



January 2023

BATTLE MANAGEMENT

DOD and Air Force Continue to Define Joint Command and Control Efforts

GAO Highlights

Highlights of [GAO-23-105495](#), a report to congressional addressees

Why GAO Did This Study

DOD military commanders require a real-time, complete picture of the battlespace to quickly make informed decisions. Historically, DOD has prioritized individual systems over joint capabilities and interoperability. DOD intends for JADC2 to address this issue by connecting warfighting capabilities through digital networks to enable commanders to effectively communicate and share information. Each military department is contributing to JADC2; the Air Force's part is called ABMS.

Members of Congress included a provision for GAO to conduct a review of ABMS. In addition, GAO was asked to evaluate how ABMS will contribute to DOD's broader goals for JADC2. This report addresses the extent to which (1) DOD has defined JADC2, and (2) the Air Force has developed plans for ABMS.

GAO reviewed planning and acquisition documents for JADC2 and ABMS, JADC2 implementation guidance, and ABMS contracts, among other documents. GAO also interviewed officials from the Joint Staff, Office of the Secretary of Defense, Air Force (including ABMS leadership), Space Force, Navy, Marine Corps, and Army.

What GAO Recommends

In April 2020, GAO recommended the Air Force develop a plan to mature technologies, develop a cost estimate, and conduct an affordability analysis for ABMS. DOD concurred. The Air Force is taking steps to address the recommendations—through acquisition and planning documents—but needs to do more to fully address them.

View [GAO-23-105495](#). For more information, contact Marie A. Mak at (202) 512-4841 or MakM@gao.gov.

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What GAO Found

Joint All-Domain Command and Control (JADC2) is a long-term effort to connect military assets across space, air, land, sea, and cyber domains. The Department of Defense (DOD) intends for JADC2 to analyze warfighting data across all of those domains to allow decision makers to identify, execute, and monitor operations more effectively.

Joint All-Domain Command and Control Concept



Source: GAO analysis of Department of Defense documentation. | GAO-23-105495

DOD is in the early stages of developing JADC2 and released initial guidance, including a strategy that outlines broad goals. However, DOD has not yet defined the details, such as which existing systems will contribute to JADC2 and what future capabilities need to be developed. A House report directed DOD to report on the scope, cost, and schedule of the overall JADC2 effort. Currently, DOD is in the early stages of determining those elements.

In April 2020, GAO reported on the Air Force's contribution to JADC2—the Advanced Battle Management System (ABMS)—and recommended that the Air Force develop acquisition and planning documents. Since then, the Air Force has taken steps to do so and has defined two ABMS efforts:

- **Capability Release 1** intends, in part, to enable F-35 data connectivity with command and control centers, and the Air Force plans to deliver prototypes in 2024. This is a shift from original Capability Release 1 plans, which also included F-22 data connectivity. The Air Force intends to update documents to reflect this change.
- **Cloud-Based Command and Control** intends to integrate a variety of air defense data sources to support homeland defense. The Air Force plans to deliver initial capabilities in 2023; however, it is in the process of identifying those capabilities.

In June 2022, the Air Force established a consortium of companies to assist in developing requirements for a network, called the ABMS Digital Infrastructure, to enable ABMS efforts. Additionally, in September 2022, the Air Force established a new leadership structure for ABMS. While these are positive steps toward developing ABMS, the Air Force has not delivered any capabilities to date and is in the process of identifying future capabilities and when they will be delivered.

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Abbreviations

ABMS	Advanced Battle Management System
CBC2	Cloud-Based Command and Control
CFT	Cross-Functional Team
DOD	Department of Defense
JADC2	Joint All-Domain Command and Control
NORAD	North American Aerospace Defense Command
NORTHCOM	U.S. Northern Command
RCO	Rapid Capabilities Office

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January 13, 2023

Congressional Addressees

To maintain a competitive advantage over adversaries, Department of Defense (DOD) military commanders require a real-time, complete picture of the battlespace so they can quickly make informed decisions, direct actions, and monitor execution of operations. Historically, when DOD and the military departments acquired weapons systems, they generally prioritized individual system capabilities over connectivity, data interoperability, and functional compatibility across systems. DOD recognizes that its systems now need to operate in battle environments that are more complex and demand greater connectivity. DOD intends for Joint All-Domain Command and Control (JADC2) to address these issues using a digital environment to analyze warfighting data across all domains to allow decision makers to identify, execute, and monitor operations more effectively.

The Advanced Battle Management System (ABMS) is the Air Force's contribution to JADC2. It is intended to establish a data network to connect Air Force and Space Force sensors, systems, and weapons. In April 2020, GAO found that the Air Force started ABMS development without key elements of a business case, such as a cost estimate to inform budget requests.¹

A House Armed Services Committee report accompanying H.R. 4350 included a provision for GAO to conduct a review of ABMS.² In addition, the House Tactical Air and Land Forces Subcommittee asked us to provide a review of ABMS and how it will contribute to DOD's broader goals for JADC2. This report addresses the extent to which (1) the Air Force has developed plans for ABMS capabilities, and (2) DOD has defined JADC2.

To assess the extent to which the Air Force has developed plans for ABMS capabilities, we reviewed ABMS acquisition planning documents to determine what capabilities the Air Force identified, and the cost and schedule to develop those capabilities. These documents included

¹GAO, *Defense Acquisitions: Action Is Needed to Provide Clarity and Mitigate Risks of the Air Force's Advanced Battle Management System*, [GAO-20-389](#) (Washington, D.C.: Apr. 16, 2020). We made recommendations to address these issues, as discussed later in the report.

²H.R. Rep. 117-118, pt. 1, at 55-56 (Sept. 10, 2021).

program briefs, acquisition strategies, requirements documents, cost assessments, and contract documents. We also reviewed Air Force ABMS status briefings to congressional staff. We analyzed these documents using acquisition leading practices GAO identified to determine whether Air Force plans address key elements of a business case.³ These elements include firm requirements, a plan to attain mature technologies, a cost estimate, and an affordability analysis.

We also compared these documents to DOD acquisition guidance, such as the Adaptive Acquisition Framework Major Capability Acquisition Pathway and the Software Acquisition Pathway, to determine whether Air Force plans included key components of acquisition planning.⁴ We also identified steps the Air Force has taken to address open recommendations from GAO's prior work on ABMS, which included recommendations to develop key elements of a business case. Furthermore, we reviewed ABMS contracts to determine how the Air Force plans to use contractors to help address ABMS requirements. In addition, we interviewed Air Force ABMS leadership and officials to understand current ABMS efforts and how the Air Force plans to identify and prioritize future ABMS efforts. We also discussed the roles and responsibilities of Air Force offices in planning and executing ABMS efforts.

To assess the extent that DOD has defined JADC2, we reviewed key policies, planning documents, implementation guidance, information papers, and overview briefings, including both classified and unclassified documents. We reviewed these documents to identify the goals of JADC2, the JADC2 governance structure, the roles and responsibilities of JADC2 officials, and the guidance from DOD leadership on how to implement JADC2 goals. We also reviewed documents related to each military department's contribution to the JADC2 effort, including the Air Force's ABMS, the Department of the Navy's Project Overmatch, and the Army's Project Convergence. Although we obtained information to gain a general understanding of Project Convergence and Project Overmatch, we did not assess these efforts in detail given our focus on how DOD has defined JADC2. In addition, we interviewed JADC2 leadership and

³See 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); and *Defense Acquisitions: Improved Business Case Is Needed for Future Combat System's Successful Outcome*, [GAO-06-367](#) (Washington, D.C.: Mar. 14, 2006).

⁴Department of Defense, *Major Capability Acquisition*, DOD Instruction 5000.85 (Aug. 6, 2020) (incorporating change 1 Nov. 4, 2021); and *Operation of the Software Acquisition Pathway*, DOD Instruction 5000.87 (Oct. 2, 2020).

officials from the Office of the Secretary of Defense and Joint Staff, who represent four of the seven JADC2 working groups. We discussed DOD's progress in carrying out JADC2 goals, potential challenges, and steps taken to address those challenges. Further, we interviewed officials from the Air Force, Space Force, Navy, Marine Corps, and Army to identify each military department's current efforts to implement JADC2 goals and to discuss how DOD leadership has provided direction on implementing JADC2.

We conducted this performance audit from October 2021 to January 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

The JADC2 concept originated from a DOD concern that military departments were developing their own specific capabilities that did not account for the increasing need for interoperability between departments, as the pace of warfighting and the volume and complexity of data increased. According to DOD, JADC2 capabilities will enhance U.S. and mission partner forces' ability to execute commanders' decisions and direct and conduct military operations at all levels across domains, including air, land, sea, space, cyber, and the electromagnetic spectrum. As a notional example, an aircraft could identify a threat and, in an automated way, transmit real-time data to a carrier strike group, whose commander could then use that information to order surface vessels to strike that threat. Figure 1 illustrates the type of information sharing across all warfighting domains that DOD envisions JADC2 will enable.

Figure 1: Overview of Joint All-Domain Command and Control Concept



Source: GAO analysis of Department of Defense documentation. | GAO-23-105495

Command and control is the collection and sharing of information to enable military commanders to make timely, strategic decisions; take tactical actions to meet mission goals; and counter threats to U.S. assets. The Deputy Director of the Joint Staff Office for Command, Control, Communications, and Computers/Cyber, organizationally identified as J6, is responsible for overseeing the implementation of JADC2 and advising the Chairman of the Joint Chiefs of Staff on requirements for joint interoperability and command and control capabilities.⁵ The Joint Requirements Oversight Council is responsible for assessing joint capabilities across the military departments and identifying, approving, and prioritizing how to address gaps in those capabilities, among other things.⁶

⁵The Chairman of the Joint Chiefs of Staff is the principal military advisory to the President, National Security Council, and the Secretary of Defense. The Joint Chiefs of Staff consist of the Chairman, the Vice Chairman, the Chief of Staff of the Army, the Chief of Naval Operations, the Chief of Staff of the Air Force, the Commandant of the Marine Corps, the Chief of the National Guard Bureau, and the Chief of Space Operations.

⁶The Joint Requirements Oversight Council is chaired by the Vice Chairman of the Joint Chiefs of Staff and is the principal advisor to the Chairman of the Joint Chiefs of Staff for making recommendations about joint military capabilities or joint performance requirements. It is composed of general or admiral officers from the Army, Navy, Air Force, Marine Corps, and Space Force.

The military departments are beginning to plan and execute their own department-specific initiatives to support JADC2 goals. Specifically:

- **Air Force ABMS.** The Air Force is working to build a digital infrastructure to enable sharing of information and provide situational awareness to enable better operational decisions. ABMS is intended to deliver capabilities to the Air Force, Space Force, and joint forces in support of JADC2. The Air Force expects ABMS capabilities to include secure processing, connectivity, data management, applications, sensor integration, and effects integration.⁷
- **Army Project Convergence.** The Army has hundreds of program-specific development efforts that intend to inform and deliver future JADC2 capabilities. According to officials, Project Convergence is an Army-hosted joint experiment focused on the integration of capabilities between operational military department headquarters. Officials indicated it is intended to identify capability shortfalls to help prioritize and align efforts to JADC2 goals. The first Project Convergence exercise in 2020 tested Army JADC2-related technologies including artificial intelligence platforms that collect and analyze sensor data and provide users with enhanced decision-making information. The 2021 Project Convergence experiment expanded to integrate Navy, Marine Corps, and Air Force systems. The 2022 experiment, which officials said took place September through November 2022, planned to include over 250 technologies across the military departments and coalition partners, and further expand, integrate, and enable joint capabilities.
- **Navy Project Overmatch.** While the Navy and Marine Corps' effort is largely classified, the primary goal is to develop and deliver an operational architecture, including infrastructure and software tools, to support maritime and expeditionary operations. Navy officials stated this project intends to improve interoperability between the Navy and Marine Corps fleet and Army and Air Force assets and weapons systems. Navy officials told us that they are currently addressing Navy-specific capability gaps.

⁷According to Air Force officials, effects integration manages and directs desired results by utilizing machine-to-machine connections, enabled by ABMS capabilities.

Prior GAO Work

In April 2020, we reported that the Air Force started ABMS development without key elements of a business case as called for in key acquisition practices we identified. These included firm requirements, a plan to attain mature technologies, a cost estimate, and an affordability analysis.⁸ Our previous work has shown that weapon systems without a sound business case are at greater risk for schedule delays, cost growth, and integration issues.⁹ To address these missing business case elements, we recommended that the Air Force develop and brief Congress quarterly on a plan to attain mature technologies, develop a cost estimate, and develop an affordability analysis. In addition, we found that the Air Force had not fully defined the authorities to plan and execute ABMS efforts. We recommended that the Air Force formalize the ABMS management structure and decision-making authorities. DOD concurred with these recommendations.

To address our recommendation related to ABMS authority and decision-making responsibilities, in November 2020, the Air Force designated the Department of the Air Force Rapid Capabilities Office (RCO) as the lead organization for designing and acquiring ABMS capabilities. The Air Force has partially addressed the other three recommendations related to the ABMS business case as discussed later in this report. In the Fiscal Year 2021 National Defense Authorization Act, Congress directed the Air Force to define its ABMS plans, including key technical requirements and cost estimates, to support its investments.¹⁰

Air Force Is Continuing to Develop Details Needed to Implement ABMS

The Air Force is continuing to evolve and further define key aspects of its ABMS acquisition strategies and management structure, but details on future acquisition efforts are in development. The Air Force developed acquisition strategies for two current ABMS efforts that outline preliminary requirements and schedules. The Air Force also took steps to establish a consortium of commercial companies to provide recommendations on the development of a data network that will underpin future ABMS capabilities. However, details are in development for future ABMS efforts, including how the Air Force intends to expand new data integration capabilities to additional Air Force commands. The management structure of ABMS efforts also continues to evolve. In September 2022, the Air Force announced that responsibility for ABMS transitioned from the RCO

⁸[GAO-20-389](#).

⁹[GAO-15-192](#); and [GAO-06-367](#).

¹⁰Pub. L. No. 116-283, § 221 (2021).

to a new program executive office for Command, Control, Communications, and Battle Management.

Air Force Initial Planning Documents for Two Current ABMS Efforts Provide Some Key Information

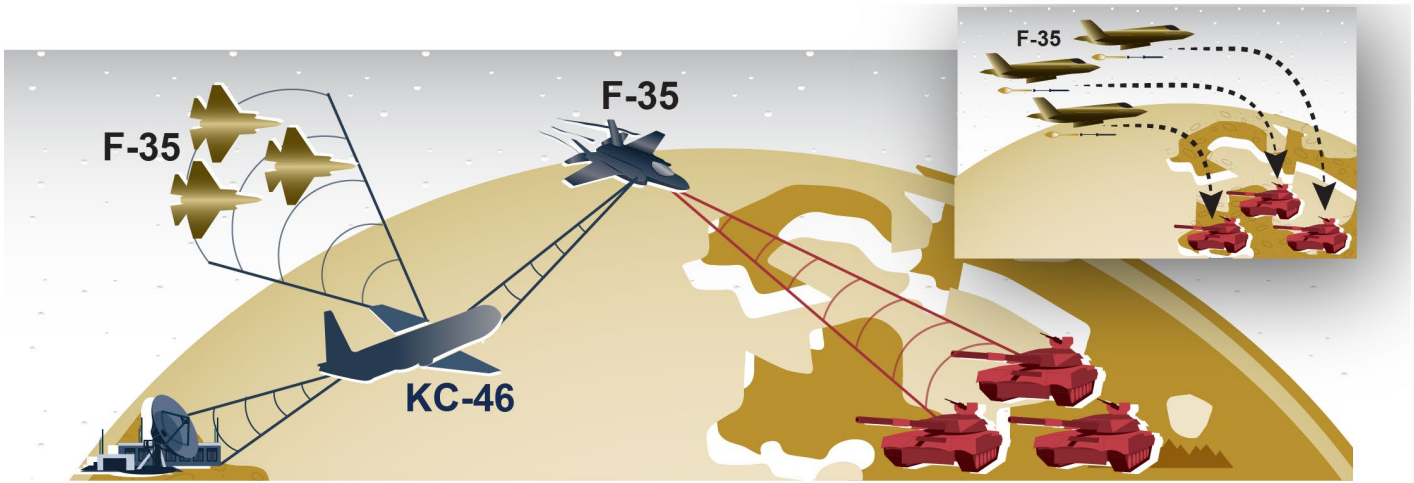
The RCO developed initial acquisition planning documents for the first phase of two current ABMS efforts, known as Capability Release 1 and Cloud-Based Command and Control (CBC2).

Capability Release 1 is intended to enable data transfer between communication systems on KC-46 refueling tanker aircraft, F-35 fighter aircraft, and command and control systems on the ground. To accomplish this, the RCO plans to develop a prototype of a communications system, which will be located on the KC-46 aircraft, to transmit real-time sensor data between these different elements. The prototype builds on an exercise from December 2019, where the Air Force reported a successful demonstration that data could be transmitted between F-35s and other aircraft. The RCO's current plan is to initially deliver and install prototypes on two KC-46 aircraft in fiscal year 2024.

Originally, the RCO also planned to include data transfer capabilities to and from F-22 aircraft. The F-35 and F-22, both fifth generation fighter aircraft, cannot currently share information, in part, due to different communication systems designed, developed, and acquired with each aircraft.¹¹ To help address this issue, the RCO initially planned for Capability Release 1 to provide links for F-35s or F-22s to share data with command and control locations on the ground. RCO officials stated they later determined that the Capability Release 1 prototype would not include the F-22 connectivity requirement, in part, because of the F-22's reduced role in the future force structure. RCO officials stated that the ABMS team is currently prioritizing F-35 data connectivity with command and control centers and they may address F-22 connectivity in a future effort based on operational needs. Figure 2 shows a notional example of Capability Release 1 where a lead F-35 aircraft identifies and transmits target information to a KC-46 aircraft for further distribution and targeting.

¹¹We previously reported on interoperability and integration challenges of fifth generation fighters such as the F-22 and F-35 with the joint force. GAO, *Defense Information Environment: Integration of Sensor Data Capabilities of 5th Generation Aircraft into the Joint Force*, GAO-21-249SU (Washington, D.C.: May 19, 2021).

Figure 2: Advanced Battle Management System Capability Release 1 Notional Operation



Source: GAO analysis of Air Force documentation. | GAO-23-105495

To develop Capability Release 1, the RCO is using the Major Capability Acquisition Pathway, which is the process DOD uses to acquire major defense acquisition programs and systems.¹² After two prototype units are delivered to meet its initial plans, officials said the Air Force plans to assess the prototypes and determine whether to continue the effort to procure additional units, and if so, what additional funding will be required.

¹²DOD Instruction 5000.85. Generally, major defense acquisition programs are those identified by DOD or that have a dollar value for all increments estimated to require eventual total expenditure for research, development, test, and evaluation of more than \$300 million, or for procurement of more than \$1.8 billion, in fiscal year 1990 constant dollars. See 10 U.S.C. § 4201. For more information on how DOD is using this pathway, see GAO, *Weapon Systems Annual Assessment: Challenges to Fielding Capabilities Faster Persist*, [GAO-22-105230](#) (Washington, D.C.: June 8, 2022).

CBC2 is intended to integrate a variety of air defense data sources for North American Aerospace Defense Command (NORAD) and U.S. Northern Command (NORTHCOM), including commercial and military sources, and provide commanders with the ability to make decisions more quickly based on that integrated information.¹³ CBC2 will build upon Pathfinder, a software tool prototype for air defense of NORAD/NORTHCOM. Pathfinder consolidates data from various aircraft and radars and analyzes the data automatically.

The RCO intends for CBC2 to replace one legacy command and control system and incorporate data feeds from three other systems.¹⁴ To provide this capability, the Air Force plans to establish a cloud-based command and control network that enables on-demand access to shared computing resources.¹⁵ To develop CBC2, the RCO plans to use the Software Acquisition Pathway, which facilitates rapid development and delivery of software-intensive systems.¹⁶ Using this pathway, developers plan to produce incremental releases of small software applications to deliver basic capabilities to users. These software releases are intended to progress toward meeting CBC2 requirements. RCO officials reported that

¹³NORAD is a binational United States and Canadian organization charged with the missions of aerospace warning and aerospace control for North America. Aerospace warning includes the monitoring of manufactured objects in space, and the detection, validation, and warning of attack against North America whether by aircraft, missiles, or space vehicles, through mutual support arrangements with other commands. Aerospace control includes ensuring air sovereignty and air defense of the airspace of Canada and the United States. NORTHCOM provides and manages homeland defense and civil support. NORTHCOM's area of responsibility includes the 48 contiguous states, Alaska, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands, in addition to coordinating with the defenses of Canada and Mexico.

¹⁴CBC2 will replace Battle Control System-Fixed and integrate data feeds from Theater Battle Management Core Systems and other missile defense and missile warning systems.

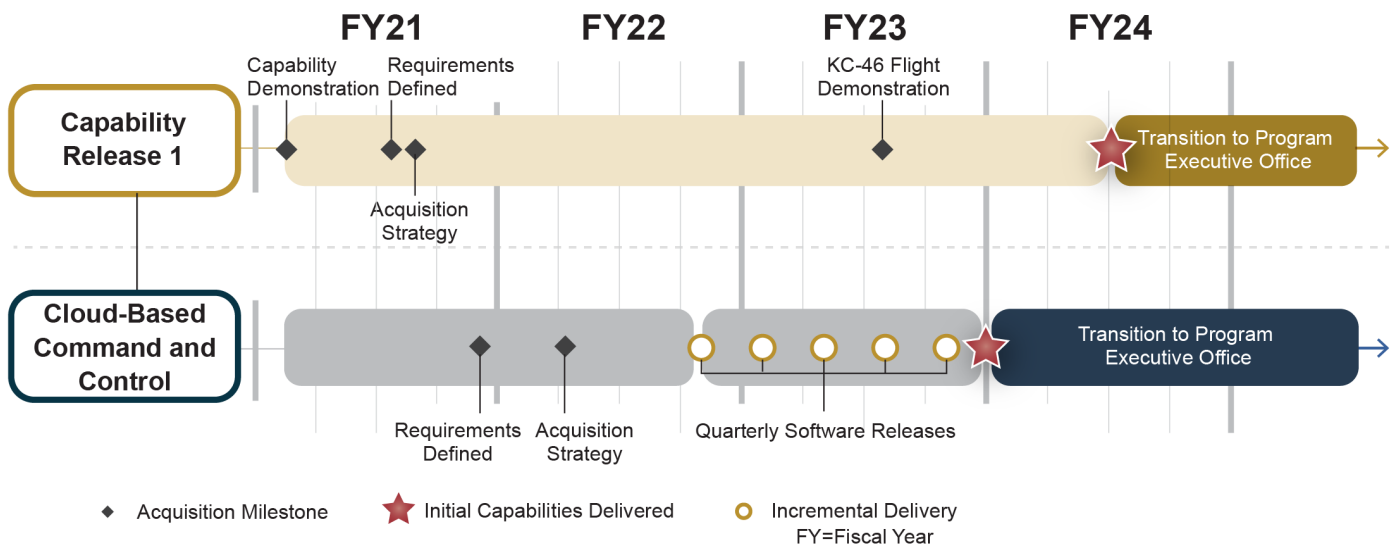
¹⁵According to the National Institute of Standards and Technology, cloud computing is a model for enabling on-demand access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. Cloud services can offer federal agencies a means to buy services more quickly, potentially at a lower cost than building, operating, and maintaining these computing resources themselves.

¹⁶DOD Instruction 5000.87. For more information on our prior work assessing DOD's implementation of this instruction, see GAO, *Defense Acquisitions: Cyber Command Needs to Develop Metrics to Assess Warfighting Capabilities*, [GAO-22-104695](#) (Washington, D.C.: Mar. 30, 2022); *Leading Practices: Agency Acquisition Policies Could Better Implement Key Product Development Principles*, [GAO-22-104513](#) (Washington, D.C.: Mar. 10, 2022); and *DOD Software Acquisition: Status of and Challenges Related to Reform Efforts*, [GAO-21-105298](#) (Washington D.C.: Sept. 30, 2021).

they have a notional roadmap for how to develop the overall required capabilities, but plan the content of each software increment on a quarterly basis, based on user feedback of the previous increment.

The RCO developed schedules to achieve initial plans for Capability Release 1 and CBC2, as shown in figure 3.

Figure 3: Capability Release 1 and Cloud-Based Command and Control Schedules



Source: GAO analysis of Air Force documentation. | GAO-23-105495

The Air Force’s current plans for ABMS reflect some elements of a business case. For example, the Air Force developed acquisition strategies for Capability Release 1 and CBC2. These acquisition strategies demonstrate that the Air Force has made progress in implementing our prior recommendations, which were to develop a technology maturity plan, a cost estimate, and an affordability analysis for ABMS. However, the planning documents do not outline a complete business case to deliver initial Capability Release 1 and CBC2 capabilities. For example, according to RCO officials, the ABMS team has not updated the Capability Release 1 requirements documents or cost estimate to reflect the focus on F-35 capabilities, but is currently working to do so. Table 1 outlines the acquisition planning documents that are complete, not complete, or awaiting updates.

Table 1: Status of Air Force Actions to Develop Business Case Documents for Advanced Battle Management System Efforts

	Capability Release 1 Prototype	Cloud-Based Command and Control - North American Aerospace Defense Command and U.S. Northern Command
Acquisition strategy	Complete: Approved strategy in June 2021 that includes elements such as acquisition approach, program schedule, risk management, and contracting strategy.	Complete: Approved strategy in April 2022 that includes elements such as acquisition approach, acquisition schedule, risk management, and contracting strategy.
Defined requirements	Awaiting Updates: While the Rapid Capabilities Office (RCO) finalized prototype requirements in April 2021, according to RCO officials, they are planning to update these requirements to reflect current prototype priorities, such as excluding the F-22 from initial development efforts.	Awaiting Updates: Identified relevant capability gaps in August 2021 and finalized system requirements in February 2022. However, the Air Force has yet to define the initial operational capabilities required by the end of fiscal year 2023.
Plan to mature technologies	Not Complete: The acquisition strategy identifies the current and planned technology maturity of components, such as the communications subsystems. While the critical technologies are immature, an independent Air Force assessment found that there would be sufficient maturity to determine whether to continue the effort beyond the initial prototype. However, there is no maturation plan, as recommended by leading practices, to help ensure the Air Force sufficiently matures the technologies when delivering prototypes.	Awaiting Updates: The acquisition strategy indicates that the RCO plans to use mature technologies, but does not identify the required technologies. RCO officials stated that industry experts will advise them on mature technologies that will enable the RCO to field capabilities quickly.
Cost estimate	Awaiting Updates: In September 2021, Air Force cost estimators developed a summary estimate of \$246.6 million for initial prototype efforts through fiscal year 2024. RCO officials stated they plan to update the cost estimate to reflect that F-22 connectivity will not be part of the initial prototype, and include actual development costs.	Awaiting Updates: In June 2022, Air Force cost estimators developed a summary estimate of \$338.4 million for all capabilities through fiscal year 2025 and documented the challenges that limited the analysis. Specifically, because the RCO has not defined capabilities, estimators noted it was extremely difficult to estimate what software developers could deliver within the schedule. Therefore, the cost estimate through fiscal year 2025 remains at risk of not reflecting required resources until the requirements and schedule are clarified and incorporated into an updated cost estimate.
Affordability analysis	Awaiting Updates: The Air Force identified that the initial prototyping effort is fully funded in the budget based on the September 2021 cost estimate, which is no longer current. The Air Force is unable to conduct an affordability analysis until it revises the cost estimate.	Awaiting Updates: While the Air Force has budgeted to fully fund efforts through fiscal year 2025, it is uncertain whether the planned funding will be sufficient since capabilities have not yet been defined. The Air Force is unable to conduct an affordability analysis until capabilities are fully defined.

Source: GAO analysis of Air Force documentation and interviews. | GAO-23-105495

RCO officials indicated that they have experienced significant challenges in developing the Capability Release 1 communication system and hardware to support integration with KC-46 aircraft, such as technical issues in developing F-35 data links. They said that these issues have

delayed prototype delivery by almost 1 year to fiscal year 2024. The RCO updated the current schedule accordingly.

RCO officials expect to deliver CBC2 initial operational capabilities in September 2023, but the Air Force has not yet identified what capabilities it will deliver at that point. RCO officials stated they have identified the capabilities CBC2 will deliver through December 2022 and do not expect the lack of longer-term capability planning to affect CBC2 development. These officials pointed to three recent software releases as evidence that the current capability definitions are sufficient to support development efforts. These releases, however, have not delivered capabilities, but instead focused on migrating software to a cloud network, testing software to identify deficiencies, and obtaining early user input on the releases. While these software releases demonstrate some development progress, the Air Force has not committed to what initial capabilities CBC2 will have by the end of fiscal year 2023.

Both ABMS efforts will require additional acquisition planning in the future to deliver full operational capabilities. ABMS program documents indicate that the Air Force will develop additional planning documents to support later phases of development, including full operational capabilities and transition plans, and a separate acquisition strategy for the procurement of additional units for Capability Release 1. Until the Air Force addresses our prior recommendations to document a plan to mature technologies, prepare a cost estimate, and complete an affordability analysis for Capability Release 1 and CBC2, the Air Force risks that the requisite technologies will not be mature when needed. It also will be limited in its ability to determine whether it has sufficient resources for ABMS in future years.

Air Force Has Taken Initial Steps to Develop a Network to Support ABMS Efforts

The Air Force plans to develop the first phase of the underlying data network, called the ABMS Digital Infrastructure, which will support the operations of future ABMS capabilities. The objectives of the Digital Infrastructure are to provide the Air Force an adaptable network and secure communications that provide data only to those authorized to access them. According to Air Force documents, the Digital Infrastructure will be comprised of many initiatives that will build the digital network environment through three lines of effort:

- **Secure processing** to establish services for processing and storage of data at multiple security levels. This includes leasing secure cloud capabilities and technical support.
- **Connectivity** to build a distribution network to securely move data, using existing systems when possible. This includes managing data from space and ground communications.

-
- **Data management** to establish common data elements and provide rules on how data are organized and stored. This includes using systems engineering expertise to provide data sharing across platforms.

The RCO established a Digital Infrastructure Consortium (which we refer to as the consortium)—a group of five companies that specialize in defense IT—to assist the RCO in defining the specific Digital Infrastructure requirements needed to support ABMS capabilities. To do so, in June 2022, the Air Force awarded contracts to five companies.¹⁷ Each contract, which includes firm-fixed-price contract line items, has an initial period of performance of 1 year with 4 additional priced option years.¹⁸ The Air Force expects the consortium members to collaboratively perform the systems engineering and planning activities necessary to build the ABMS Digital Infrastructure. For example, the consortium is expected to recommend a design approach for the development, deployment, and maintenance of the Digital Infrastructure, and aid the Air Force in defining the requirements needed for cloud networks. As the consortium recommends a Digital Infrastructure design, it also plans to make recommendations on the necessary technologies and capabilities to implement the design. As of October 2022, the RCO is in the process of defining the time frames for delivering Digital Infrastructure-related capabilities. While the Air Force is responsible for setting requirements and retains ownership of the Digital Infrastructure technical baseline, the consortium will be expected to manage this baseline on behalf of the Air Force. Consortium documents indicate that every 6 months, the Air Force will assess whether the consortium is meeting its objectives, and the government will step in for cases where the consortium cannot achieve consensus.¹⁹ RCO officials stated that using a consortium will ensure that no single contractor determines the design of the Digital Infrastructure

¹⁷These contracts are multiple-award, indefinite-delivery, indefinite-quantity contracts, and each of the five awardees is eligible to compete for task orders under its contract. In general, these are task-order or delivery-order contracts that provide for an indefinite quantity, within stated limits, of supplies or services during a fixed period. The government places orders for individual requirements. See Federal Acquisition Regulation (FAR) §§ 2.101, 16.504.

¹⁸Under a firm-fixed-price contract type, the government may agree to purchase an item or services for a firm price and the contractor is required to deliver the item or provide the services regardless of its actual costs. FAR § 16.202-1.

¹⁹All members of the consortium will be equal partners and will strive for consensus decision-making, but move to majority when consensus cannot be achieved, according to acquisition documents. Should majority be unachievable, the government will break ties or make the decision.

and will help ensure that it avoids locking the Air Force into utilizing one contractor for actual system development.

The consortium's progress has been affected because of the Air Force's delays in awarding the initial contracts. Specifically, the award of the five contracts to consortium members occurred 6 months later than planned. RCO officials stated that several factors, such as coordinating acquisition strategy approval and receiving funding later than expected due to the fiscal year 2022 continuing resolution, contributed to the delays. To mitigate the impact of schedule delays, officials said the RCO took steps to start Digital Infrastructure planning efforts before awarding the consortium contracts. For example, Federally Funded Research and Development Centers, such as MITRE and MIT Lincoln Labs, assisted with developing ABMS technical requirements before the consortium was established.²⁰ Officials said the RCO is now transitioning that work to the consortium. RCO officials stated that as of October 2022, the consortium is in the process of developing a delivery schedule. Once the consortium completes its initial objectives, the Air Force will have more defined time frames for developing the Digital Infrastructure.

Air Force Is Defining Details Needed to Implement Future ABMS Efforts

The Air Force has not yet defined its future ABMS efforts, but RCO officials stated they are currently working to do so. Officials expect to leverage Air Force planning and Digital Infrastructure consortium activities for NORAD/NORTHCOM CBC2 to inform future cloud efforts because of the common need for battle management capabilities across commands. The Air Force's 5-year plan for implementing and expanding the ABMS Digital Infrastructure states that the Air Force will expand its ABMS cloud efforts for CBC2 to the following commands:

- Pacific Air Forces;
- U.S. Air Forces in Europe and Air Forces Africa; and
- U.S. Space Command.

RCO officials told us they are working to determine the development schedule for these commands' ABMS capabilities. As of October 2022, RCO officials stated that they are working with the commands to identify

²⁰Federally Funded Research and Development Centers are intended to meet the special, long-term research or development needs of sponsoring agencies in areas integral to their missions and operations that cannot be met as effectively by existing in-house or other contractor resources. FAR § 35.017(a)(2). They provide federal agencies with research and development functions, technical systems engineering capabilities, and policy development and decision-making studies, among other things. These centers have historically assisted DOD in assessing individual programs or identifying trends among the department's weapon system acquisitions.

the needs for users in the Pacific and European areas of operation and developing acquisition strategies for each, with expected completion in fiscal year 2023. Once complete, officials stated that the Air Force will award contracts to develop capabilities for those commands and will release a more detailed schedule for when it will deliver these capabilities. The RCO officials stated that they expect to acquire hardware and software, as well as contract for support services, to enable a cloud-based network for those commands, and the consortium will help define detailed requirements and identify relevant available technologies. As the Air Force further defines its planning for these future ABMS efforts, we will continue to monitor its efforts to address our prior recommendations to develop a technology maturation plan, a cost estimate, and an affordability analysis for each of these efforts.

In addition, the Air Force is in the process of analyzing how those commands conduct operations to aid in prioritizing future ABMS capabilities, as well as determining which current weapons systems will support those capabilities. To support this analysis, the Air Force developed a battle management model to identify and prioritize requirements. ABMS officials stated that this model identifies the steps of battle management decision-making and identifies command and control capability gaps to inform future ABMS requirements. ABMS officials stated that this analytical approach is in line with the Secretary of the Air Force's emphasis that ABMS should prioritize efforts with the greatest impact on operations.

Air Force officials stated that the planning efforts outlined above are critical to advancing ABMS efforts, but they recognize that the focus going forward needs to be on delivering capabilities. They said that they are reorganizing the management of ABMS to emphasize that need. In September 2022, the Air Force announced that responsibility for ABMS transitioned from the RCO to a new program executive office for Command, Control, Communications, and Battle Management. According to the new program executive officer, the new organization will allow the Air Force to prioritize ABMS efforts at a higher level and under the leadership of a single office. However, the program executive officer noted that the full scope of the new office is in the process of being determined, and the Air Force is defining how the office will coordinate with other programs supporting ABMS.

This is the third leadership restructure of ABMS since 2018. While previous restructures led to new ABMS definitions and plans, Air Force officials, including the new program executive officer, stated that they do not plan to change direction for ABMS, and the ABMS team will continue

to manage current efforts. To date, the Air Force has allocated nearly \$600 million on ABMS efforts, but has not delivered any new capabilities. This is in part due to the changes in overall ABMS planning and management structure. The new program executive officer stated that there will be increased emphasis on delivering capabilities to users going forward. Further, the new program executive officer stated that the RCO's efforts laid the groundwork so that the Air Force could start delivering capabilities, beginning with initial operational capabilities for CBC2 for NORAD/NORTHCOM in late 2023.

DOD Is in Early Stages of Defining JADC2 and Identifying Related Challenges

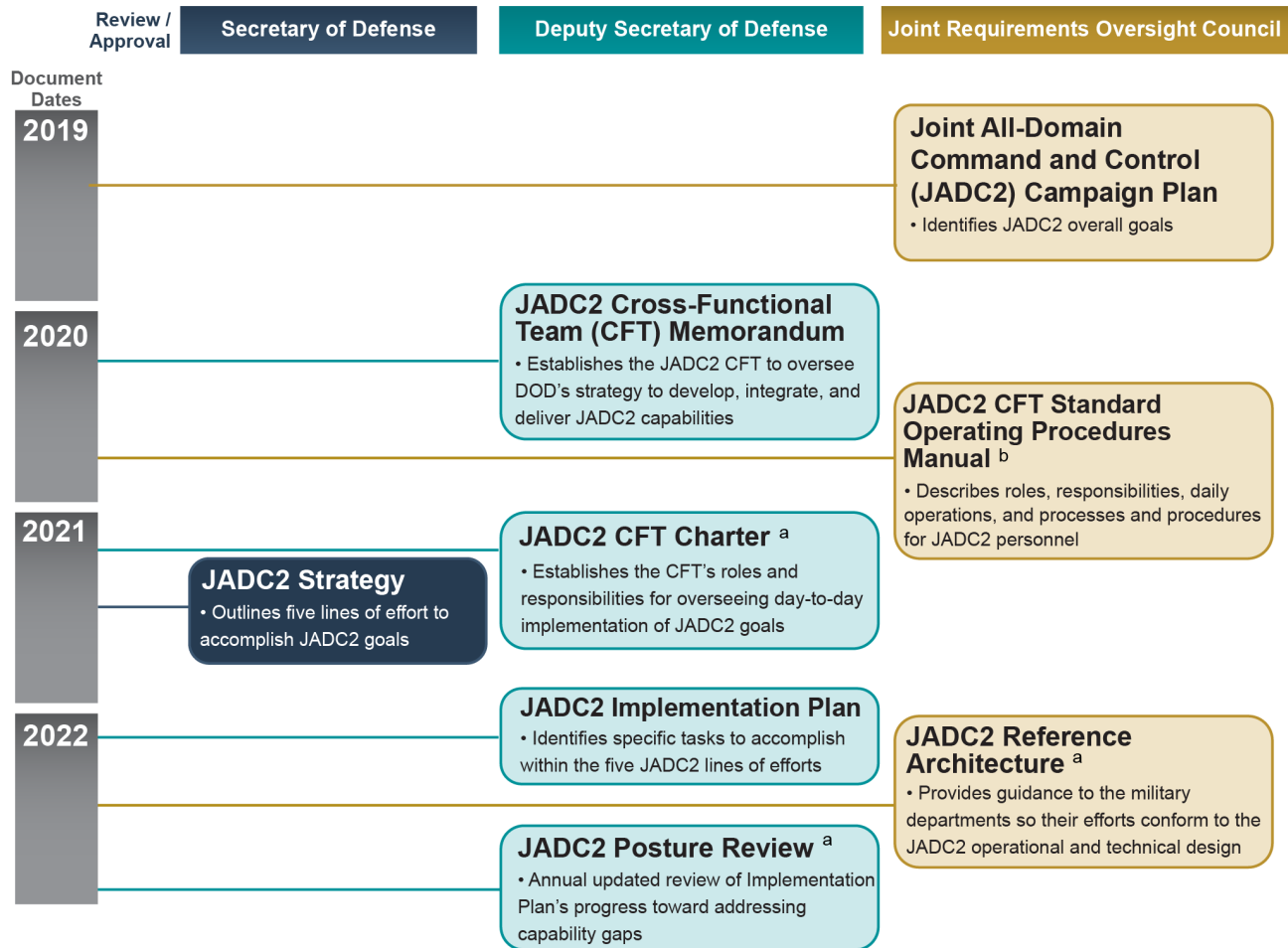
In 2019, DOD outlined the overall goals for JADC2, including to provide a secure data sharing environment across warfighting domains. Subsequently, in 2020, DOD established a team to oversee the implementation of JADC2 and issued initial guidance that outlined how to accomplish JADC2 goals. While DOD has made progress in JADC2 planning, it is in the process of identifying capabilities and challenges to implementing these goals. DOD is required to report to Congress in December 2022 on JADC2 development efforts and progress.

DOD Defined JADC2 Goals and Roles and Developed Initial Implementation Guidance

Goals. In July 2019, the Joint Requirements Oversight Council defined the overall goals for JADC2, and in 2020 DOD began developing the governance structure and initial guidance to implement those goals.²¹ At a high level, the Joint Requirements Oversight Council determined that JADC2 must provide a secure environment that shares data on threats across warfighting domains. In addition, JADC2 must connect headquarters to forces so that joint command and control decisions are executed at a faster pace than potential adversaries to maximize operational effectiveness. The Joint Requirements Oversight Council also noted that these goals will continue to evolve as DOD gathers more information on JADC2. Figure 4 provides an overview of the key documents that DOD has developed to define and implement JADC2 goals.

²¹Joint Requirements Oversight Council, *Joint All-Domain Command and Control Campaign Plan*, JROCM 075-19 (July 16, 2019).

Figure 4: Key Guidance to Define and Implement Joint All-Domain Command and Control Goals



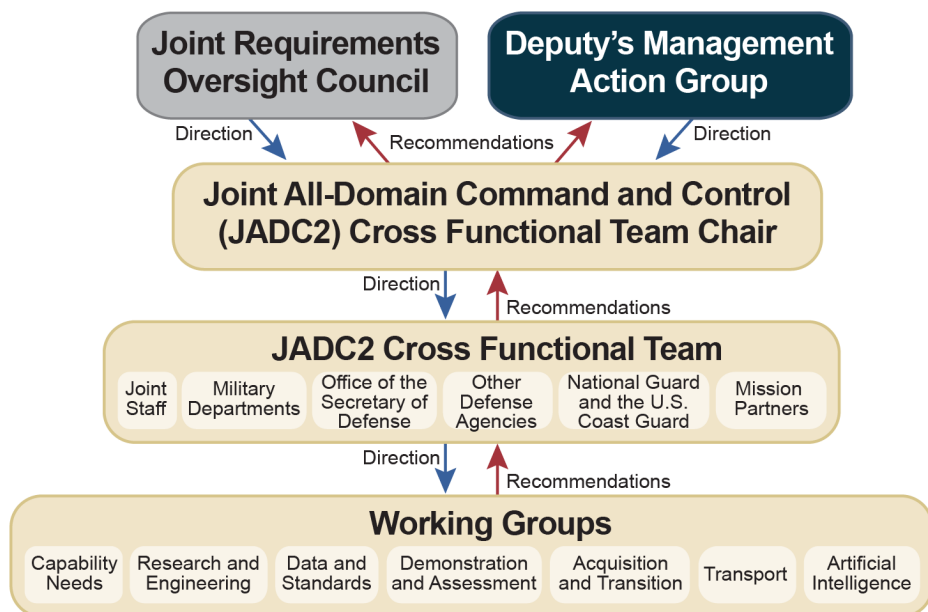
Source: GAO analysis of Department of Defense documents. | GAO-23-105495

^aThis date reflects the most current version of this document.

^bThe manual was signed by the Joint Staff, Deputy Director for Command, Control, Communications, and Computers/Cyber Integration.

Roles. To oversee the day-to-day implementation of tasks to achieve strategic JADC2 goals, the Deputy Secretary of Defense chartered the JADC2 Cross-Functional Team (CFT) in January 2020 as the governance body to coordinate efforts across DOD.²² The CFT was established to oversee DOD’s strategy to rapidly develop, integrate, and deliver JADC2 capabilities. It is also intended to track plans and milestones to oversee progress toward overarching goals, and ensure outcomes are consistent across DOD. Figure 5 illustrates the organizational structure of the JADC2 CFT.

Figure 5: Joint All-Domain Command and Control Cross-Functional Team Organizational Structure



Source: GAO analysis of Department of Defense documents. | GAO-23-105495

²²Deputy Secretary of Defense, *Revised Joint All-Domain Command and Control Cross-Functional Team Charter* (Feb. 1, 2021).

The JADC2 CFT is chaired by the Joint Staff J6 Deputy Director. The CFT Chair reports to the Deputy's Management Action Group—co-chaired by the Deputy Secretary of Defense and the Vice Chairman of the Joint Chiefs of Staff—which advises on resource decisions for top DOD-wide issues.²³ The CFT Chair also supports the Joint Requirements Oversight Council to assess joint military capabilities, and identify and prioritize gaps in those capabilities. To support these decision makers, the CFT intends to recommend funding for the development and fielding of JADC2 capabilities and propose changes in policy.

The JADC2 CFT established seven working groups and five supporting operational planning teams to provide subject matter expert analysis to guide JADC2 decisions makers. Specifically, working groups identify JADC2 needs and challenges, recommend solutions to the CFT to address JADC2 capability gaps, and coordinate JADC2 exercises and experiments with the military departments. For example, the Data and Standards Working Group works to standardize data sharing formats and best practices. The operational planning teams seek to coordinate across DOD to identify and assess command and control efforts. The teams are to focus on high priority command and control challenges, such as commanders' situational awareness of globally integrated operations. The October 2020 JADC2 CFT Standard Operating Procedures Manual identifies the roles and responsibilities of these working groups and operational planning teams.²⁴

Initial Implementing Guidance. In addition to the documents that establish the JADC2 CFT roles and responsibilities, DOD issued initial implementing guidance that outlines lines of effort and specific tasks to accomplish JADC2 goals. Further, DOD provided guidance to ensure that all JADC2 efforts enable data interoperability and functional compatibility across DOD systems.

²³According to DOD, the Deputy's Management Action Group is the primary civilian-military management forum that supports the Secretary of Defense, and addresses top departmental issues that have resource, management, and broad strategic or policy implications. The primary mission is to produce advice for the Deputy Secretary of Defense in a collaborative environment and to ensure that the Deputy's Management Action Group execution aligns with the Secretary of Defense's priorities as well as the planning and programming schedule. The Deputy's Management Action Group is co-chaired by the Deputy Secretary of Defense and Vice Chairman of the Joint Chiefs of Staff, with Secretaries of the military departments, Chiefs of the military services, and DOD Principal Staff Assistants holding standing invitations.

²⁴Joint Staff, *Joint All-Domain Command and Control Cross-Functional Team Standard Operating Procedures Manual* (Oct. 6, 2020).

- The Secretary of Defense outlined five lines of effort in the May 2021 JADC2 Strategy to implement JADC2 goals.²⁵ Table 2 provides an overview of the lines of effort and examples of objectives and tasks.

Table 2: Joint All-Domain Command and Control Lines of Effort, Objectives, and Tasks

Lines of effort	Examples of objectives	Examples of tasks
Data enterprise	Data are visible, accessible, understandable, interoperable, linked, secure, and trustworthy	Publish data assets in a catalog with common interface specifications Identify data management capabilities, tools, and practices for data security and protection
Human enterprise	Establish pre-determined, pre-approved authorities Accelerate decision-making of command and control Deliver leadership education, professional development, and training Employ and design analysis, wargames, experiments, demonstrations, assessments, training, and exercises	Identify and develop procedures and legal instruments necessary to execute authorities Identify policies and processes used to find, track, and target threats Develop and update Joint All-Domain Command and Control (JADC2) Posture Reviews Leverage demonstration and assessment events to introduce capabilities to coalition partners
Technology enterprise	Develop artificial intelligence and machine learning solutions Build a common design framework Modernize network and transport capabilities Enable rapid experimentation, prototyping, demonstration, and insertion of emerging technologies	Develop a roadmap to implement JADC2 artificial intelligence and machine learning Deliver Agile reference design to guide capability development efforts Identify opportunities for military department participation in joint demonstrations and assessments Leverage multi-level security environments to support data-centricity and integration of systems
Nuclear command, control, and communication	Collaborate and integrate with nuclear command, control, and communications	Identify policy, strategy, requirements, and capabilities complementary to both nuclear and conventional command, control, and communications Leverage demonstration and assessment events to validate opportunities for integration

²⁵Secretary of Defense, *Joint All-Domain Command and Control Strategy* (May 2021).

Mission partner information sharing	Modernize information-sharing with allies Create a robust, resilient environment for communication with allies	Develop and deliver an information sharing and data exchange capability that includes data security mechanisms Engage with mission partners to update information sharing agreements to address data interoperability shortfalls Develop a strategy for enabling global collaboration across combatant commands and their mission partner environments
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Source: GAO analysis of Department of Defense documentation. | GAO-23-105495

- The JADC2 Implementation Plan provides the framework and methodology to achieve the JADC2 strategy and goals. Specifically, it identifies tasks within the five JADC2 lines of effort.²⁶ Each task is assigned to an office of primary responsibility, with a defined deliverable for the current fiscal year and, if applicable, a schedule for any other future deliverables. For example, the plan directs the Office of the Under Secretary of Defense for Research and Engineering to identify and implement broadly applicable machine-to-machine command and control standards for the technology enterprise line of effort. The plan tasked the office with delivering these standards no later than the second quarter of fiscal year 2022. Officials told us that they delivered the first iteration of these standards in February 2022 and will continue efforts on this task.
- The JADC2 Reference Architecture describes the operational and technical design necessary to achieve JADC2 capability development goals through 2030. The guidance should ensure that JADC2 capabilities are synchronized, integrated, and interoperable. This guidance provides a common approach for each military department to use as they connect their assets, data, and tools across domains to support missions. For example, it outlines standards and specifications for how data must be exchanged and provides the core-enabling digital infrastructure required to create and sustain JADC2 capabilities. In April 2022, the Joint Requirements Oversight Council issued a memorandum directing military departments to conform to the reference architecture as they develop their JADC2 capabilities.²⁷
- The JADC2 Posture Review is an annual assessment conducted by the CFT that provides a joint review of capability gaps between the desired outcomes in the JADC2 Strategy and the existing Joint Force

²⁶Deputy Secretary of Defense, *Joint All-Domain Command and Control Strategy Implementation Plan* (Mar. 2022).

²⁷Joint Requirements Oversight Council, *Joint All-Domain Command and Control Recommendations*, JROCM 023-22 (Apr. 27, 2022).

command and control capabilities. Beginning in 2023, CFT officials stated that the Posture Review will also assess progress toward achieving the goals laid out in the Implementation Plan and prioritize the remaining work, which will then inform future updates to the Implementation Plan. The initial Posture Review was approved in July 2021 and is to be updated annually. The CFT completed the Fiscal Year 2022 Posture Review in late 2022. As of August 2022, according to CFT documents, almost all critical tasks identified in the Implementation Plan are on schedule.

DOD Is Identifying JADC2 Capabilities and Challenges

While DOD has made progress in JADC2 planning, it has not yet identified which existing systems will contribute to JADC2 goals or what future capabilities need to be developed. In addition, DOD is in the process of identifying challenges to implementing JADC2. Initially, CFT officials identified several challenges related to achieving JADC2 goals and described the steps that DOD is taking to address them.

Aligning JADC2 Efforts

The military departments started prioritizing which JADC2-related capabilities to develop based on their own needs, which do not necessarily align with DOD's highest priorities. When military departments started their JADC2 efforts, the CFT had not yet established the JADC2 Strategy and each military department was carrying out its efforts independently. For example, the Air Force set initial requirements for ABMS in 2018, which is 3 years before the JADC2 Strategy was approved. The Implementation Plan acknowledges that DOD was slow to prioritize and incentivize joint capability needs.²⁸ Further, the plan states that current development efforts do not adhere to interoperability and common data standards, emphasizing the importance of synchronizing future JADC2 efforts. Each military department often produces its own solutions for command and control and other military departments may not be aware of ongoing efforts. According to the CFT Chair, DOD recently identified the need to address capability gaps in priority mission areas, and the CFT is working to align those efforts across the department.

Defining the Scope of JADC2

DOD has not yet identified which weapon systems, including current systems or those that are in development, will contribute to meeting the overall goals for JADC2. However, according to the CFT Chair, over the next year DOD will assess joint capability gaps, identify and prioritize requirements, and recommend where to allocate resources to accomplish near-, mid-, and long-term JADC2 goals. This effort—called the JADC2

²⁸Deputy Secretary of Defense, *Joint All-Domain Command and Control Strategy Implementation Plan* (Mar. 2022).

Campaign Plan—will update the 2019 Campaign Plan, and should inform which existing capabilities contribute to JADC2 and what additional development efforts are needed to close joint capability gaps and meet JADC2 goals. CFT officials noted that the information will be used to prioritize work within the JADC2 Implementation Plan and further develop plans and milestones to meet JADC2 goals. According to officials, the CFT presented the JADC2 Campaign Plan approach to the Vice Chairman of the Joint Chiefs of Staff in October 2022 and plans to provide a completed Campaign Plan to the Deputy Secretary of Defense for endorsement by spring 2023.

In support of the JADC2 Campaign Plan, the CFT Budget Operational Planning Team compiled an initial inventory of current JADC2 efforts to track investments across DOD. This inventory includes any system in which at least half of its planned funding is related to command and control, including radios, datalinks, sensors, and satellite communications, among other systems. Working group officials stated that this inventory may not capture all efforts that contribute to JADC2 goals. CFT officials noted that military departments had different interpretations of the JADC2 definition when listing inventory, and the CFT will continue to revise the inventory list.

Assessing Cost and Schedule to Deliver JADC2 Capabilities

DOD has not developed an overall assessment of the cost and schedule requirements to deliver JADC2 capabilities. Military departments have developed cost estimates and schedules for some individual JADC2 efforts, but they do not have complete cost and schedule information for all of their efforts. For example, the Air Force has identified initial cost and schedule requirements for two current ABMS efforts. CFT officials noted that they are working to develop an overall JADC2 Investment Strategy, which will help the CFT make resource recommendations and determine the cost and schedule of JADC2 efforts. To inform this investment strategy, officials from the CFT Budget Operational Planning Team stated they plan to complete the annual inventory of JADC2 efforts, which will support investment tracking and resource recommendations, and can help DOD assess the sufficiency of funding. The Budget Operational Planning Team plans to identify funding for efforts that support JADC2, as well as JADC2-specific efforts. The military departments and defense agencies submitted their budget requests for JADC2 investments in July 2022, which informed the program and budget review process for fiscal years 2024-2028.

Addressing Limitations of Authority and Personnel Resources

Officials from offices across DOD have expressed concerns that the CFT does not have sufficient authority to direct the military departments to acquire, develop, or prioritize JADC2 capabilities. Specifically, officials

from four JADC2 working groups noted that the CFT's level of authority limits its role because military departments are not required to implement CFT recommendations to address JADC2 issues or tasks. Officials stated that it could be a challenge for the CFT to maintain momentum for JADC2 efforts going forward without this authority.

In contrast, the CFT Chair stated that the position has sufficient authority to ensure that the military departments complete the tasks necessary to achieve JADC2 goals. For example, if the CFT and military departments cannot reach consensus on pursuing JADC2 capabilities, the CFT Chair stated the Chair has the ability to raise issues for resolution, direction, and budgetary decisions to authoritative bodies, including the Deputy's Management Action Group. Further, it is the CFT's responsibility to facilitate coordination and resources of military-department-specific development efforts, as the Implementation Plan states that JADC2 cannot be constrained to a singular action or program of record.²⁹

The CFT Chair stated, however, that the CFT does not have sufficient personnel resources to carry out its responsibilities in a timely manner. According to CFT officials, the Air Force conducted a personnel assessment from February to July 2022 to review Joint Staff J6 missions, organization, and personnel resource requirements to assist with addressing personnel challenges in supporting the JADC2 effort. The assessment recommended 10 additional personnel to support JADC2. The Joint Staff validated this recommendation and proposed it for inclusion in the 2024 budget request.

DOD Is Required to Inform Congress on Progress toward JADC2 Goals

In addition to the challenges identified by the JADC2 CFT, members of Congress have raised questions about DOD's progress in implementing JADC2, including what capabilities will be delivered, how much they will cost, and when they will be delivered. In a House report accompanying H.R. 7900, Congress included a provision for DOD to report by December 30, 2022 on:

- an inventory of JADC2-related development efforts, with a description of each one's respective performance objectives, costs, and schedules;
- a description of JADC2 performance goals and how the development efforts will contribute to achieving those goals, including performance metrics; and

²⁹Deputy Secretary of Defense, *Joint All-Domain Command and Control Implementation Plan* (Mar. 2022).

-
- a list of potential JADC2 capability gaps and a plan for how DOD will ensure those capabilities are addressed and funded.³⁰

According to DOD officials, the CFT will provide an update to Congress between January and March 2023 that addresses progress to date with the JADC2 Campaign Plan and efforts to develop an Investment Strategy based on near-, mid-, long-term JADC2 goals. The House report accompanying H.R. 7900 also included a provision for us to conduct a review of DOD's JADC2 efforts, including an evaluation of DOD's process for monitoring JADC2 costs, schedule, and performance, and DOD's plan to address challenges in developing and implementing JADC2 efforts. We plan to review DOD's JADC2 report when it becomes available and continue to monitor DOD's progress of JADC2 efforts in our forthcoming review.

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 and the Secretary of Defense. In addition, the report is available at no charge on the GAO website at <https://www.gao.gov>.

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or MakM@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 I.



Marie A. Mak
Director, Contracting and National Security Acquisitions

³⁰H.R. Rep. No. 117-397, pt.1, at 255 (2022).

List of Addressees

Chair
Ranking Member
Committee on Armed Services
United States Senate

Chair
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Mike Rogers
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

Chair
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

The Honorable Donald Norcross
House of Representatives

Appendix I: GAO Contact and Staff Acknowledgments

GAO Contact

Marie A. Mak, (202) 512-4841 or MakM@gao.gov

Staff Acknowledgments

In addition to the contact above, the following staff members made key contributions to this report: Justin Jaynes, Assistant Director; Jessica Karnis, Analyst-in-Charge; Leigh Ann Haydon; and Ethan Kennedy. Other contributions were made by Pete Anderson, Jeff Cirillo, Tonya Humiston, Miranda Riemer, and Don Springman.

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