from all DOD armed forces, assume responsibilities for all major military space acquisition programs—including those for SATCOM, and create the appropriate career tracks for military and civilian space personnel. Congress is deliberating the final composition of the proposed Space Force.
- **Established the Space Development Agency.** In March 2019, DOD established the Space Development Agency to unify and integrate efforts across DOD to define, develop, and field innovative satellite solutions, including communications. The Space Development Agency is focused on a low-Earth-orbit constellation to provide communications and other satellite-based operational support for DOD, which could also provide information for selecting a post-WGS architecture. As of this time, DOD has not determined how this new organization will mesh with the Air Force Space and Missile Systems Center that acquires satellite systems; the Defense Advanced Research Projects Agency, which creates breakthrough technologies and capabilities; and similar organizations within the department.

Conclusions

The Wideband AOA's recommendations for gathering additional information to reduce risk and inform DOD's decision-making are good first steps to ensure any post-WGS architecture will effectively and efficiently meet DOD's needs. The addition of one or two more WGS satellites provides some extra time for DOD to field new satellites, avoid capability gaps, and implement the AOA recommendations. However,

[16]Pub. L. No. 115-91, § 1601 (2017).

given the typical 7-year development timelines for space systems, DOD will need to decide on a way forward within the next several years so that new satellites will be available when needed. Attempting to implement the Wideband AOA recommendations without developing a plan for guiding multiple knowledge-building efforts across DOD raises risk that information gaps will not be closed in time to be useful or not closed at all. Consequently, it is important for DOD to coordinate these efforts and focus on how best to obtain a future wideband architecture that provides critical communications for military operations.

Recommendation for Executive Action

The Secretary of Defense should ensure that the Under Secretary of Defense for Acquisition and Sustainment develop and implement a plan to guide and coordinate efforts to implement the Wideband AOA recommendations to support timely, informed decisions on its next wideband satellite communications architecture. (Recommendation 1)

Agency Comments

We provided a draft of this report to DOD for review and comment. DOD provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Defense, and other interested parties. In addition, the report is available at no charge on the GAO 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 by email at 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 key contributions to this report are listed in appendix III.

Cristina T. Chaplain
Director
Contracting and National Security Acquisitions

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Appendix I: Best Practices for the Analysis of Alternatives Process

The analysis of alternatives (AOA) process is an analytical study that is intended to compare the operational effectiveness, cost, and risks of a number of potential alternatives to address valid needs and shortfalls in operational capability. This process helps ensure that the best alternative that satisfies the mission need is chosen on the basis of the selection criteria, such as safety, cost, or schedule.

GAO has identified 22 best practices for an AOA process by (1) compiling and reviewing commonly mentioned AOA policies and guidance used by different government and private-sector entities and (2) incorporating experts' comments on a draft set of practices to develop a final set of practices.[1]

These practices can be applied to a wide range of activities and situations in which a preferred alternative must be selected from a set of possible options, as well as to a broad range of capability areas, projects, and programs. These practices can also provide a framework to help ensure that entities consistently and reliably select the project alternative that best meets the mission need. The guidance below is meant as an overview of the key principles that lead to a successful AOA process and not as a "how to" guide with detailed instructions for each best practice identified because each entity may have its own process in place.

The 22 best practices that GAO identified are grouped into the following five phases:

- **Initialize the AOA Process**: includes best practices that are applied before starting the process of identifying, analyzing, and selecting alternatives. This includes determining the mission need and functional requirements, developing the study time frame, creating a study plan, and determining who conducts the analysis.
- **Identify Alternatives**: includes best practices that help ensure the alternatives that will be analyzed are sufficient, diverse, and viable.

[1]GAO first identified 24 best practices to establish an AOA process in *DOE and NNSA Project Management: Analysis of Alternatives Could Be Improved by Incorporating Best Practices* (GAO-15-37). GAO refined these best practices and condensed them to 22 best practices in *Amphibious Combat Vehicle: Some Acquisition Activities Demonstrate Best Practices; Attainment of Amphibious Capability to be Determined* (GAO-16-22). For our assessment, we used the updated version of the AOA best practices that will appear in our planned update to the GAO Cost Guide (GAO-09-3SP), which we anticipate issuing in early 2020.

- **Analyze Alternatives**: includes best practices that compare the alternatives selected for analysis in terms of costs, benefits, and risks. The best practices in this category help ensure that the team conducting the analysis uses a standard, quantitative process to analyze the alternatives.
- **Document and Review the AOA Process**: includes best practices that are applied throughout the AOA process, such as documenting in a single document all steps taken to initialize, identify, and analyze alternatives, selecting a preferred alternative, and independently reviewing the AOA.
- **Select a Preferred Alternative**: includes the final step of comparing alternatives and selecting a preferred alternative that best meets the mission need.

The five phases address different themes of analysis necessary to complete the AOA process and comprise the beginning of the AOA process (defining the mission need and functional requirements) through the final step of the AOA process (select a preferred alternative).

There are three key entities who are directly involved in the AOA process: the customer, the decision maker, and the AOA team.

- The **customer** refers to the group that implements the final decision (i.e. the program office, agency, and the like). A complex AOA process that impacts multiple agencies can have multiple customers.
- The **decision maker** is the person or entity who signs off on the final decision and analysis documented by the AOA report, and who will select the preferred alternative based on the established selection criteria. The decision maker should remain informed throughout the AOA process. For example, the decision maker could form a committee that consists of management and other groups independent of the AOA process who possess the required technical expertise or broad organizational knowledge to keep the decision maker apprised of and to inform the AOA process.
- The **AOA team** is the group involved in the day-to-day work of the AOA process and who conducts the identification and assessment of alternatives that is the foundation of the AOA process.

We assessed the Department of Defense's (DOD) Wideband Communication Services AOA against the "comprehensive" characteristic. Overall, the AOA met the six best practices we identified. Table 5 shows the relevant AOA best practices for the "comprehensive" characteristic.

Table 5: Analysis of Alternatives (AOA) Best Practices for Comprehensiveness

Define mission need
Definition: The customer defines the mission needs (i.e., a credible gap between current capabilities and those required to meet the goals articulated in the strategic plan) without a predetermined solution. To ensure that the AOA process does not favor one solution over another, the AOA is conducted before design and development of the required capabilities. The customer decides at which point in a project's design an AOA should be performed, with the understanding that the more complete the design, the more information is available to support a robust analysis and to select a preferred alternative that best meets the mission need.
Effect: Allowing mission needs to be defined in solution-specific terms creates a potential bias, which could prevent the inclusion of viable alternatives and invalidate the analysis.
Define functional requirements
Definition: The customer defines functional requirements (i.e., the general parameters that the selected alternative must have to address the mission need) based on the mission need without a predetermined solution. The customer defines the capabilities that the AOA process seeks to refine through characterized gaps between capabilities in the current environment and the capabilities required to meet the stated objectives for the future environment. These functional requirements are realistic, organized, clear, prioritized, and traceable. It is advisable that functional requirements be set early in the AOA process, prior to the identification of the alternatives, and agreed upon by all stakeholders.
Effect: The AOA process is tied to the identified mission need. Setting functional requirements to a standard other than the mission need allows bias to enter the study because the functional requirements might then reflect arbitrary measures, preventing the inclusion of viable alternatives. Additionally, functional requirements that are not tied to mission need make it difficult to quantify the benefits of each alternative relative to what is required and make it challenging for decision makers to assess which capability gaps will be met for each alternative. If functional requirements are established after the analysis has begun, bias may influence the study's results.
Develop AOA timeframe
Definition: The customer provides the team conducting the analysis enough time to conduct a robust and complete analysis. Since an AOA process requires a large team with many diverse resources and expertise, the process requires sufficient time to be accomplished thoroughly. A detailed schedule to conduct the AOA is developed prior to starting the process. The duration of the AOA process depends on the number of viable alternatives and availability of the team members. The time frame is tailored for the type of system to be analyzed and ensures that there is adequate time to properly accomplish all of the AOA process steps.
Effect: The AOA process identifies and thoroughly analyzes a comprehensive range of alternatives. Recommending an alternative without adequate time to perform the analysis is a contributing factor to high dollar acquisitions that have significantly overrun both cost and schedule while falling short of expected performance.
Develop list of alternatives
Definition: The AOA team identifies and considers a diverse range of alternatives to meet the mission need. To fully address the capability gaps between the current environment and the stated objectives for the future environment, market surveillance and market research is performed to develop as many alternative solutions as possible for examination. Alternatives are mutually exclusive, that is, the success of one alternative does not rely upon the success of another.
Effect: An AOA process encompasses numerous alternatives in order to ensure that the study is comprehensive; that is, it provides a broad view of the issue. If the AOA team does not perform thorough research to capture diverse alternatives, the optimal alternative could be overlooked and invalidate the AOA's results and bias the process.

Assess alternatives' viability

Definition: The AOA team screens the list of alternatives to eliminate those alternatives that are not viable, and it documents the reasons for eliminating any alternatives. All alternatives are examined using predetermined qualitative technical and operational factors to determine their viability. Only those alternatives found viable are examined fully during the analysis phase. However, all assumptions regarding the alternatives' viable and nonviable status are fully documented, including reasons why an alternative is not viable, in order to justify the recommendation. Additionally, if project budgets are known, viable alternatives that are not affordable within the projections are dropped from final consideration.

Effect: Not eliminating alternatives based on viability could needlessly extend the study's duration and burden the AOA team or lead to the selection of a technically nonviable alternative. Furthermore, unless the AOA team considers affordability as part of the final recommendation, an alternative that is not feasible based on the current fiscal environment could be selected. Documenting the alternatives that are deemed nonviable is important so that decision makers can clearly see why those alternatives are not considered for further analysis, confirming that the AOA process is comprehensive.

Develop life-cycle cost estimates (LCCEs)

Definition: The AOA team develops a LCCE for each analyzed alternative, including all costs from inception of the project through design, development, deployment, operation, maintenance, and disposal. The AOA team includes a cost expert who is responsible for development of a comprehensive, well-documented, accurate, and credible cost estimate for each viable alternative in the study. The LCCE for each alternative follows the GAO 12-step guide, as appropriate for an early acquisition cost estimate, and uses a common cost element structure for all alternatives and includes all costs for each alternative.[a] Costs that are the same across the alternatives (for example, training costs) are included so that decision makers can compare the total cost rather than just the portion of costs that varies across all viable alternatives. The level of detail included in the LCCE should be consistent with the maturity of the alternatives. The AOA team expresses the LCCE in present value terms and explains why it chose the specific discount rate used. The AOA team ensures that economic changes, such as inflation and the discount rate, are properly applied, realistically reflected, and documented in the LCCE for all alternatives.[b]

Effect: An LCCE that is incomplete (e.g. does not include all phases of an alternative's life cycle) does not provide an accurate and complete view of the alternatives' costs. Without a full accounting of life-cycle costs, decision makers will not have a comprehensive picture of the costs for each alternative and will have difficulty comparing the alternatives because comparisons may not be based on accurate information. Additionally, applying a discount rate is an important step in cost estimating because all cost data for each analyzed alternative must be expressed in like terms for comparison. Unless the AOA team properly normalizes costs to a common standard, any comparison would not be accurate, and any recommendations resulting from the flawed analysis would be negated. Properly normalizing costs is particularly important if various alternatives have different life cycles.

Source: GAO. | GAO-20-80

[a]GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: Mar. 2009)

[b]The present value of the estimate reflects the time value of money—the concept that a dollar today can be invested and earn interest.

Appendix II: Department of Defense Wideband Communications Services Analysis of Alternatives Recommendations

The Department of Defense (DOD) made the following recommendations in its Wideband Communications Services Analysis of Alternatives (AOA) report:

1. Immediately conduct a business case analysis that examines incorporating anti-jam and cybersecurity features that improve upon legacy capability into the Wideband Global SATCOM (WGS) Space Vehicle (SV) 11/12 procurement.
2. Investigate the impacts of WGS SV 11/12 to ground infrastructure, mission management, and user terminals to understand necessary modifications.
3. Develop and implement a DOD Enterprise Satellite Communications (SATCOM) Terminal Strategy that targets an approved Joint Information Environment architecture, reduces complexity of terminal diversity and programmatic governance, facilitates rapid modernization, and drives innovating business reforms, optimizing cost, schedule, and performance and interoperability.
4. Fund a purpose-built capability post-WGS SV 11/12 meeting user demands, including all weather capabilities, with a recommended start in fiscal year 2020, including consideration of alternate orbital regimes and approaches to cost-effectively meet needs while addressing proliferation, protection, and resiliency. The purpose is to ensure availability of DOD SATCOM resources to meet requirements where anticipated commercial offerings fail to materialize or are insufficient.
5. Continue efforts to invest in and shape commercial capabilities to support future DOD needs, including protection features, resilience, contested and all-weather capabilities, and polar coverage. Additionally, invest in and shape commercial industry development and risk reduction efforts focused on cybersecurity, terminal militarization/weapon system integration, management and control, technology assessment and development, and spectrum access.
6. Continue to fund existing and new SATCOM risk reduction efforts, evaluate blended commercial/military constellations, and expand the scope of pilots to include development of architectural standards and interface controls for enterprise management and control, terminal recapitalization plans, and means for terminals and/or weapon system platforms to transition satellite constellations and any DOD managed services.
7. Fund the design and implementation of a prototype wideband enterprise SATCOM management and control capability based on an approved Joint Information Environment architecture that integrates

the management of Military, Commercial, and International Partner-provided SATCOM services and networks and supports the Enterprise Operational Management requirement in the Joint Space Communications Layer Initial Capabilities Document Change 1.

8. Plan for investment in Protected Tactical Waveform capabilities to commercial and military band terminals to align with the Protected Anti-Jam Tactical SATCOM planned ground and space milestones.
9. Fund pilot efforts to identify risks and opportunities to use commercially-managed services for Army's Combat Support Logistics Very Small Aperture Terminals and ways to mitigate that risk.
10. Pursue partnership opportunities with Norway and Canada to achieve earlier Arctic coverage capability.

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the contact named above, Rich Horiuchi, Assistant Director; Burns C. Eckert (Analyst in Charge); Erin Cohen; Emile Ettedgui; Jon Felbinger; Kurt Gurka; Stephanie Gustafson; Jennifer Leotta; Roxanna Sun; and Jay Tallon made key contributions to this report.

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