United States Government Accountability Office

Report to Congressional Committees

JUNE 2023

Weapon Systems Annual Assessment

Programs Are Not Consistently Implementing Practices That Can Help Accelerate Acquisitions

AIR FORCE AND SPACE FORCE | NAVY AND MARINE CORPS | JOINT DOD | ARMY

GAO-23-106059

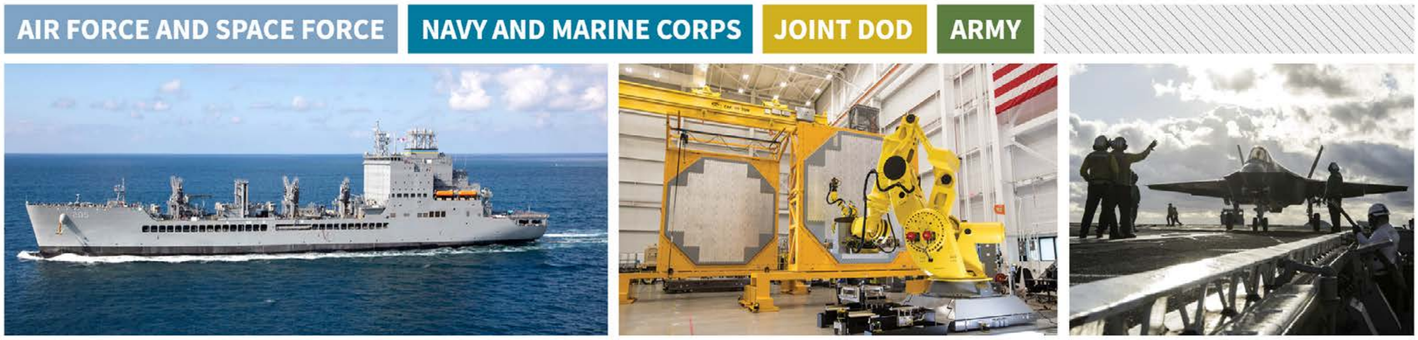
Highlights

Highlights of GAO-23-106059

A Report to Congressional Committees June 2023

Weapon Systems Annual Assessment

Programs Are Not Consistently Implementing Practices That Can Help Accelerate Acquisitions



T-AO 205 John Lewis Class Fleet Replenishment Oiler, Air and Missile Defense Radar (AMDR), and F-35 Lightning II (F-35)

Source: General Dynamics NASSCO, Raytheon Company, and U.S. Navy photo courtesy Lockheed Martin/Dane Wiedmann, respectively. | GAO-23-106059

Why GAO Did This Study

In 2020, in an effort to deliver more timely and effective solutions to the warfighter, DOD revamped its department-wide acquisition policies. These policy changes responded to statutory provisions and long-standing concerns from some members of Congress that the defense acquisition process was overly bureaucratic and too slow.

As part of these changes, DOD established the Adaptive Acquisition Framework, which has a variety of pathways for acquisition programs. This framework includes the major capability acquisition pathway to acquire and modernize DOD programs that provide enduring capability, including major defense acquisition programs, and the middle tier of acquisition pathway for rapid prototyping and rapid fielding.

This report, GAO's 21st annual assessment, responds to a statutory provision for GAO to review selected DOD acquisition programs and efforts.

What GAO Found

The Department of Defense (DOD) continues to face challenges quickly developing innovative new weapons. These challenges persist even with recent reforms to its acquisition process intended to help deliver systems to the warfighter in a timelier manner.

Major defense acquisition programs. From DOD's 2020 submission of reports on their major defense acquisition programs to 2022, the number of these programs declined. However, the portfolio's total cost increased, and the average planned cycle time to deliver operational capabilities shows new delays. DOD did not produce these reports in 2021 due to the lack of future year funding data in the fiscal year 2022 budget request.

Major Defense Acquisition Programs Are Taking Longer to Deliver Capabilities

Source: GAO analysis of Department of Defense data. | GAO-23-106059

Over half of the 26 major defense acquisition programs GAO assessed that had yet to deliver operational capability reported new delays. Driving factors included supplier disruptions, software development delays, and quality control deficiencies. Additionally, these programs continue to make investment decisions without sufficient knowledge, which can increase the risk of delays. Net costs for the 32 major defense acquisition programs that GAO assessed both this year and last year increased by $37 billion. Rising modernization costs, production inefficiencies, and supply chain challenges drove the majority of costs.

Middle tier of acquisition (MTA) programs. Two MTA efforts transitioned to become major defense acquisition programs since GAO's last assessment and could begin delivering capabilities soon. However, other MTA efforts' schedule delays and lack of progress in maturing technologies raise questions about MTA programs' overall ability to deliver capabilities more quickly.

This report assesses the characteristics and performance of 101 of DOD's costliest weapon programs (75 major defense acquisition programs, 19 MTA programs, and 7 future major weapon acquisitions); and selected programs' implementation of leading acquisition practices and principles, modern software development approaches, and cybersecurity practices.

Additionally, the report describes recent legislative, organizational, and policy changes pertaining to modular open systems approaches; and the extent to which selected programs reported implementing a modular open systems approach.

GAO identified programs for review based on cost and acquisition status; reviewed relevant legislation and policy; collected program documents; used a questionnaire to obtain data from program offices; and interviewed DOD officials.

What GAO Recommends

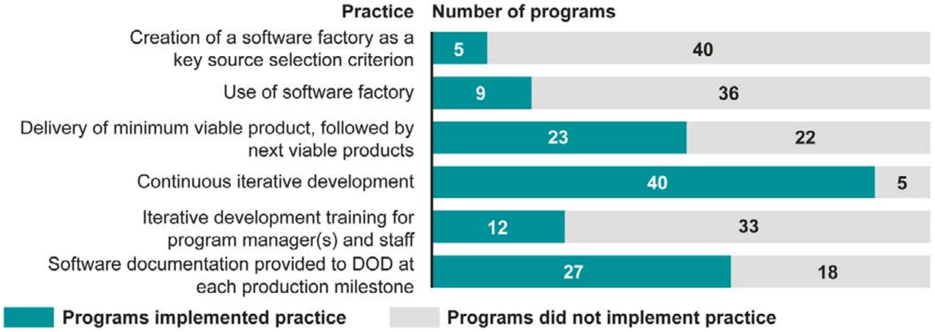
GAO recommends that DOD ensure that any new guidance and updates to relevant policies include details on when programs using a modular open systems approach should complete verification testing and how they should document planning. DOD concurred with the recommendation.

View GAO-23-106059. For more information, contact Shelby S. Oakley at (202) 512-4841 or oakleys@gao.gov.

Of the 16 rapid prototyping efforts included in both GAO's current and prior assessments, six have delayed planned operational demonstrations by at least 12 months. The later that demonstrations occur during the MTA effort, the less time programs will have to address emerging issues. This delay heightens the chance that programs will transition with more technical risk.

Software development approaches and cybersecurity practices. Programs reporting use of modern software development approaches increased over the past year from 43 of 59 programs (73 percent) to 45 of 58 programs (78 percent). But, programs reported limited implementation of the Defense Science Board's recommended practices to accelerate software development.

Programs Report Limited Implementation of the Defense Science Board's Recommended Practices to Accelerate Software Development (out of 45 programs)



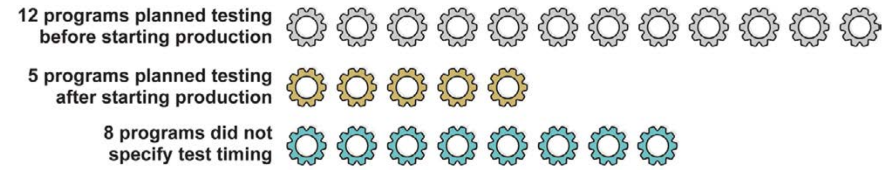
Source: GAO analysis of Department of Defense data. | GAO-23-106059

GAO also observed mixed progress in cybersecurity planning. All programs had or planned to have a cybersecurity strategy. But, programs did not consistently report scheduling cybersecurity test events in time to inform key milestones. Without timely cybersecurity testing, programs are at greater risk of delays if issues are discovered later in development.

Key product development principles. GAO found that some—but not all—MTA and future programs used certain product development practices aligned with key product development principles employed by leading companies to deliver innovative capabilities quickly. Examples reported by programs included practices such as using 3D modeling and printing to help design and test products, and holding regular user testing events to obtain feedback. GAO has ongoing work to define associated metrics to help inform future assessments.

Modular open systems approach. Most programs GAO reviewed reported using a modular open systems approach. But they did not consistently report planning to verify successful implementation of the approach before key points in the acquisition process, such as before beginning production. A modular open systems approach enables weapon programs to better respond to changing threats, in part, by allowing them to more easily add, remove, and replace components over the system's life cycle.

More than Half of Major Defense Acquisition Programs Using a Modular Open Systems Approach Do Not Report Plans to Verify Conformance before Production



Source: GAO analysis of programs' questionnaire responses; GAO (icons). | GAO-23-106059

Neither DOD systems engineering policy nor modular open systems approach guidance specifically addresses when programs should complete or document verification testing. Ensuring that any new guidance and updates to relevant policies address when programs should conduct verification testing and document planning could help DOD ensure its systems can incorporate innovative technologies over time to remain responsive to emerging threats.

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Abbreviations

AAF	Adaptive Acquisition Framework
ACAT	Acquisition Category
DAES	Defense Acquisition Executive Summary
DAVE	Defense Acquisition Visibility Environment
DOD	Department of Defense
MDAP	major defense acquisition program
MOSA	modular open systems approach
MTA	middle tier of acquisition
NDAA	National Defense Authorization Act
OSD	Office of the Secretary of Defense
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment
USD(R&E)	Under Secretary of Defense for Research and Engineering

U.S. GOVERNMENT ACCOUNTABILITY OFFICE

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Comptroller General
of the United States

June 8, 2023

Congressional Committees

I am pleased to present our 21st annual assessment of the Department of Defense's (DOD) acquisition of weapon systems. This year's report offers observations on the performance of 101 of the department's most expensive weapon system acquisition programs, an area on GAO's High-Risk List.[1] These programs include 75 major defense acquisition programs (MDAP), 19 programs using the middle tier of acquisition (MTA) pathway, and seven future major weapon acquisitions.

We highlight key aspects of weapon acquisition, including cost and schedule performance, progress in attaining product knowledge, and implementation of recommended software development approaches and cybersecurity practices. This year, for the first time, we report preliminary observations of whether programs are incorporating aspects of key product development principles used by leading companies. We also examine DOD's implementation of a modular open systems approach (MOSA).

For the last several years, we have reported on DOD's efforts to increase the speed of delivering capability to the warfighter to meet current and emerging threats, a need emphasized in the unclassified 2018 National Defense Strategy. The unclassified 2022 National Defense Strategy further underscores the importance of delivering capability when needed, calling for DOD to act urgently to sustain and strengthen U.S. deterrence.

We see a few bright spots this year in DOD's efforts to use new acquisition pathways to field systems to the warfighter in a timely manner. Namely, over the past year, two programs—the Army's Mobile Protected Firepower program and the Air Force's F-15EX program—transitioned from the MTA pathway (used for rapid prototyping and rapid fielding) to the major capability acquisition pathway at production start and could be well-positioned to start producing systems in the near future. Both programs began with largely mature technologies and used their time on the MTA pathway to obtain the knowledge they needed to make informed decisions about starting production. We will continue to monitor the

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[1] GAO, *High Risk Series: Efforts Made to Achieve Progress Need to Be Maintained and Expanded to Fully Address All Areas,* GAO-23-106203 (Washington, D.C.: Apr. 20, 2023).

progress of these programs to better understand how starting on the MTA pathway affects their speed of delivering capabilities at scale.

We continue to see far more programs, however, experiencing delays in delivering capabilities. More than half of the MDAPs that we reviewed that have yet to deliver capabilities reported schedule slips over the past year. For many of these programs, this is the second or third year in a row in which they reported delays. These delays frequently result from technical and engineering challenges that are identified late in the program. We have previously found that programs attaining the knowledge needed to make informed investment decisions earlier in the program experienced reduced cost and schedule growth.

Such delays indicate that DOD must focus not only on getting programs started quickly, but also to make sure that programs are consistently applying the right approaches to set them up for success throughout the acquisition life cycle. Our recent work on the product development approaches of leading companies shows that they rely on a set of key principles that permeate each stage of the product development process to deliver innovative products to market quickly and within expected costs.[2] These principles include attaining and continuing to confirm sound business cases, applying iterative design approaches, off-ramping capabilities when needed to prioritize schedule, and incorporating feedback from users of initial capabilities.

This year, we asked MTA programs and future major weapon acquisitions about their use of practices aligned with some of these principles. Preliminary observations indicate that some programs are using practices that align with aspects of these principles, such as soliciting early user feedback and using modern design tools to enable multiple design iterations.

Programs implementing selected practices is an initial positive indicator. However, DOD will only reap the benefits if these practices are part of a disciplined approach to product development that includes all four of the key principles we identified. In our March 2022 work on leading principles, we identified that most acquisition pathways, including the pathway used by MDAPs, had yet to fully implement these principles. We recommended that DOD fully implement these principles in its acquisition policies

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[2] GAO, *Leading Practices: Agency Acquisition Policies Could Better Implement Key Product Development Principles,* GAO-22-104513 (Washington, D.C.: Mar. 10, 2022).

throughout development, an approach to which DOD agreed. We have ongoing work to identify metrics associated with these principles, and we expect to use this work to refine our approach to assessing how well programs are implementing them in future annual assessments.

Incorporating new approaches to early stage or future programs, while necessary, will not be sufficient to improve DOD’s ability to deliver innovative capabilities when needed. DOD must address challenges in programs currently under development that we assessed if it is to achieve its goal. Nevertheless, we continue to observe concerning trends in areas associated with ensuring existing acquisition programs can deliver capability in a timely manner, such as knowledge-based acquisition, and software development.

This year, we also looked at programs’ implementation of a MOSA. MOSA can facilitate innovation by enabling acquisition programs to more easily add, remove, and replace components over the life cycle of the system to meet emerging threats. We found that, while most programs told us that they were using a MOSA, they were not consistently implementing certain recommended practices to help ensure their MOSA works as intended.

The 2022 National Security Strategy describes the U.S. as being in the early years of a decisive decade, in which the U.S. must ensure it is well prepared to deter or counter adversaries. Given their planned fielding time frames, the weapon systems in this report form an essential part of this deterrence. DOD’s introduction of the Adaptive Acquisition Framework in 2020, including the creation of new acquisition pathways, was an important first step to improving the speed of capability delivery. Our findings in the years since, however, indicate that DOD must persist in identifying the underlying practices that can help the pathways work as intended and ensure that these practices are aligned with DOD’s goal of going faster to meet current and emerging national security needs.

Gene L. Dodaro

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Comptroller General of the United States

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June 8, 2023

Congressional Committees

In response to title 10, section 3072 of the United States Code, this report provides insight into 101 of the Department of Defense's (DOD) most costly weapon programs.[3] Specifically, this report covers the following sets of programs:

- 75 major defense acquisition programs (MDAP),
- 19 programs currently using the middle tier of acquisition (MTA) pathway, and
- seven future major weapon acquisitions.[4]

This report assesses (1) the characteristics of DOD's costliest weapon programs and how these programs have performed according to selected cost and schedule measures; (2) the extent to which MDAPs have implemented knowledge-based acquisition practices; (3) the extent to which MTA programs and future major weapon acquisitions are using practices aligned with selected leading principles for product development; (4) the extent to which programs have implemented modern software development approaches and recommended cybersecurity practices; and (5) recent legislative, organizational, and policy changes pertaining to modular open system approaches (MOSA)

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[3] Title 10, section 3072 of the U.S. Code includes a provision for us to submit to the congressional defense committees an annual assessment of selected DOD acquisition programs and efforts by March 30 of each year from 2020 through 2026. Our assessment of the performance of DOD's IT programs is included in a separate report, which we also prepared in response to title 10, section 3072 of the U.S. Code. We plan to issue that report later this year.

[4] Throughout this report, we refer to programs currently using the MTA pathway as "MTA programs," although some of these programs may also currently use or plan to subsequently use one or more other pathways before fielding an eventual capability. For the purposes of this report, we use the word "effort" to refer specifically to the activities undertaken using a single Adaptive Acquisition Framework (AAF) pathway or any of the paths provided by an AAF pathway (for example, the rapid prototyping path of the MTA pathway). Our use of the word "effort" excludes other paths or pathways that a program may be using simultaneously, or may plan to use in the future, to field an eventual capability. Future major weapon acquisitions are those identified by DOD as pre-MDAPs as of April 2022, and other programs that had yet to be formally initiated on an AAF pathway, with costs expected to exceed thresholds for designation as a MDAP under title 10, section 4201(a) of the U.S. Code.

and the extent to which selected programs report they are implementing a MOSA.

To conduct our work, we analyzed cost and schedule data from a variety of sources, including DOD's December 2021 Selected Acquisition Reports, Defense Acquisition Executive Summaries (DAES), MTA program identification data, and cost data provided by program offices. We determined that the Selected Acquisition reports, the DAES data, MTA program identification data, and the MTA program cost data were sufficiently reliable for the purposes of this report.

We also provided a questionnaire to program offices to obtain information on

- the extent to which MDAPs were planning for or following knowledge-based acquisition practices for technology maturity, design stability, and production readiness;
- the extent to which MTA programs and future major weapon acquisitions were using practices aligned with selected leading principles for product development;
- programs' cost and schedule performance;
- programs' approach to software development and cybersecurity practices; and
- the extent to which programs are implementing a MOSA and any associated challenges.

To examine recent legislative, organizational, and policy changes related to MOSA, we identified and summarized relevant provisions signed into law from fiscal year 2017 to fiscal year 2022. We also reviewed DOD policies and other documents and conducted interviews with officials from the Office of the Secretary of Defense (OSD) to identify policy changes DOD implemented or is in the process of implementing. For all objectives, we also conducted interviews with program officials.

In addition, this report presents individual knowledge-based assessments of 65 programs that we selected based on their phase in the acquisition process (see appendix I).

Appendix II provides additional information on our objectives, scope, and methodology.

We conducted this performance audit from May 2022 to June 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

Defense Acquisition Principles and Authorities

DOD generally acquires its weapon systems through a management process known as the Defense Acquisition System, governed by the overarching principles and procedures described in DOD Directive 5000.01 and DOD Instruction 5000.02.[5] According to DOD Directive 5000.01, the objective of the defense acquisition system is to support the National Defense Strategy through the development of a more lethal force based on U.S. technological innovation and a culture of performance that yields a decisive and sustained U.S. military advantage. Further, delivering performance “at the speed of relevance” is one of the overarching policies governing the defense acquisition system. DOD Directive 5000.01 states that the defense acquisition system will be designed to acquire products and services that satisfy user needs with measurable and timely improvements to mission capability.

To deliver effective, suitable, survivable, sustainable, and affordable solutions to the warfighter in a timely manner, DOD established the Adaptive Acquisition Framework (AAF) in January 2020. The AAF emphasizes several principles that include simplifying acquisition policy, tailoring acquisition approaches, and conducting data-driven analysis. Oversight of the department’s costliest weapon systems is shared between several entities within OSD and the military departments. Appendix III provides more detail on oversight responsibilities for DOD weapon systems.

DOD Instruction 5000.02 establishes the groundwork for the operation of the AAF. The AAF is comprised of six acquisition pathways, each with

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[5] Department of Defense, *The Defense Acquisition System,* DOD Directive 5000.01 (Sept. 9, 2020) (incorporating change 1, July 28, 2022); and *Operation of the Adaptive Acquisition Framework*, DOD Instruction 5000.02 (Jan. 23, 2020) (incorporating change 1, June 8, 2022).

processes, reviews, documentation requirements, and metrics that program managers can match to the characteristics and risk profile of the capability being acquired. Programs, with approval from the decision authority or the milestone decision authority, may leverage a combination of acquisition pathways to provide value not otherwise available through use of a single pathway.[6] DOD issued policy documents to address each of these six acquisition pathways as well as additional functional policy documents in areas such as engineering and test and evaluation.[7] Figure 1 shows the AAF pathways.

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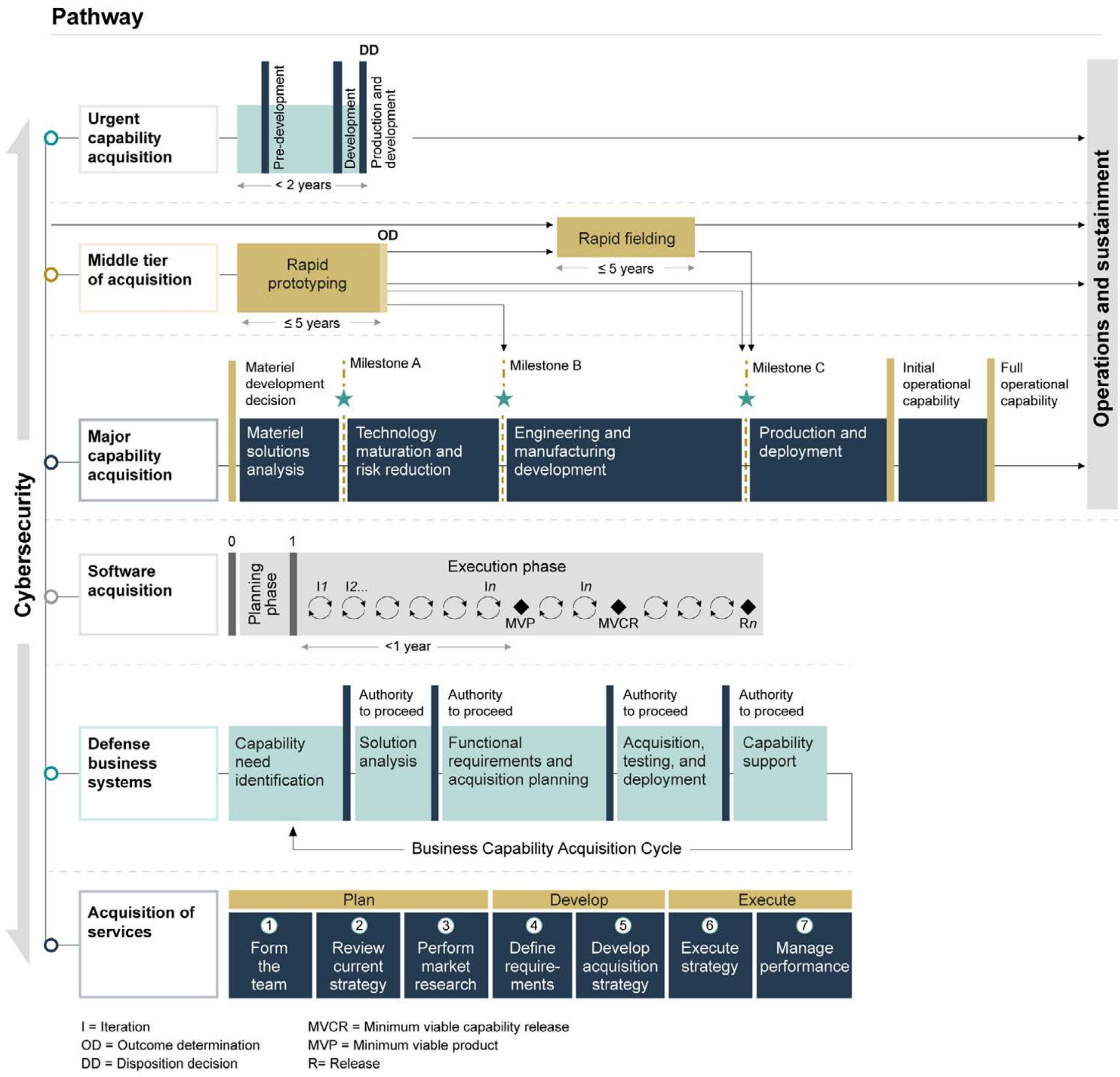
[6] According to DOD Instruction 5000.02, the milestone decision authority is the program decision authority and specifies the decision points and procedures for assigned programs. Milestone decision authorities for MDAPs and major systems will approve, as appropriate, the acquisition strategy at all major decision points.

[7] Additional functional policy documents include Department of Defense, *Engineering of Defense Systems,* DOD Instruction 5000.88 (Nov. 18, 2020)*; Test and Evaluation,* DOD Instruction 5000.89 (Nov. 19, 2020); and *Cost Analysis Guidance and Procedures,* DOD Instruction 5000.73 (Mar. 13, 2020).

Figure 1: Adaptive Acquisition Framework Pathways



Source: GAO analysis of Department of Defense (DOD) data. I GAO-23-106059

In this report, we focus on selected programs using the (1) major capability acquisition pathway, used by MDAPs, and (2) MTA pathway, used for rapid prototyping and rapid fielding efforts. We also make broad observations regarding the software acquisition pathway.

MDAPs

Under DOD Instruction 5000.02, DOD's major capability acquisition pathway is designed to support certain complex acquisitions such as MDAPs.[8] DOD Instruction 5000.85, released in August 2020 and updated in November 2021, established the policy and prescribed procedures that guide acquisition programs using the major capability acquisition pathway. Within this pathway, programs generally proceed through a number of phases, the following three of which are most relevant to this report:

- technology maturation and risk reduction,
- engineering and manufacturing development, and
- production and deployment.

In this report, we refer to these three phases as technology development, system development, and production. Programs typically complete a series of milestone reviews and other key decision points that authorize entry into a new acquisition phase.

Our body of work on MDAPs shows that attaining high levels of knowledge before programs make significant commitments during

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[8] MDAPs generally include those programs that are not a highly sensitive classified program and that are either (1) designated by the Secretary of Defense as a MDAP; or that are (2) estimated to require an eventual total expenditure for research, development, test, and evaluation, including all planned increments or spirals, of more than $525 million in fiscal year 2020 constant dollars or, for procurement, including all planned increments or spirals, of more than $3.065 billion in fiscal year 2020 constant dollars. See 10 U.S.C. § 4201(a); DOD Instruction 5000.85, *Major Capability Acquisition* (Aug. 6, 2020) (incorporating change 1, Nov. 4, 2021) (reflecting statutory MDAP cost thresholds in fiscal year 2020 constant dollars). Certain programs that meet these thresholds, including programs using the MTA pathway, are not considered MDAPs. See 10 U.S.C. § 4201(b).

product development drives positive acquisition outcomes.[9] We have found that, to reduce risk, there are three key points at which programs should demonstrate critical levels of knowledge before proceeding to the next major investment decision: development start (milestone B), system-level critical design review, and production start (milestone C). Figure 2 aligns the acquisition milestones associated with the major capability acquisition pathway with these three key decision points.

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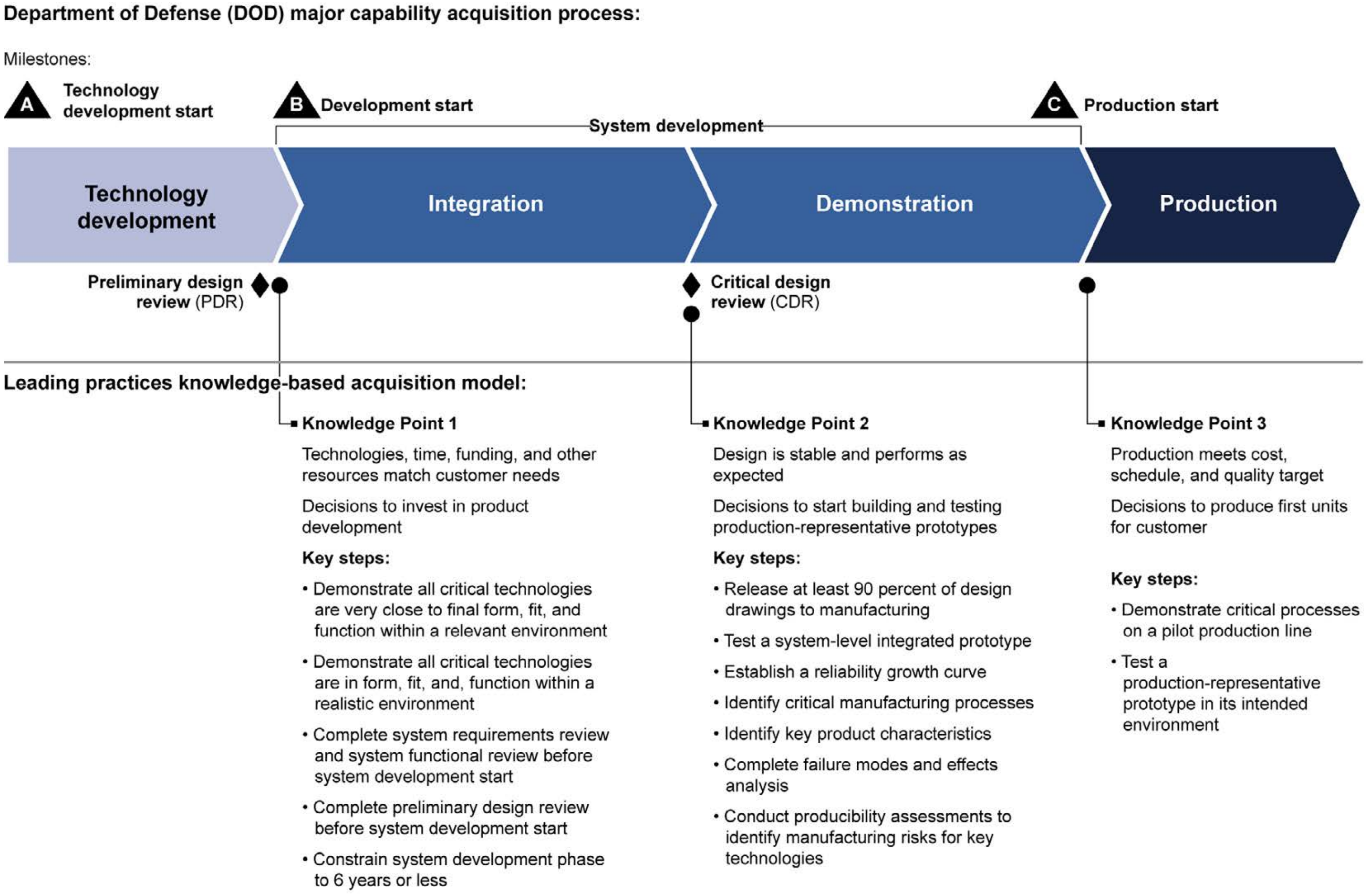
[9] GAO*, Best Practices: DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed*, GAO-10-439 (Washington, D.C.: Apr. 22, 2010); *Best Practices: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding*, GAO-09-322 (Washington, D.C.: May 13, 2009); *Defense Acquisitions: A Knowledge-Based Funding Approach Could Improve Major Weapon System Program Outcomes*, GAO-08-619 (Washington, D.C.: July 2, 2008); *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, GAO-02-701 (Washington, D.C.: July 15, 2002); *Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes*, GAO-01-288 (Washington, D.C.: Mar. 8, 2001); and *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, D.C.: July 30, 1999).

Figure 2: DOD Major Capability Acquisition Pathway and GAO-Identified Knowledge Points



Knowledge Point 1

Technologies, time, funding, and other resources match customer needs

Decisions to invest in product development

Key steps:

- Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment
- Demonstrate all critical technologies are in form, fit, and, function within a realistic environment
- Complete system requirements review and system functional review before system development start
- Complete preliminary design review before system development start
- Constrain system development phase to 6 years or less

Knowledge Point 2

Design is stable and performs as expected

Decisions to start building and testing production-representative prototypes

Key steps:

- Release at least 90 percent of design drawings to manufacturing
- Test a system-level integrated prototype
- Establish a reliability growth curve
- Identify critical manufacturing processes
- Identify key product characteristics
- Complete failure modes and effects analysis
- Conduct producibility assessments to identify manufacturing risks for key technologies

Knowledge Point 3

Production meets cost, schedule, and quality target

Decisions to produce first units for customer

Key steps:

- Demonstrate critical processes on a pilot production line
- Test a production-representative prototype in its intended environment

Source: GAO analysis of DOD-provided data, DOD Instruction 5000.85, and GAO's body of knowledge-based acquisition practices. | GAO-23-106059

Program knowledge builds over time. Our prior work on knowledge-based approaches shows that a knowledge deficit early in a program can cascade through design and production. This leaves decision makers with less knowledge to support decisions about when and how to move into subsequent acquisition phases that require more budgetary resources.[10] Under a knowledge-based approach, demonstrating technology maturity is a prerequisite for moving forward into system development, during

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[10] GAO, *Best Practices: Using A Knowledge-Based Approach to Improve Weapon Acquisition*, GAO-04-386SP (Washington, D.C.: Jan. 2004). In addition, a list of Related GAO Products is included at the end of the report.

which time the focus should be on design and integration. Similarly, a stable and mature design is a prerequisite for moving into production, where the focus should be on efficient manufacturing. Appendix IV provides additional details about key practices at each of the knowledge points.

Overview of the MTA Pathway

The National Defense Authorization Act (NDAA) for Fiscal Year 2016 required DOD to establish guidance for an alternative acquisition process, now referred to as the middle tier of acquisition (MTA), for programs intended to be completed in a period of 2 to 5 years.[11] In December 2019, DOD issued Instruction 5000.80, Operation of the Middle Tier of Acquisition, which formally established the department's MTA policy, assigned responsibilities, and prescribed procedures for the management of the MTA rapid prototyping and rapid fielding paths. The policy states that the MTA pathway is intended to fill a gap in the Defense Acquisition System for capabilities with a level of maturity that allows them to be rapidly prototyped within an acquisition program or fielded within 5 years of MTA program start. The pathway may be used to accelerate capability maturation before transitioning to another acquisition pathway or to minimally develop a capability before rapid fielding. DOD Instruction 5000.80 also outlines the distinctions between the two MTA paths as described in statute:

- The **rapid prototyping** path provides for the use of innovative technologies to rapidly develop fieldable prototypes to demonstrate new capabilities and meet emerging military needs. The objective of a program using the rapid prototyping path is to field a prototype that meets defined requirements, which can be demonstrated in an operational environment and provide for residual operational capability within 5 years of the MTA program start date.[12] Virtual prototypes can meet this requirement if they result in a residual operational capability that can be fielded.
- The **rapid fielding** path provides for the use of proven technologies to field production quantities of new or upgraded systems with minimal development required. The objective of a program using the rapid

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[11] Pub. L. No. 114-92, § 804 (2015).

[12] DOD Instruction 5000.80 states that for rapid prototyping programs, residual operational capability is any military utility for an operational user that can be fielded.

fielding path is to begin production within 6 months and complete fielding within 5 years of the MTA program start date.[13]

DOD policy states that, for programs initiated on or after December 30, 2019, the MTA program start date is the date that an acquisition decision memorandum initiating the effort as an MTA program is signed by a decision authority. MTA programs designated before December 30, 2019, generally maintain their MTA program start date as the date that funds were first obligated.

Programs using the MTA pathway are generally exempt from the documentation requirements in the Chairman of the Joint Chiefs of Staff Instruction 5123.01, which outlines processes to implement DOD's traditional requirements process. DOD's MTA policy requires MTA programs that are major systems to submit documentation to the Office of the Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)), including an acquisition decision memorandum, approved requirements, a cost estimate, and an acquisition strategy.[14] Our prior work shows that this type of information helps to establish a program's business case and is important to help decision makers make well-informed decisions about MTA program initiation.[15]

For each MTA program using the rapid prototyping path, DOD Instruction 5000.80 states that DOD components will develop a process for transitioning successful prototypes to new or existing acquisition programs for production, fielding, and operations and sustainment. Programs have numerous options for transition, such as transitioning into the rapid fielding path or another acquisition pathway, including the major capability acquisition pathway. For each MTA program using the rapid

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[13] The statutory objectives for MTA efforts are outlined in section 804 of the National Defense Authorization Act for Fiscal Year 2016. See Pub. L. No. 114–92, § 804(b) (2015).

[14] Major systems generally refer to a combination of elements that will function together to produce the capabilities required to fulfill a mission need, including hardware, equipment, software, or any combination thereof, but excluding construction or other improvements to real property. A DOD system is considered a major system if (1) the milestone decision authority designates it as a major system; (2) it is estimated to require an eventual total expenditure for research, development, test, and evaluation of more than $200 million in fiscal year 2020 constant dollars, or for procurement of more than $920 million in fiscal year 2020 constant dollars. See 10 U.S.C. § 3041(a)-(c); DOD Instruction 5000.85 (reflecting statutory major system cost thresholds in fiscal year 2020 constant dollars).

[15] GAO, *DOD Acquisition Reform: Leadership Attention Needed to Effectively Implement Changes to Acquisition Oversight*, GAO-19-439 (Washington, D.C.: June 5, 2019).

fielding path, DOD components are required to develop a process for transitioning successful programs to operations and sustainment.

While the MTA pathway offers DOD a useful tool to develop and deliver innovative capabilities with speed, in February 2023, we identified factors that hinder effective implementation and oversight of these programs.[16] For example, an unclear data framework and reporting guidance limit the visibility of MTA program structures, scope, and technical data. As a result, the oversight role of USD(A&S) with regard to the MTA pathway is diminished. We also found that DOD components provided USD(A&S) with inaccurate data. These issues complicate DOD's efforts to conduct data-driven oversight of the MTA pathway.

We recommended that USD(A&S) improve its MTA data framework and reporting guidance to better capture program structure and changes in MTA program scope. DOD partially concurred, stating that it is reviewing the existing framework and reporting procedures to determine whether changes are needed. We also recommended that the Air Force, Army, Navy, and U.S. Special Operations Command identify and implement additional actions needed to improve the reliability of MTA program data submitted to USD(A&S). DOD concurred with these recommendations.

Key Principles for Product Development

In a March 2022 report, we found that leading companies prioritize developing and delivering new, innovative products to customers with speed.[17] To achieve this objective, leading companies rely on four principles that, when implemented during product development, position them to satisfy their customers' needs and correspondingly retain or grow their market share. Figure 3 outlines these four principles, which also comprise several related subprinciples.

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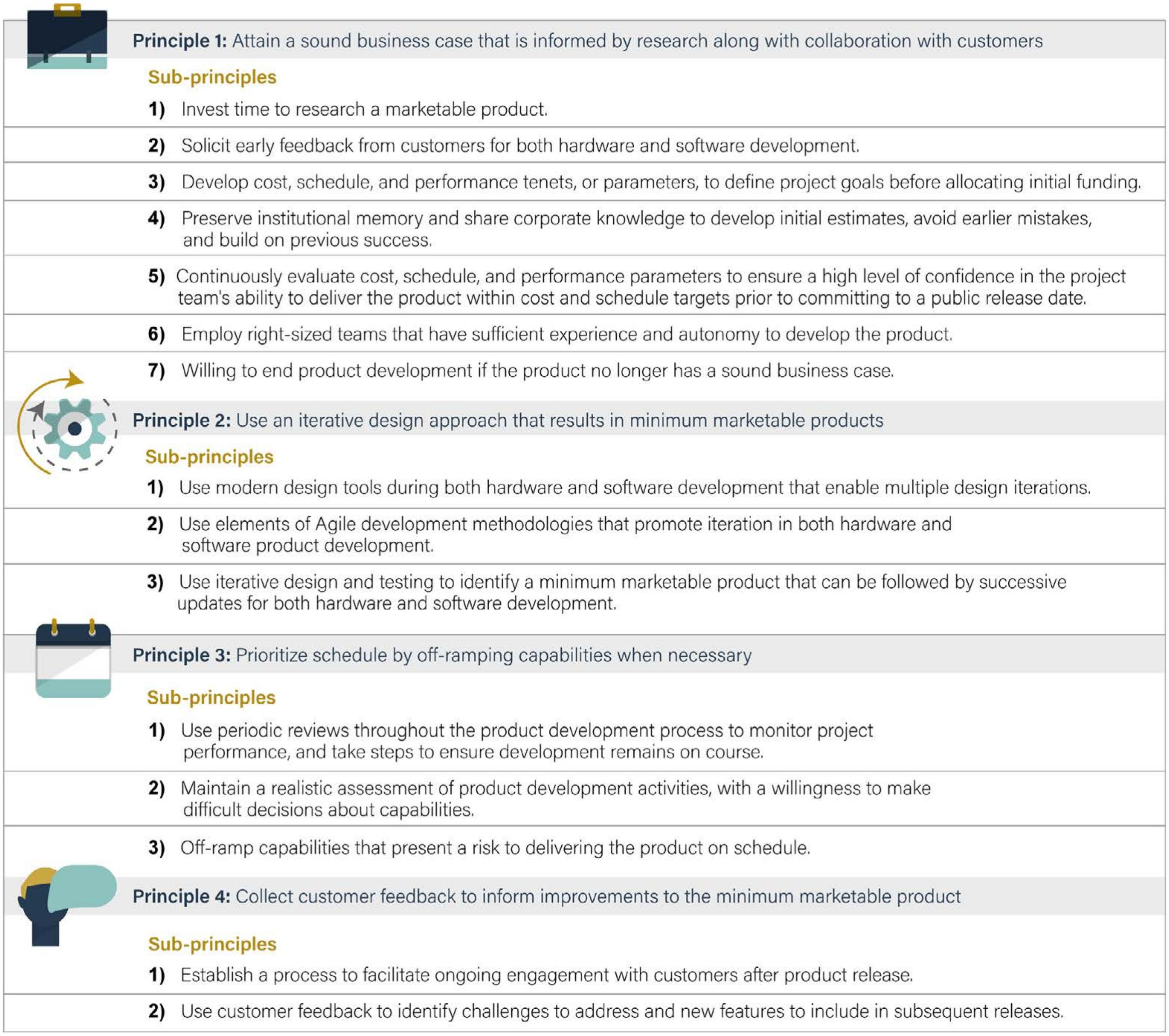
[16] GAO, *Middle-Tier Defense Acquisitions: Rapid Prototyping and Fielding Requires Changes to Oversight and Development Approaches,* GAO-23-105008 (Washington, D.C.: Feb. 7, 2023).

[17] GAO, *Leading Practices: Agency Acquisition Policies Could Better Implement Key Product Development Principles,* GAO-22-104513 (Washington, D.C.: Mar. 10, 2022).

Figure 3: Key Principles for Product Development Identified in GAO's Prior Work



Principle 1: Attain a sound business case that is informed by research along with collaboration with customers

Sub-principles

1) Invest time to research a marketable product.

2) Solicit early feedback from customers for both hardware and software development.

3) Develop cost, schedule, and performance tenets, or parameters, to define project goals before allocating initial funding.

4) Preserve institutional memory and share corporate knowledge to develop initial estimates, avoid earlier mistakes, and build on previous success.

5) Continuously evaluate cost, schedule, and performance parameters to ensure a high level of confidence in the project team's ability to deliver the product within cost and schedule targets prior to committing to a public release date.

6) Employ right-sized teams that have sufficient experience and autonomy to develop the product.

7) Willing to end product development if the product no longer has a sound business case.

Principle 2: Use an iterative design approach that results in minimum marketable products

Sub-principles

1) Use modern design tools during both hardware and software development that enable multiple design iterations.

2) Use elements of Agile development methodologies that promote iteration in both hardware and software product development.

3) Use iterative design and testing to identify a minimum marketable product that can be followed by successive updates for both hardware and software development.

Principle 3: Prioritize schedule by off-ramping capabilities when necessary

Sub-principles

1) Use periodic reviews throughout the product development process to monitor project performance, and take steps to ensure development remains on course.

2) Maintain a realistic assessment of product development activities, with a willingness to make difficult decisions about capabilities.

3) Off-ramp capabilities that present a risk to delivering the product on schedule.

Principle 4: Collect customer feedback to inform improvements to the minimum marketable product

Sub-principles

1) Establish a process to facilitate ongoing engagement with customers after product release.

2) Use customer feedback to identify challenges to address and new features to include in subsequent releases.

Source: GAO review of company information; GAO (icons). | GAO-23-106059

As part of our March 2022 work, we found that DOD's primary, department-wide acquisition policies partially implement the four key product development principles and their accompanying subprinciples. Our work found that the DOD policies include multiple examples of language that emphasizes attaining a sound business case, iterating on design, prioritizing schedule through a realistic assessment of product development activities, and collecting end-user feedback. However, in many cases, we found that this policy language was limited to certain product types—such as software—and did not generally apply across all acquisition programs.

We made four recommendations that DOD update its acquisition policies to fully implement the four principles throughout development. DOD concurred with the recommendations and noted that it will consider implementing the leading product development principles when it next updates its acquisition policies, which it estimates it will complete in June 2024.

Building on this work, in February 2023, we reported that component-level MTA policies from the Air Force, Army, Navy, and U.S. Special Operations Command partially implement some of the aforementioned principles.[18] We recommended that the Air Force, Army, Navy, and U.S. Special Operations Command update their policies to fully implement these four leading principles throughout development. DOD concurred with these recommendations.

We have additional work ongoing to define metrics associated with these leading principles, which we expect will help refine our evaluation of programs' use of the principles in future assessments.

Software Development and Acquisition

Modern Software Development Approaches

Software has become one of the most important components of DOD systems. DOD's ability to respond to evolving threats and compete with its identified strategic competitors, such as Russia and China, is increasingly determined by its ability to rapidly develop and deploy software-intensive systems, such as weapon and IT systems. Our past work found that DOD acquisition programs employ a wide range of software development approaches, including Agile frameworks and various incremental models. Table 1 provides descriptions of selected software development approaches employed by DOD acquisition programs.

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[18] GAO-23-105008.

Table 1: Selected Software Development Approaches Employed by Department of Defense Acquisition Programs

Software development approach	Description
Waterfall	This approach relies on strict phases, and each phase needs to be completed before going to the next phase. The phases include requirements definition, design, execution, testing, and release. Each phase relies on information from the previous phase. This approach is a linear sequential flow in which progress is seen as flowing steadily downwards (like a waterfall) through the phases of software implementation.
Incremental	This approach sets high-level requirements early in the effort, and functionality is delivered in stages. Multiple increments deliver parts of the overall required program capability. Several builds and deployments are typically necessary to satisfy approved requirements.
Agile	This approach breaks a product into components where, in each cycle or iteration, a working model of a component is delivered. The approach produces ongoing releases, each time adding small changes to the previous release. During each iteration, as the product is being built, it is also tested to ensure that at the end of the iteration the product is shippable. Agile emphasizes collaboration, as the customers, developers, and testers work together throughout the project.
DevOps	DevOps combines “development” and “operations,” emphasizing communication, collaboration, and continuous integration between both software developers and users.
DevSecOps	DevSecOps is an iterative software development approach that combines development, security, and operations as key elements in delivering useful capability to the user of the software.

Source: GAO-20-590G and GAO analysis of Department of Defense and software industry documentation. I GAO-23-106059

Our recent work found that DOD has made numerous efforts to modernize its software acquisition and development approaches over the past several years.[19] For example, we found that the department has taken steps to improve its software development approach such as:

- issuing a Software Modernization Strategy in February 2022;
- establishing the Software Modernization Senior Steering Group in December 2021; and
- finalizing guidance in October 2020 for the software acquisition pathway, which includes streamlined processes for programs using the pathway.[20]

However, we have also reported that DOD continues to face challenges in executing modern approaches and rapidly delivering software to users,

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[19] GAO, *Software Acquisition: Additional Actions Needed to Help DOD Implement Future Modernization Efforts*, GAO-23-105611 (Washington, D.C.: Apr. 5, 2023) and *DOD Software Acquisition: Status of and Challenges Related to Reform Efforts*, GAO-21-105298 (Washington, D.C.: Sept. 30, 2021).

[20] Department of Defense, *Operation of the Software Acquisition Pathway,* DOD Instruction 5000.87 (Oct. 2, 2020).

which senior DOD leaders have acknowledged.[21] According to DOD, software modernization will entail a cohesive department-wide effort that will take time. The department noted, in its 2022 Software Modernization Strategy, that this major digital transformation requires significant changes to processes, policies, workforce, technology, and the establishment of partnerships across the department—all of which will require sustained engagement over many years.[22]

Practices Recommended by the Defense Science Board

A February 2018 Defense Science Board study found that DOD can, and should, leverage today's commercial software development leading practices to its advantage, including for its weapon systems.[23] The Defense Science Board made seven recommendations to help DOD modernize its software development and acquisition approach. The recommendations included—but were not limited to—a number of software development practices that the Defense Science Board encouraged DOD to adopt, summarized in table 2.

Table 2: GAO Summary of Selected Practices Recommended by the Defense Science Board in February 2018

Recommended practice	Description
Creation of a software factory as a key source selection criterion	Development of a software factory as a factor in evaluating proposals for a potential government contractor.
Use of software factory[a]	Cloud-based computing used to assemble a set of software tools enabling developers, users, and management to work together on a daily tempo.
Delivery of minimum viable product[b]	Development technique in which a new product or website is developed with sufficient features to satisfy early adopters, followed by a successive next viable product.
Continuous iterative development	Way of developing software in smaller blocks that can be incrementally evaluated by a user community. This incremental approach allows updates and improvements to be rapidly incorporated into the software.

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[21] GAO, *Business Systems: DOD Needs to Improve Performance Reporting and Cybersecurity and Supply Chain Planning*, GAO-22-105330 (Washington, D.C.: June 14, 2022); *Weapon Systems Annual Assessment: Challenges to Fielding Capabilities Faster Persist*, GAO-22-105230 (Washington, D.C.: June 8, 2022); and GAO-21-105298.

[22] Department of Defense, *Software Modernization Strategy* (Washington, D.C.: Feb. 1, 2022).

[23] Defense Science Board, *Design and Acquisition of Software for Defense Systems* (Washington, D.C.: Feb. 14, 2018).

Recommended practice	Description
Iterative development training for program managers and staff	Development of a training curriculum to create and train a cadre of software-informed program managers, sustainers, and software acquisition specialists.
Software documentation provided to Department of Defense at each production milestone	Delivery of software documentation includes all documentation, test files, coding, application programming interfaces, design documents, results of fault, performance tests conducted using the framework, and tools developed during the development, as well as the software factory framework.

Source: GAO analysis of Defense Science Board report. I GAO-23-106059

[a] The Defense Science Board recommended that all current programs plan a transition to the use of a software factory.

[b] Department of Defense Instruction 5000.87 defines a minimum viable product as an early version of the software to deliver or field basic capabilities to users to evaluate and provide feedback.

In April 2023, we reported that DOD had partially implemented each of the Defense Science Board's seven recommendations by taking actions such as issuing new policies and guidance and developing training for DOD's software development and acquisition workforce.[24] We noted, however, that DOD had yet to take certain actions outlined in the recommendations, such as creating a cadre of software development experts. In this report, we assessed the extent to which selected DOD weapon programs implemented the software development practices encouraged by the Defense Science Board's recommendations.

Modular Contracting

The use of modular contracting practices—in which an acquisition is divided into smaller increments—can help an organization achieve the compressed time frames envisioned when using Agile development practices. Modular contracting eliminates the delay between when the government defines its requirements and when the contractor begins delivering workable solutions.[25] Achieving timely results requires the contracting cycle to be in alignment with the technology cycle. Modular contracting is intended to reduce program risk and incentivize contractor performance while meeting the government's need for timely access to

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[24] GAO-23-105611. We also found that DOD had made progress but not fully implemented software acquisition recommendations made by the Defense Innovation Board in 2019. These recommendations emphasized, among other things, speed and delivery time, hiring and retaining qualified staff, and focusing on continuous improvement throughout the software life cycle. Defense Innovation Board, *Software Is Never Done: Refactoring the Acquisition Code for Competitive Advantage* (May 3, 2019).

[25] GAO, *Agile Assessment Guide: Best Practices for Agile Adoption and Implementation,* GAO-20-590G (Washington, D.C.: Sept. 28, 2020).

rapidly changing technology.[26] As a result, it can enable delivery of capabilities more rapidly and permit easy adoption of newer and emerging technologies. DOD's software acquisition pathway instruction states that a key element of an acquisition strategy includes a flexible and modular contract strategy that enables software development teams to rapidly design, develop, test, integrate, deploy, and support software capabilities.[27]

According to the Defense Acquisition University, a modular contracting strategy for one program is likely to look different from one for another program. The strategy should be tailored to the unique needs of the program to enable the program to develop a collection of contracts with different objectives to meet different requirements that support the overall program objectives. The collection of modular contracts should be expected to change and evolve throughout the program life cycle, especially as scaling occurs and more development activities are added.

Software Acquisition Pathway

In January 2020, DOD introduced the software acquisition pathway as part of the AAF.[28] This pathway is governed by DOD Instruction 5000.87 and is intended to facilitate rapid and iterative delivery of software capability, including software-intensive systems, to users. The pathway involves the use of small cross-functional teams that include operational users, developmental and operational testers, software developers, and cybersecurity experts to deliver software rapidly and iteratively to meet highest priority user needs. It is intended to address recommendations made by the Defense Science Board to enable DOD to deploy software quickly and adopt continuous iterative development, among other things. As of February 2023, DOD was tracking 49 programs using the software acquisition pathway.

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[26] FAR 39.103. Modular contracting was established in title 41, section 2308 of the U.S. Code.

[27] DOD Instruction 5000.87.

[28] Prior to the publication of DOD Instruction 5000.87, the department had an interim policy in effect. Department of Defense, *Software Acquisition Pathway Interim Policy and Procedures* (Washington, D.C.: Jan. 3, 2020).

Cybersecurity in DOD Weapon Programs

As we reported in October 2018, cybersecurity for weapon systems has increasingly been recognized as a critical area in which DOD must improve.[29] We noted that cyberattacks can target any weapon system that is dependent on software, potentially leading to an inability to complete military missions or even loss of life.

In November 2020, DOD issued DOD Instruction 5000.89, which establishes policy and procedures for test and evaluation across five of the six AAF pathways—including the major capability acquisition and MTA pathways—that addresses cybersecurity planning and execution.[30] In particular, the instruction requires all DOD acquisition programs and systems, regardless of acquisition pathway, to execute an iterative cybersecurity test and evaluation process detailed in the DOD *Cybersecurity Test and Evaluation Guidebook* throughout the program's life cycle, including for new increments of capability.[31] Table 3 outlines the DOD cybersecurity test and evaluation phases from the DOD *Cybersecurity Test and Evaluation Guidebook*.

Table 3: Department of Defense Cybersecurity Test and Evaluation Phases

Cybersecurity test and evaluation phase	Description
Phase 1: Understand cybersecurity requirements	Examine cybersecurity, system cyber survivability, and other requirements for developing approaches and plans for conducting test and evaluation.
Phase 2: Characterize the attack surface	Identify vulnerabilities of attack an adversary may use and make plans to evaluate effects to the mission. This may include a cyber tabletop exercise—an intellectually intensive exercise to introduce and explore potential threats.
Phase 3: Cooperative vulnerability identification	Conduct early cyber vulnerability tests to identify known cybersecurity vulnerabilities, assess the risks associated with those vulnerabilities, and determine appropriate mitigations.
Phase 4: Adversarial cybersecurity developmental test and evaluation	Conduct tests of a system's cyber survivability and operational resilience in a mission context, using realistic threat exploitation techniques, while in a representative operating environment.
Phase 5: Cooperative vulnerability and penetration assessment	Conduct tests during operational test and evaluation to assess the system's ability to execute critical missions and tasks in the expected operational environment.

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[29] GAO, *Weapon Systems Cybersecurity: DOD Just Beginning to Grapple with Scale of Vulnerabilities*, GAO-19-128 (Washington, D.C: Oct. 9, 2018).

[30] Department of Defense, *Test and Evaluation,* DOD Instruction 5000.89 (Nov. 19, 2020). The sixth pathway, acquisition of services, does not require test and evaluation policy and procedures.

[31] Department of Defense, *Cybersecurity Test and Evaluation Guidebook 2.0, Change 1* (February 2020).

Cybersecurity test and evaluation phase	Description
Phase 6: Adversarial assessment	Conduct tests to characterize the operational effects to critical missions caused by threat-representative cyber activity against a unit training and equipped with a system as well as the effectiveness of the defensive capabilities.

Source: GAO analysis of Department of Defense *Cybersecurity Test and Evaluation Guidebook*. I GAO-23-106059

Additionally, DOD issued a functional policy on cybersecurity in December 2020, which establishes policy and procedures to manage cybersecurity risk. The policy also highlights the need to incorporate cybersecurity into all aspects of the defense acquisition system and operations.[32]

DOD guidance also generally states that MDAPs are to develop a cybersecurity strategy by milestone A (technology development start) and update the strategy at subsequent milestones.[33] The strategy is expected to detail the cybersecurity practices the program will use to address cybersecurity risks and reduce the likelihood of severe effects from a cyberattack. DOD guidance for MTA programs requires components to develop processes resulting in a test strategy, or assessment of test results, to be included in the acquisition strategy. This test strategy or assessment of test results should document the evaluation of the demonstrated operational performance, to include validation of required cybersecurity.[34]

Modular Open Systems Approach

A MOSA for weapon systems includes a combination of engineering and business practices in which weapons systems are designed with modular components that are linked by clearly-defined system interfaces and can be acquired from independent vendors. Designing weapons with a MOSA offers significant repair, upgrade, and competition benefits that could translate to millions of dollars in savings as the weapons age. An open system enables DOD to acquire warfighting capabilities with more flexibility and competition by allowing independent suppliers to build

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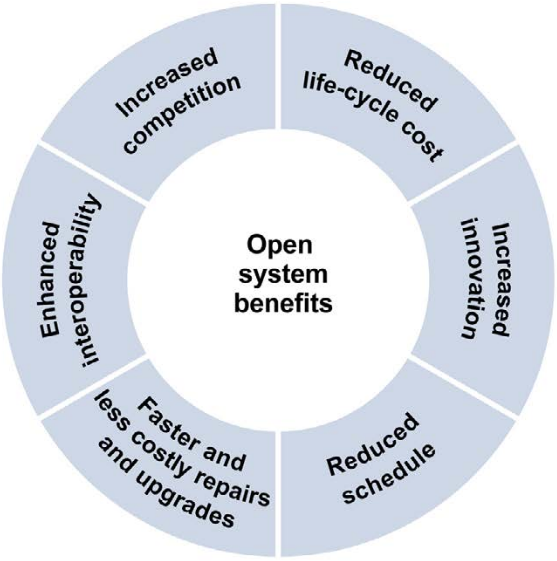
[32] Department of Defense, *Cybersecurity for Acquisition Decision Authorities and Program Managers*, DOD Instruction 5000.90 (Dec. 31, 2020).

[33] The Defense Acquisition University's Adaptive Acquisition Framework Document Identification tool identifies statutory and regulatory program information requirements for programs using certain AAF pathways, including the major capability acquisition pathway, as referenced in DOD Instruction 5000.85. The information requirements include milestone and phase information requirements, statutory program breach definitions, recurring program reports, and other requirements. See https://www.dau.edu/aafdid.

[34] DOD Instruction 5000.80.

components that can plug into the existing system through the open connections. We have previously reported on the benefits of a MOSA for weapons programs.[35] We have also found that DOD has opportunities to institutionalize a MOSA to take advantage of emerging technologies for position, navigation and timing.[36] Figure 4 illustrates potential benefits associated with a MOSA.

Figure 4: Benefits of an Open Systems Approach



Source: GAO analysis of Department of Defense and industry data. | GAO-23-106059

We previously reported that fundamental elements of an open systems approach include:

- designing a system with modular components that isolate functionality. This design makes the system easier to develop, maintain, and modify because components can be changed without majorly affecting the remainder of the system.

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[35] GAO, *Defense Acquisitions: DOD Efforts to Adopt Open Systems for Its Unmanned Aircraft Systems Have Progressed Slowly,* GAO-13-651 (Washington, D.C.: July. 31, 2013).

[36] GAO, *GPS Alternatives: DOD Is Developing Navigation Systems But Is Not Measuring Overall Progress,* GAO-22-106010 (Washington, D.C.: Aug. 5, 2022).

- developing and using open, publicly available standards for the key interfaces, or connections between the components. Interface standards specify the physical, power, data, and other connections between components. All interfaces in a system do not need to use open standards for a system to be considered “open,” and it can be costly and impractical to manage hundreds or thousands of interfaces within a system. Rather, open standards should be identified at key interfaces between the modules that are likely to change, may frequently fail or need to be replaced, or are needed for interoperability.
- obtaining appropriate data rights to interfaces when open standards are not available. DOD describes the acquisition of technical data, such as design drawings, specifications, and standards, as critical to enabling the department opportunities for competition for modification and sustainment of weapon systems throughout their life cycles.[37]

Many consumer products, including U.S. appliances, personal computers, and smartphones, are considered to be open systems because they use widely available hardware and software standards at key interfaces. For example, U.S. appliances are designed to use a particular wall socket standard, so that they can plug into any power outlet without consumers needing to worry about which brand of product is compatible in their homes. This gives customers more choices to best meet their needs and helps keep prices low by fostering market competition.

Similar to providing public consumers with product choice and competitive prices, DOD weapon system programs can also gain efficiencies from competition with a MOSA. Although a MOSA requires more planning and investment in the weapons system development phase, it may enable programs to incorporate new components beyond what a proprietary system can offer through the original manufacturer, both for technology upgrades and to facilitate competition for sustainment. Figure 5 illustrates how key components in a MOSA can have a wider variety of contractors to meet mission needs.

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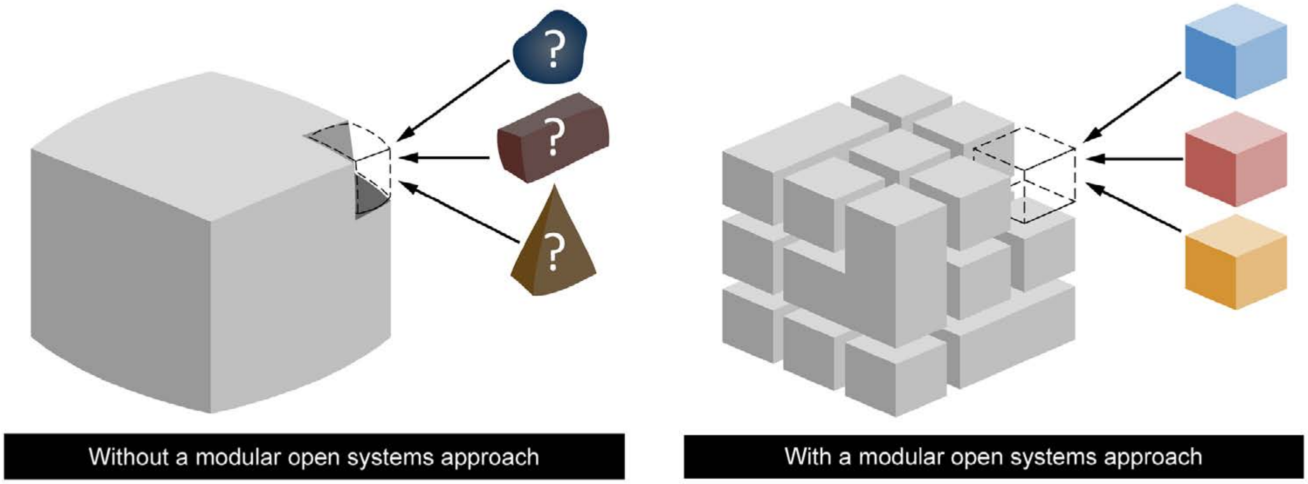
[37] GAO-13-651. For the current statutory definition of a MOSA, see 10 U.S.C. § 4401(b).

Figure 5: Greater Availability of Suitable Replacements with a Modular Open Systems Approach



Source: GAO analysis of Department of Defense information. | GAO-23-106059

To verify whether a program has successfully implemented a MOSA for a particular open standard, programs must test whether the system as it was built can operate with different components that were built with interfaces using the same standards. An everyday example of verification is a Wi-Fi certification sticker on a wireless internet router. That certification confirms that examples of this model of router were tested in a laboratory to prove that it can connect with any other device developed, using the same open Wi-Fi standards.

Policy, Guidance, and Implementing Organizations

Within DOD, the Office of the Under Secretary of Defense for Research and Engineering (USD R&E) and the Office of the USD(A&S) both have roles for creating policy and guidance for MOSA implementation. The military departments are responsible for implementing a MOSA within their acquisition programs.

MOSA is addressed in a number of policy and guidance documents, including DOD instructions and guidebooks, and policy issued by the military departments. For example:

- DOD Instruction 5000.88, *Engineering of Defense Systems*, which governs systems engineering, directs programs’ lead systems engineers, under the direction of program managers, to use a MOSA in product designs to the maximum extent practical in accordance with certain statutes, and provides more specific instructions on considerations when pursuing a MOSA.[38]

- USD(R&E)'s *Engineering of Defense Systems Guidebook* describes the activities, processes, and acquisition practices involved in developing DOD systems. USD(R&E)'s *Systems Engineering Guidebook* provides guidance and recommended best practices for defense acquisition programs. Both include sections on MOSA that discuss the potential benefits and considerations for implementing a MOSA during a system's development.
- Air Force Policy Directive 63-1/20-1 *Integrated Life Cycle Management* provides an acquisition and sustainment integrated life-cycle management framework across Air Force systems.[39] This policy directs programs to apply systems engineering standard processes and practices, including using MOSA to the maximum extent practicable.

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[38] Department of Defense, *Engineering of Defense Systems*, DOD Instruction 5000.88 (Nov. 18, 2020).

[39] Secretary of the Air Force, *Integrated Life Cycle Management*, Air Force Policy Directive 63-1 / 20-1 (Aug. 7, 2018).

FFG 62 Constellation Class Frigate (FFG 62)

Source: Fincantieri Marinette Marine. | GAO-23-106059

OVERVIEW

DOD Weapon Portfolio for 2023

DOD plans to spend at least $1.9 trillion to acquire its costliest weapon programs.

The portfolio we assessed is smaller and slightly more expensive than last year, consisting of 101 programs: 75 MDAPs, 7 future major weapon acquisitions, and 19 MTA programs. The number of MDAPs declined from 86 to 75; while the number of MTA programs we assessed remained constant since our last report. As shown in table 4 below, DOD is also investing in future major weapon acquisition efforts exceeding the MDAP cost threshold that have yet to select an AAF pathway.

Table 4: Department of Defense (DOD) Planned Acquisition Investments in Selected Weapon Programs GAO Reviewed (fiscal year 2023 dollars in billions)

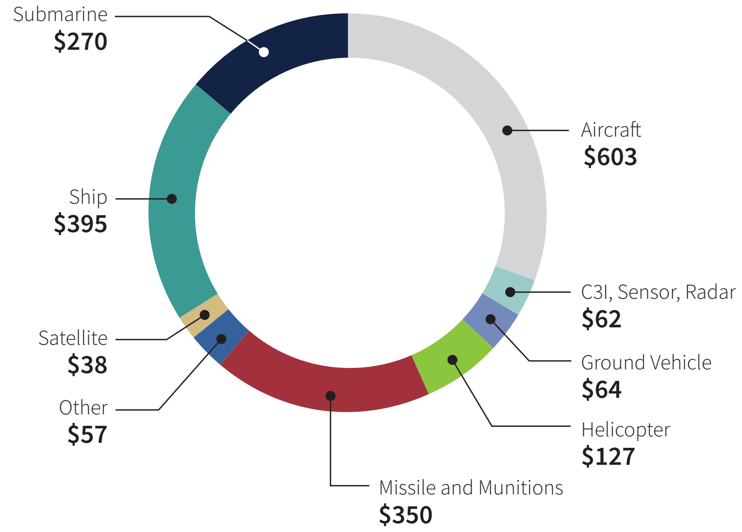
Type of program	Number of programs reviewed	Total planned investment	Air Force and Space Force	Navy and Marine Corps	Army	Joint DOD
Major defense acquisition programs	75	$1,913.7	20	38	14	3
Future major weapon acquisitions	7	$14.5	0	5	2	0
Middle tier of acquisition programs	19	$36.2	12	1	6	0

Source: GAO analysis of Department of Defense data. | GAO-23-106059

Note: Planned middle tier of acquisition investment amounts reflect the current costs reported by those programs, many of which are planning follow-on efforts that are not included in these costs. Similarly, the planned investment amounts for future major weapon acquisitions reflect current costs reported by those programs, which may not include the costs of later development and procurement efforts

Figures 6 and 7 break out DOD's planned spending by the type of commodity being developed and total spending by military department, respectively. Our reporting does not include total life-cycle sustainment costs or classified programs, which constitute a substantial portion of military department spending.

Figure 6: Planned Acquisition Investment by Commodity for Programs GAO Reviewed (fiscal year 2023 dollars in billions)

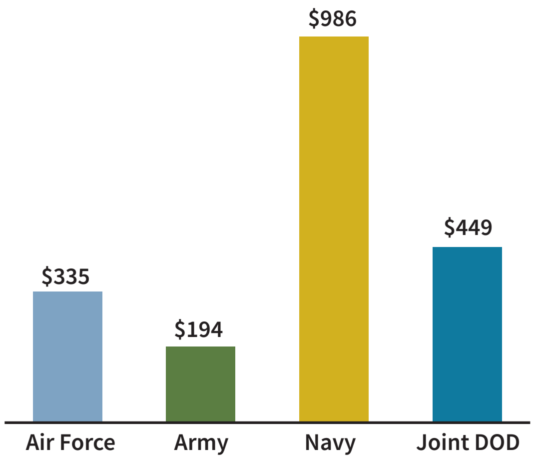


C3I = Command, Control, Communications and Intelligence

Source: GAO analysis of Department of Defense data. | GAO-23-106059

Note: "Other" includes programs that did not list a program type in their Selected Acquisition Reports.

Figure 7: Planned Acquisition Investment by Military Department for Programs GAO Reviewed (fiscal year 2023 dollars in billions)



Source: GAO analysis of Department of Defense (DOD) data. | GAO-23-106059

DOD MDAP Portfolio

OBSERVATIONS FROM DOD'S ANNUAL MDAP REPORTING

Number of programs declined, costs increased, and capability delivery lagged.

F-15EX

Source: U.S. Air Force. | GAO-23-106059

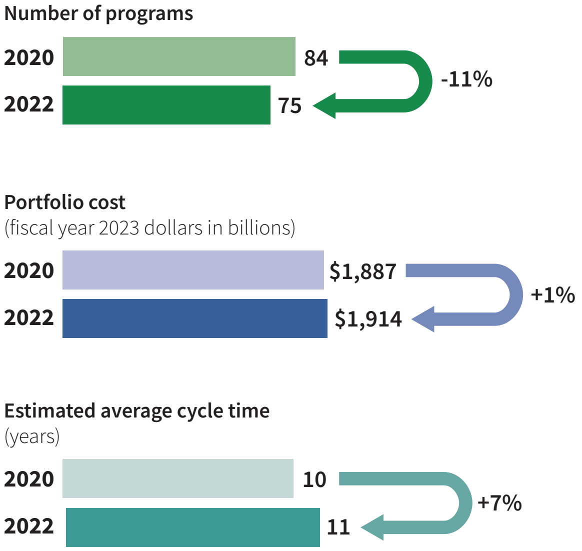
While DOD is investing in fewer MDAPs than it was in 2020, the total cost of the portfolio of MDAPs for which it produced unclassified Selected Acquisition Reports (SARs) increased by $27 billion —1.4 percent—as the remaining programs became more expensive. Our analysis shows that changes to planned order quantities drove 55 percent—$15 billion—of the total cost change from 2020 for the total MDAP portfolio.

Figure 8 shows an overview of major trends in DOD's 2020 and 2022 MDAP annual reports. DOD did not produce annual reports for MDAPs in 2021 due to the lack of future year funding data included in the fiscal year 2022 budget request.

However, we were unable to conduct a detailed analysis of the causes of cost changes based on DOD's annual reports, because DOD no longer includes that information in its SARs as of 2022.

The average MDAP in 2022 plans to take longer to deliver usable capabilities to the warfighter than in 2020. For programs that have yet to achieve operational capability, the average planned time between program start and achieving initial operational capability increased to an average estimated 11 years in 2022.

Figure 8: Key Metrics from DOD's 2022 Major Defense Acquisition Program Reporting Compared to DOD's 2020 Reporting (fiscal year 2023 dollars in billions)



Source: GAO analysis of Department of Defense data. | GAO-23-106059

Note: The estimated average planned cycle time includes data only for programs that have yet to achieve initial operational capability.

OVERVIEW OF COST CHANGES

DOD is paying more for less capability since our prior report.

Combined total cost estimates rose by $37 billion—4 percent—in the past year for the 35 MDAPs for which we completed 2 page assessments (see fig. 9). This increase was largely driven by cost growth on the most expensive programs. For this report, we analyzed the cost changes of the 32 MDAPs that we also assessed in our prior report in detail because DOD no longer includes information about the reasons for cost variance in its SARs as of 2022.

More than half of the programs we reviewed reported cost reductions since last year. However, of the 18 programs that reported cost reductions, about a third of that reduction was due to reducing the number of units programs plan to buy, rather than finding efficiencies. We cover how quantity changes affected programs' cost performance in greater detail on the following page.

Factors Driving the Largest Cost Changes Not Related to Quantity since Our Prior Report

DOD's F-35 Lightning II's (F-35) total cost grew 10 percent—$39 billion—in part due to increasing modernization costs and rising procurement costs driven by delaying aircraft deliveries into the future years.

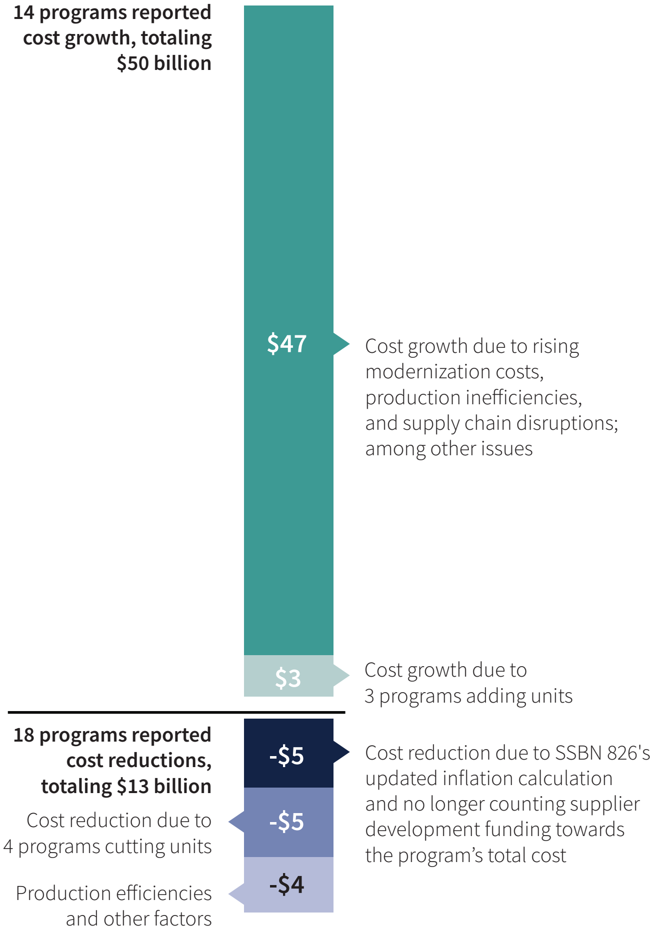
Changes to the way the **Navy's *Columbia* class ballistic missile submarine's (SSBN 826)** total cost is calculated complicated tracking the program's cost performance. Specifically, the program has updated its inflation calculation, which yielded a lower total cost. It also no longer includes supplier development funding towards its cost because the Navy told us that it now considers this funding as costs shared with another program. While this change for supplier funding reduced SSBN 826's total reported cost, it does not change the Navy's final cost to deliver Columbia on time.

Costs continue to rise on **the Navy's *Ford* class nuclear aircraft carrier (CVN 78)**, totaling $4 billion since our last report. This is due to increasing construction costs above cost estimates we previously reported were optimistic. Additionally, the program is considering whether to replace the lead ship's unique Dual Band Radar—which it already purchased for the lead ship—with a radar system used on other ships, potentially increasing costs further.

F-35 Lightning II (F-35)

Source: U.S. Navy photo courtesy Lockheed Martin/Dane Wiedmann. | GAO-23-106059

Figure 9: One-Year Cost Changes across Major Defense Acquisition Programs Assessed by GAO (fiscal year 2023 dollars in billions)



Source: GAO analysis of Department of Defense data. | GAO-23-106059

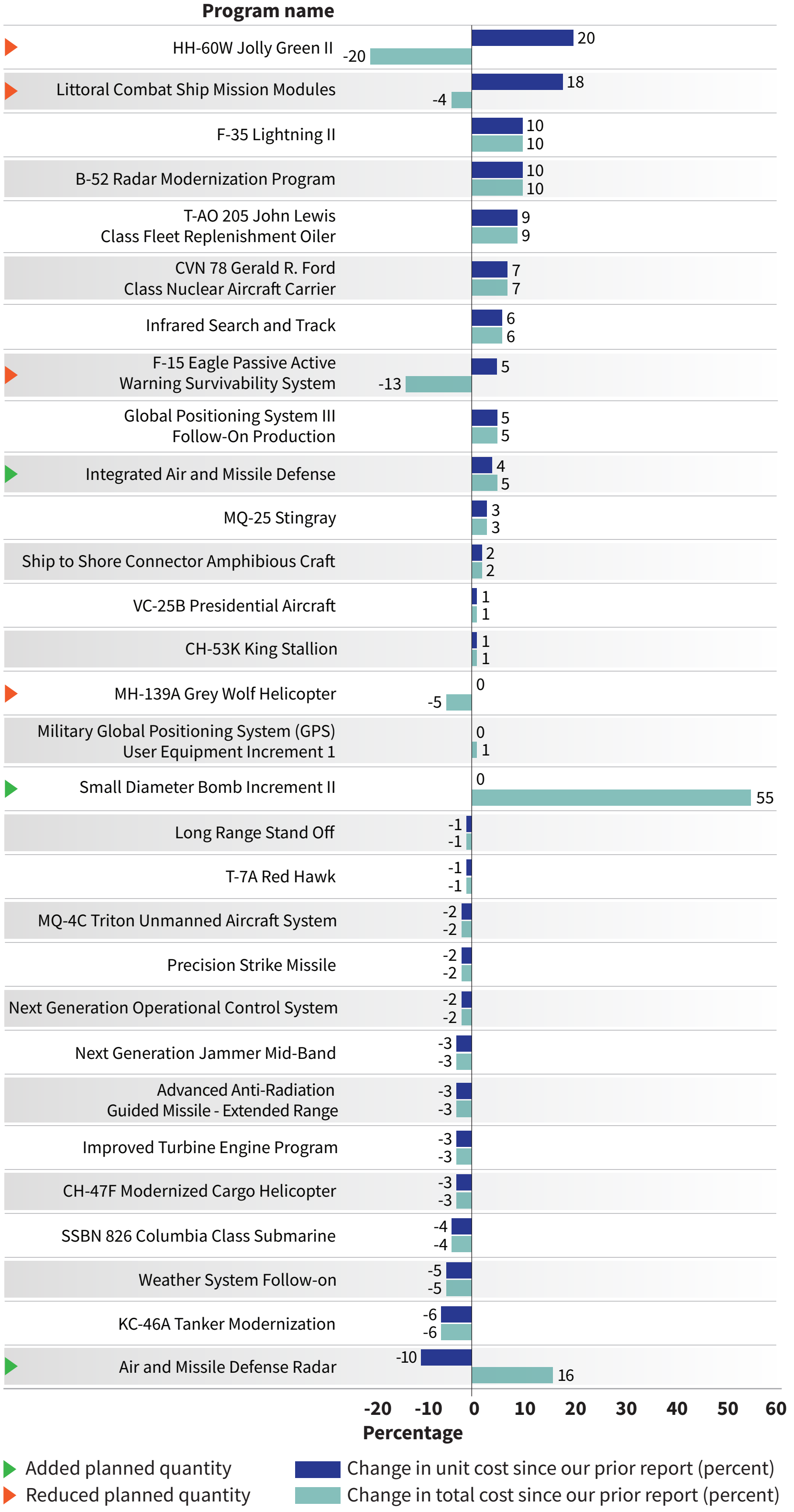
Note: Subdivisions of cost reductions do not sum to the total due to rounding.

EFFECT OF QUANTITY CHANGES ON COST PERFORMANCE

Quantity increases are not consistently resulting in lower unit costs.

This year, seven programs reported changing the number of units of their systems that they plan to buy. Our past work suggests that it is reasonable to expect that unit costs will decrease as more units are produced. Programs can achieve cost reductions through economies of scale or, conversely, can see unit costs rise if they reduce the total quantity procured. However, for some programs we reviewed this year, developmental challenges undermined potential economies of scale, as shown in figure 10 below.

Figure 10: Percent Change in Reported Total and Program Unit Cost since Our Prior Report



Source: GAO analysis of Department of Defense data. | GAO-23-106059

Factors Driving Quantity Changes since Our Prior Report

The **Air Force's Small Diameter Bomb II (SDB II)** guided glide bomb program's procurement quantity increased from 17,000 to 26,610 bombs. However, unit costs did not decrease because the program will have to complete a costly technical redesign of the weapon's seeker to replace obsolete parts.

Despite recent progress in resolving performance and testing issues, the **Air Force's F-15 Eagle Passive Active Warning Survivability System (EPAWSS)** aircraft protection system is reducing its quantity by 18 percent after the Air Force announced plans to reduce the number of F-15EX aircraft—which included the system—that it plans to procure. This reduction also drove a 5 percent increase in unit cost.

The **Navy** proposed canceling **Littoral Combat Ship Mission Modules'** antisubmarine warfare (ASW) package in its fiscal year 2023 budget request. We previously reported that performance issues with the package's variable depth sonar had delayed ASW capability. Due to the expected elimination of nine ASW packages, the program's updated cost estimate shows an 18 percent increase in average unit costs.

The **Navy's Air and Missile Defense Radar (AMDR)** program updated its baseline to add other pre-existing radar variants to the program. This increases the program's total cost estimate and creates the appearance of lower average unit costs by spreading costs across more units without achieving new economies of scale. Program officials stated that estimated contract costs for AMDR units are rising due to the contractor's optimistic cost estimates, supply chain challenges, and issues with key components. This indicates that unit costs for the original AMDR assemblies may be increasing.

DOD MDAP Portfolio

SCHEDULE PERFORMANCE

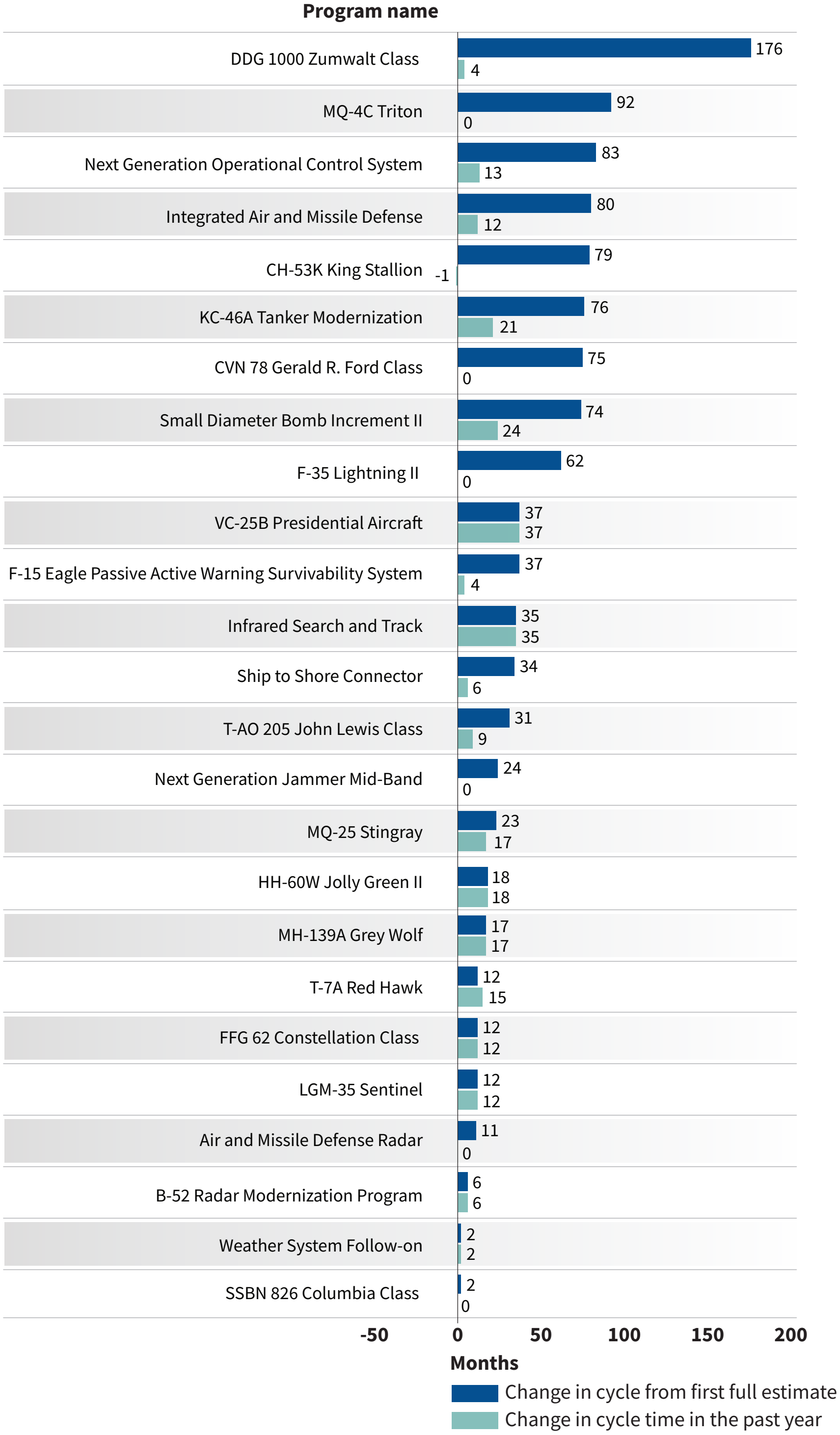
Schedule changes signal risk to fielding capabilities faster.

Small Diameter Bomb II (SDB)

Source: © 2009 Raytheon Company. | GAO-23-106059

MDAPs continue to experience delays to planned initial operational capability dates, despite DOD's efforts to accelerate delivery by tailoring acquisition processes. Long delays increase the risk that the threat a program was originally intended to meet may evolve and make the program obsolete. Almost two thirds of the 26 MDAPs that we assessed in 2022 and this year that had yet to reach initial operational capability reported delays since our 2022 report, as shown in figure 11 below. These delays were driven by a broad range of factors, including supplier disruptions, quality control deficiencies, and software development delays. Eleven of the 18 programs that reported delays this year also reported delays to operational capability last year.

Figure 11: Programs Reporting Cumulative or 1-Year Delays to Planned Initial Operational Capability (months)



Source: GAO analysis of Department of Defense data. | GAO-23-106059

Note: T-7A had reported accelerating its cycle time below its original estimate in 2022; however, recent schedule shifts have resulted in a 1-year delay that exceeds the original cycle time. Consequently, the 1-year delay is greater than the first full estimate's cycle time. CH-47F plans to delay its initial operational capability date but has yet to determine a new date.

Factors Contributing to the Five Largest 1-year Delays to Initial Operational Capability since Our 2022 Report

1. **37 months: VC-25B presidential aircraft** (VC-25B, Air Force). Issues including a change of interior suppliers, wiring design errors, and workforce limitations forced the program to develop a new schedule baseline.
2. **35 months: Infrared Search and Track** (IRST, Navy). Defective components critical to IRST's target tracking capability delayed production-representative units needed to complete developmental testing.
3. **24 months: Small Diameter Bomb II** (SDB II, Air Force). Software needed to start integration testing with the F-35 has been delayed, resulting in a breach to the program's initial capability schedule threshold dates.
4. **21 months: KC-46A aerial refueling tanker** (KC-46A, Air Force). COVID-19-related disruptions delayed delivery of a sufficient number of wing aerial refueling pods to support a requirement for 18 operational aircraft that will permit the Air Force to declare the program has reached initial operational capability.
5. **18 months: HH-60W Jolly Green II** (HH-60W, Air Force). Aircraft availability delays affected several of the program's planned milestones over the past year.

Future Major Weapon Acquisitions

EFFORTS OUTSIDE OF AAF PATHWAYS

Some future major weapon acquisitions have near-term plans to deliver operational capability.

Many of DOD's costliest future acquisition efforts are not tracked by OSD until they are formally initiated using an AAF pathway. We gathered available information about those research and development efforts, which, collectively with future MDAPs, we refer to as future major weapon acquisitions.

We are currently tracking seven such early-stage efforts that report spending plans of at least $14.5 billion combined. These efforts include the Army's Long-Range Hypersonic Weapon System and Future Attack Reconnaissance Aircraft; and the Navy's DDG(X) Guided Missile Destroyer, Light Amphibious Warship, Large Unmanned Surface Vessel, Mk 54 Mod 2 Advanced Lightweight Torpedo, and Orca Extra Large Unmanned Undersea Vehicle. Figure 12 highlights examples of future major weapon acquisitions that plan to deliver operational capabilities prior to initiating on an acquisition pathway.

Figure 12: Examples of Future Major Weapon Acquisitions Reviewed by GAO (fiscal year 2023 dollars in millions)

Source: U. S. Army. | GAO-23-106059

Long-Range Hypersonic Weapon System (LRHW)

Military department: Army

Estimated cost: $3,121

Current quantity: 8

Description: Started in 2019, LRHW is a ground-launched hypersonic missile designed to engage an adversary's long-range weapons and high-value, time-sensitive targets. It is a joint effort with the Navy's Conventional Prompt Strike program, which is developing a ship-fired version of the system.

Current acquisition approach: Research and development effort managed by the Army's Rapid Capabilities and Critical Technologies Office.

Fielding plans before initiation on an AAF pathway: The Army expects to field a system with eight missiles by the end of fiscal year 2023.

AAF transition plan: The program has proposed transitioning to the MTA rapid fielding pathway, but, as of January 2023, the Army had not finalized that decision.

Source: U. S. Navy. | GAO-23-106059

Orca Extra Large Unmanned Undersea Vehicle (XLUUV)

Military department: Navy

Estimated cost: $1,402 (includes potential costs in the event the Navy decides to exercise the option for up to four additional vehicles after successful government testing of the original prototype vehicles).

Current quantity: 6

Description: XLUUV is an uncrewed undersea vehicle that is expected to meet various undersea missions by leveraging a modular payload bay that can carry and deploy various payload types, including minelaying. The effort started in fiscal year 2017 in response to an urgent operational need.

Current acquisition approach: Research and development project in response to an emergent operational need.

Fielding plans before initiating on an AAF pathway: The Navy procured six operationally relevant prototypes that it currently expects to be delivered by June 2024. We previously reported that effort is over 3 years later than planned and has exceeded costs by at least $242 million due, in part, to the Navy's decision to not require the contractor to demonstrate its readiness to fabricate the prototype XLUUVs, as called for by leading acquisition practices.

AAF transition plan: The Navy plans to transition the XLUUV prototype effort to the major capability acquisition pathway in the next several years.

Source: GAO analysis of Department of Defense data. | GAO-23-106059

Note: GAO, *Extra Large Unmanned Undersea Vehicle: Navy Needs to Employ Better Management Practices to Ensure Swift Delivery to the Fleet*. GAO-22-105974 (Washington, D.C.: Sep. 28, 2022).

DOD MTA Portfolio

Some MTA programs face schedule and technology development risks.

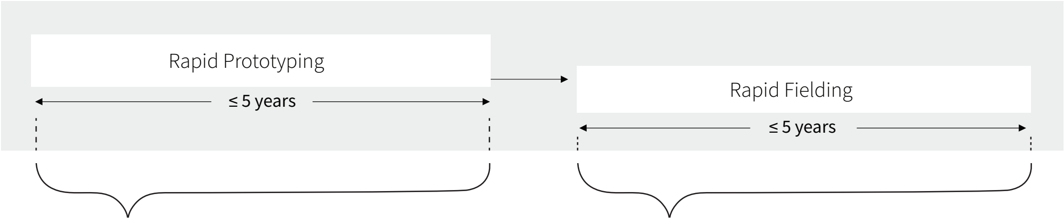
MTA programs that have transitioned to the major capability acquisition pathway indicate the potential benefits of the pathway, but schedule and technology risk remain for programs continuing on this pathway. Our coverage of the MTA pathway this year remained steady at 19 programs—18 rapid prototyping efforts and one rapid fielding effort, as shown in figure 13. We reviewed two new rapid prototyping efforts, while two that we had reviewed in our prior assessment have since transitioned to the major capability acquisition pathway.

B-52 Commercial Engine Replacement Program (CERP) Rapid Virtual Prototype (RVP)

Source: U.S. Air Force. | GAO-23-106059

Figure 13: Overview of 19 MTA Programs Reviewed by GAO

Middle tier of acquisition (MTA) pathway



We reviewed 18 rapid prototyping efforts:

Air Force
- Air-launched Rapid Response Weapon (ARRW)
- B-52 Commercial Engine Replacement Program (CERP) Rapid Virtual Prototype (RVP)
- F-22 Rapid Prototyping

Army
- Extended Range Cannon Artillery (ERCA)
- Future Long Range Assault Aircraft (FLRAA)
- Indirect Fire Protection Capability Increment 2 (IFPC Inc 2)
- Lower Tier Air and Missile Defense Sensor (LTAMDS)
- Optionally Manned Fighting Vehicle (OMFV)

Navy
- Conventional Prompt Strike (CPS)

Space Force
- Deep Space Advanced Radar Capability (DARC)
- Evolved Strategic SATCOM (ESS)
- Future Operationally Resilient Ground Evolution (FORGE)
- Military GPS User Equipment (MGUE) Increment 2
- Next Generation Overhead Persistent Infrared Block 0-Geosynchronous Earth Orbit Satellites (Next Gen OPIR Block 0 GEO)
- Protected Tactical Enterprise Service (PTES)
- Protected Tactical SATCOM (PTS)
- ★ **Tranche 1 Tracking Layer (T1 TRK)**
- ★ **Tranche 1 Transport Layer (T1TL)**

We reviewed one rapid fielding effort:

Army
- Integrated Visual Augmentation System (IVAS)

Two MTA efforts from our prior report are no longer included:

The **Army's Mobile Protected Firepower (MPF)** and the **Air Force's F-15EX** each transitioned to the major capability acquisition pathway at production. **MPF** and **F-15EX** are included in our major defense acquisition program portfolio.

★ **New MTA effort reviewed by GAO this year**

Source: GAO analysis of Department of Defense data. | GAO-23-106059

DOD MTA Portfolio

SCHEDULE

Two MTA efforts transitioned to a new pathway as planned.

Two MTA efforts included in our prior assessment transitioned to the major capability acquisition pathway at production over the past year after completing their MTA objectives in less than 4 years. These programs provide an early indication that the MTA pathway, when used thoughtfully, can be a helpful tool to accelerate the production of needed capabilities from relatively mature systems.

Limited Technical Risk Enabled Successful MTA Transitions since Our Prior Assessment

9/2018	**12/2018**	**Fiscal Year 2021**	**9/2021**	**6/2022**
MTA funds obligated	Contract award	Soldier vehicle assessments	Limited User Test	Transition to major capability acquistion pathway

Source: U.S. Army. I GAO-23-106059

The **Army's Mobile Protected Firepower (MPF)** MTA effort featured competitive prototyping between two vendors, yielding 24 prototype vehicles. The vehicles underwent soldier assessments and limited user testing to evaluate the designs, and participating units provided feedback. The Army selected one proposal and exercised contract options for production prior to transitioning to the major capability acquisition pathway in June 2022. During the MTA effort, the program reported that it was using technologies that were already mature and that it had no critical technologies.

3/2020	**3/2021**	**4/2021**	**5/2021**	**9/2022**
MTA funds obligated	First aircraft delivered	Second aircraft delivered	Flight test	Transition to major capability acquistion pathway

Source: U.S. Air Force. I GAO-23-106059

The **Air Force's F-15EX** MTA effort upgraded a current foreign military sales aircraft with Air Force-specific capabilities. The program delivered the first two aircraft in early 2021 to support test and evaluation and plans to deliver the remaining 18 MTA quantities by early fiscal year 2025. The program transitioned to the major capability acquisition pathway in September 2022. Contract awards and delivery for subsequent production lots are expected to occur on the major capability acquisition pathway. Among the 10 critical technologies reported by the program during the MTA effort, eight were already mature at MTA initiation and the remaining two reached maturity during the effort.

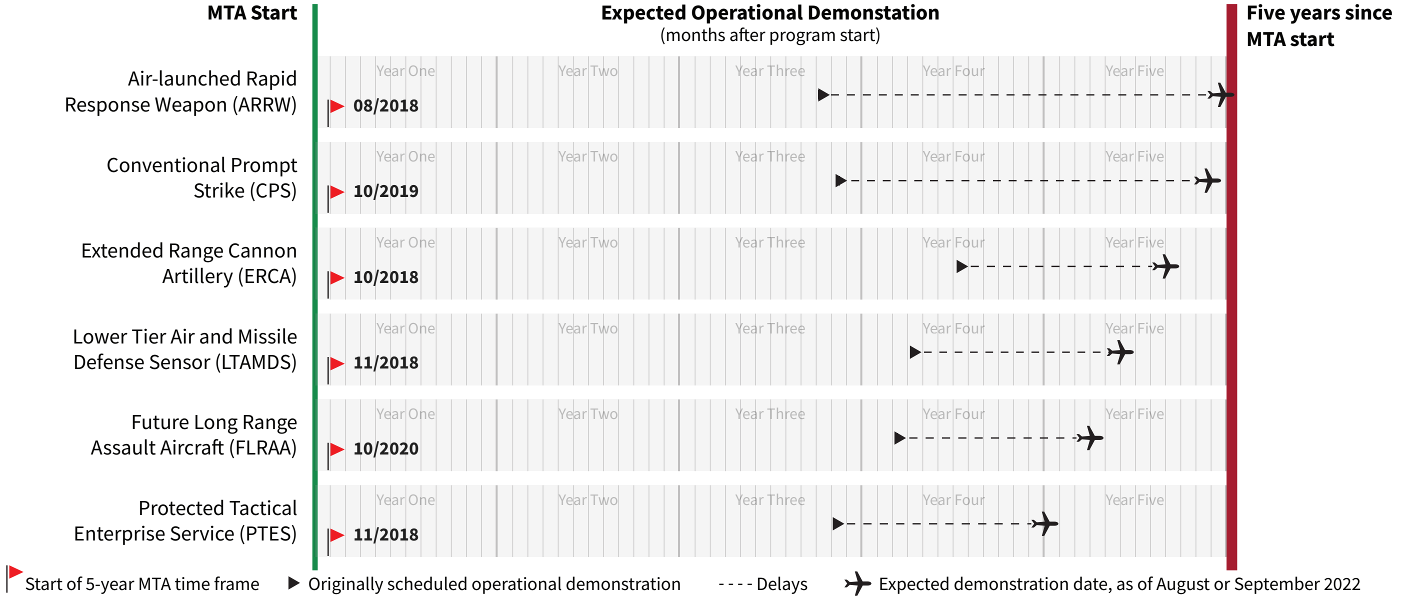
DOD MTA Portfolio

SCHEDULE

Accelerated schedules are at risk for some MTA programs.

Five years since DOD issued its interim MTA guidance, some programs are reporting delays to a key milestone intended to demonstrate capability.[1] Of the 16 rapid prototyping efforts included in both our current and prior assessments, six have delayed planned operational demonstrations by at least 12 months since program start. These delays suggest that initial plans for demonstrating capabilities may have been too ambitious (see fig. 14). The later that demonstrations occur within the 5-year window, the less time programs will have to address issues that may emerge before the end of the effort.

Figure 14: Delays Exceeding 12 Months to Planned Operational Demonstrations since Program Start for Selected Middle Tier of Acquisition (MTA) Programs



Source: GAO analysis of Department of Defense data. | GAO-23-106059

Notes: According to DOD Instruction 5000.80, MTA efforts may not exceed 5 years after the start date without a waiver from the Defense Acquisition Executive. The program start date for MTA programs designated on or after December 30, 2019, is generally the date an acquisition decision memorandum was signed initiating an MTA rapid prototyping or rapid fielding program. MTA programs designated before December 30, 2019, and certain programs designated after this date, generally maintain their MTA program start date as the date funds were first obligated. The current expected operational demonstration dates depicted in the figure above were reported by the programs in August or September 2022. According to a program official, PTES successfully conducted its operational demonstration in January 2023.

However, MTA programs' reporting to OSD may not reflect the full extent of known schedule delays. We previously identified concerns that MTA schedule reporting did not reflect known delays. For example, in February 2023, we reported that selected MTA programs did not update schedule dates in reporting to the OSD—in some cases, despite known delays and increasing schedule risk.[2] We recommended that the military departments and Special Operations Command each identify and implement actions needed to improve the reliability of MTA program data. DOD concurred. Taking this action will better position DOD to identify and address risks to meeting its priority of rapid capability development and delivery.

→ We previously reported that technology maturation issues led the **Army's Extended Range Cannon Artillery (ERCA)** program to pursue a waiver to extend the effort for an additional year beyond the 5-year MTA period described in DOD policy. However, according to Army officials, the Under Secretary of Defense for Acquisition and Sustainment denied the request.

While the program made some progress towards addressing technical challenges over the past year, schedule delays persist. According to Army officials, the Army now plans to end the MTA effort at 5 years in the first quarter of fiscal year 2024. However, under the oversight of the Army Acquisition Executive, the program plans to complete additional development, testing, and documentation prior to transitioning to the major capability acquisition pathway in late fiscal year 2024, according to these officials.

→ Since our last assessment, the **Army's Lower Tier Air and Missile Defense Sensor (LTAMDS)** program delayed its planned transition, which may cause the program to exceed its 5-year point since program start. According to officials, this was because integration challenges delayed prototype delivery and testing. The program office told us that it anticipates obtaining a memorandum from the Army Acquisition Executive to authorize remaining MTA program activities leading up to entering production in the major capability acquisition pathway.

→ The **Air Force's Air-launched Rapid Response Weapon (ARRW)** program has three flight tests planned in 2023 with little margin for error. If ARRW is unable to complete planned testing during the 5-year period, program officials said that they would need to request a waiver to extend the program or finish with fewer tests than planned. They added that the Air Force has not committed to any follow-on efforts.

[1] Department of Defense, Under Secretary of Defense for Acquisition and Sustainment, *Middle Tier of Acquisition (Rapid Prototyping/Rapid Fielding) Interim Authority and Guidance* (Apr. 16, 2018).

[2] GAO-23-105008.

DOD MTA Portfolio

COST

DOD plans to invest at least $36 billion in 19 of its largest current MTA efforts.

Overall, combined cost estimates totaled $36.3 billion for the 19 MTA programs we reviewed (see fig. 15). This amount accounts for the current MTA effort only and does not include any further investments DOD may make to develop or acquire a capability after the current MTA effort. The largest portion of our MTA portfolio is Space Force MTA programs, accounting for over $19 billion. This trend is also reflected in our analysis of the commodities DOD is spending the most to procure via the MTA pathway—with Space Force's satellites forming the largest category based on dollars spent, as shown in figure 16.

Most Expensive MTA Efforts GAO Reviewed (cost for current MTA effort)

1. **$6.0 billion:** Space Force's Next Generation Overhead Persistent Infrared (Next Gen OPIR) Block 0-Geosynchronous Earth Orbit Satellites MTA effort is developing the main mission payload—an infrared sensor—for a new satellite missile warning system.
2. **$4.4 billion:** Navy's Conventional Prompt Strike (CPS) MTA effort is developing an intermediate-range hypersonic missile. The current effort—one of three planned—expects to conduct a cold-gas launch, which involves the booster igniting after the missile ejects.
3. **$3.4 billion:** Space Force's Tranche 1 Transport Layer (T1TL) MTA effort plans to launch space vehicles into low Earth orbit to provide global communications access in support of warfighter missions.

Least Expensive MTA Programs GAO Reviewed (cost for current MTA effort)

17. **$603.6 million:** Army's Future Long Range Assault Aircraft (FLRAA) is a virtual prototyping effort to execute preliminary design and development for the next generation of vertical lift tactical assault and utility aircraft.
18. **$548.9 million:** Army's Indirect Fire Protection Capability Increment 2 (IFPC Inc 2) intends to enhance and extend the range of the first IFPC increment to counter threats from rockets, artillery, and mortars.
19. **$369.3 million:** Space Force's Protected Tactical Enterprise Service (PTES) plans to prototype a tactical, anti-jam communications capability for all military services.

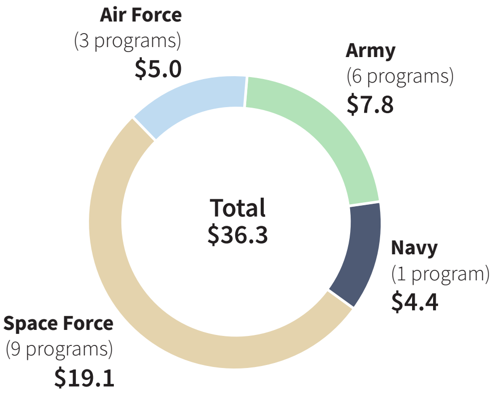
Protected Tactical Enterprise Service

Source: LinQuest. | GAO-23-106059

Conventional Prompt Strike (CPS)

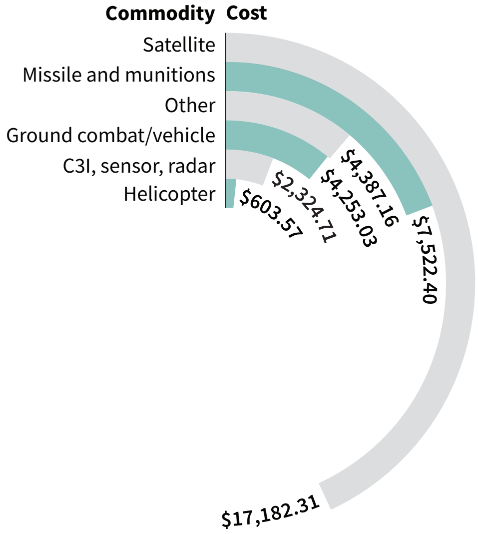
Source: U.S. Navy. | GAO-23-106059

Figure 15: Estimated Cost of Current Middle Tier of Acquisition Efforts Reviewed by GAO (fiscal year 2023 dollars in billions)



Source: GAO analysis of Department of Defense data. | GAO-23-106059

Figure 16: Estimated Costs of Current Middle Tier of Acquisition Efforts Reviewed by GAO by Commodity (fiscal year 2023 dollars in millions)



Source: GAO analysis of Department of Defense data. | GAO-23-106059

C3I = Command, Control, Communications, and Intelligence

Note: "Other" includes B-52 Commercial Engine Replacement Program Rapid Virtual Prototype (B-52 CERP RVP), F-22 Rapid Prototyping, and Military GPS User Equipment (MGUE) Increment 2.

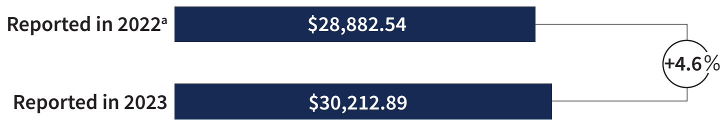
COST

Program-level cost reporting continues to vary year to year.

Among the 17 MTA efforts included in both our current and prior assessment, combined reported estimated costs increased approximately $1.3 billion over the past year (see fig. 17). Similar to our prior assessments, however, MTA programs report inconsistent cost data—as shown in figure 18—complicating DOD's efforts to maintain oversight of MTA programs' costs.

For example, reported costs for **Space Force's Protected Tactical SATCOM (PTS)** MTA effort were approximately $269 million lower than reported last year. The change is a result in how the program allocates costs to the MTA effort, according to program officials, and does not reflect a cost savings.

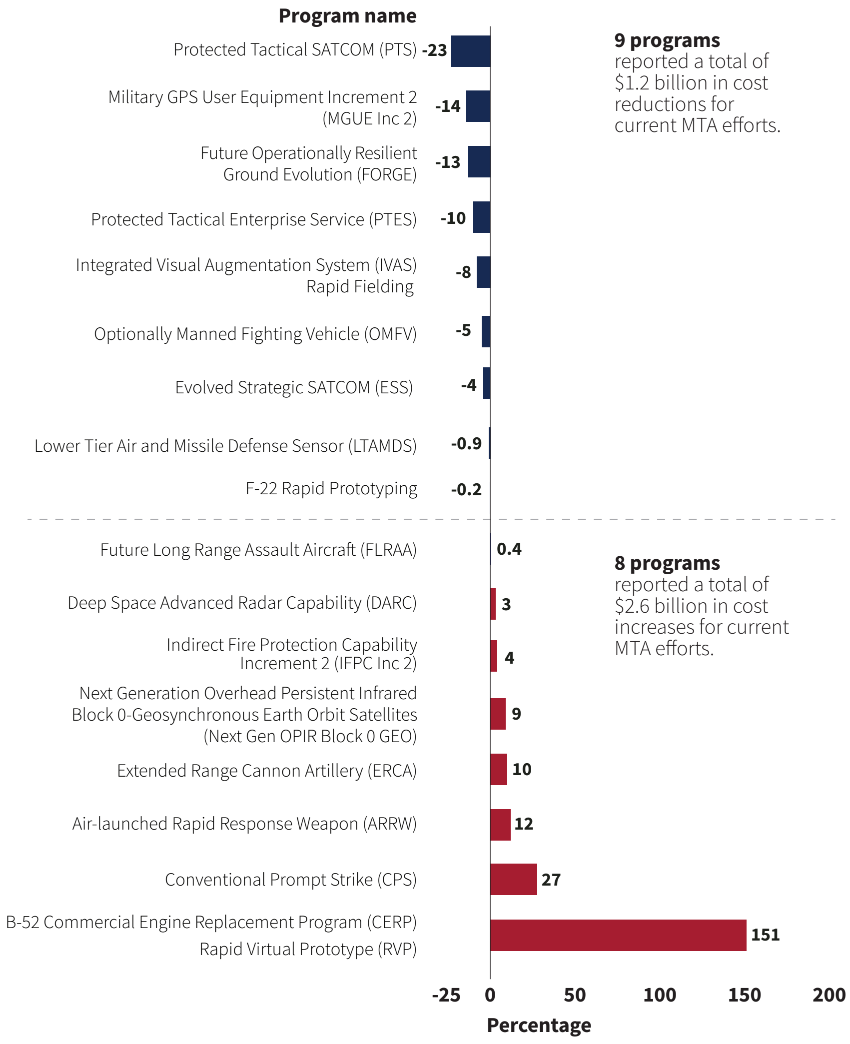
Figure 17: Estimated Combined Costs of the 17 MTA Programs Included in GAO's Current and Prior Reports (fiscal year 2023 dollars in millions)



Source: GAO analysis of Department of Defense data. | GAO-23-106059

[a] GAO-22-105230.

Figure 18: One-Year Reported Cost Changes of the 17 MTA Programs Included in GAO's Current and Prior Reports



9 programs reported a total of $1.2 billion in cost reductions for current MTA efforts.

8 programs reported a total of $2.6 billion in cost increases for current MTA efforts.

Source: GAO analysis of Department of Defense data. | GAO-23-106059

Note: See GAO-22-105230 for the prior report referenced in the figure.

Examples of Programs with Reported Cost Changes to Current MTA Efforts since Our Last Assessment

B-52 Commercial Engine Replacement Program (CERP) Rapid Virtual Prototype (RVP)

→ The Air Force's B-52 CERP RVP program reported a cost estimate approximately $859 million higher than it reported for our prior assessment.

→ Over the past year, the Air Force modified the overall B-52 CERP acquisition strategy, which previously included two separate MTA efforts. The Air Force expanded the scope of the current rapid prototyping effort and added the cost of long-lead procurements, which were originally planned as part of a follow-on MTA effort.

Air-launched Rapid Response Weapon (ARRW)

Source: U.S. Air Force. | GAO-23-106059

→ The Air Force's ARRW program reported a cost estimate approximately $179 million higher than it reported for our prior assessment—the fourth consecutive yearly increase.

→ This year's increase was due to booster testing delays and failures and the schedule extending into fiscal year 2023.

Future Operationally Resilient Ground Evolution (FORGE)

→ The Space Force's FORGE program reported a cost decrease of approximately $358 million. Program officials told us that an updated cost assessment showed a cost decrease for the MTA effort due to a better understanding of the costs that fall outside of the MTA time frame.

DOD MTA Portfolio

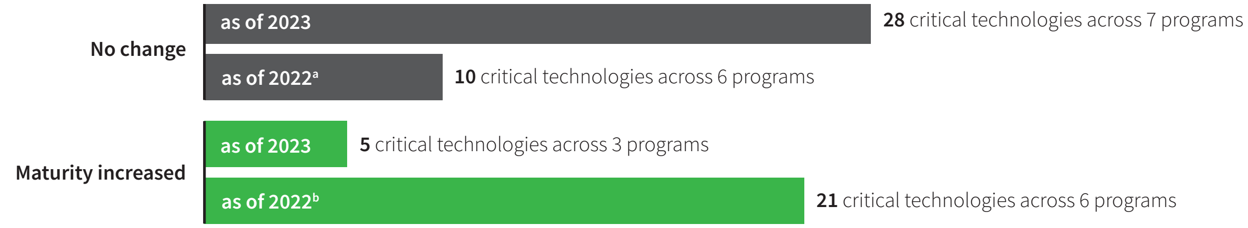
TECHNOLOGY DEVELOPMENT

MTA progress towards maturing critical technologies stagnated over the past year.

MTA programs reported limited progress in maturing their critical technologies since our prior assessment. Our past work found that, until all critical technologies are fully mature, programs risk costly and time-intensive redesign work if problems are found later in testing.

Of the 11 MTA programs that reported having critical technologies, eight have at least one technology that has yet to reach maturity. In our 2022 report, we reported that programs made progress towards maturation since our 2021 report. However, this year, most of the immature critical technologies from our prior report (28 of 33) remained at the same technology readiness level (TRL) as last year. See figures 19 and 20.

Figure 19: Maturation Progress of Immature Critical Technologies for MTA Programs since GAO's Prior Report

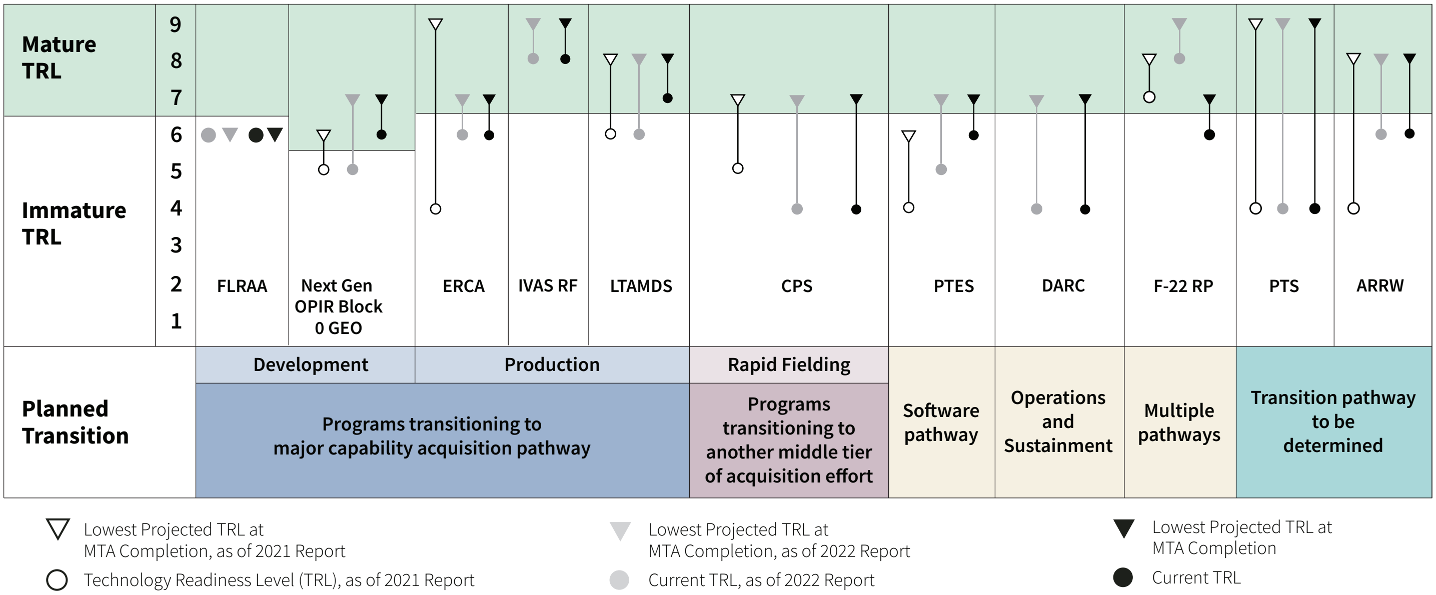


Source: GAO analysis of Department of Defense data. | GAO-23-106059

[a, b] See GAO-22-105230.

Nearly all of the MTA programs that reported having critical technologies plan for them to reach maturity before the end of the current MTA effort. However, a significant amount of work remains for some of these programs. Specifically, the **Space Force's Protected Tactical SATCOM (PTS)** and **Deep Space Advanced Radar Capability (DARC)**, and **Navy's Conventional Prompt Strike (CPS)** each reported a current TRL as low as 4—corresponding with component validation in a laboratory environment. Our prior work on MDAPs has shown that increasing even one TRL can take multiple years and becomes more challenging as the technology approaches maturity.[1] Figure 20 summarizes MTA programs' current and planned technology readiness levels, as compared with our 2021 and 2022 reports.

Figure 20: Current and Planned Technology Readiness Levels for Middle Tier of Acquisition Programs That Identified Critical Technologies, as Compared with GAO's Prior Report



ARRW	Air-launched Rapid Response Weapon
CPS	Conventional Prompt Strike
DARC	Deep Space Advanced Radar Capability
ERCA	Extended Range Cannon Artillery
IVAS RF	Integrated Visual Augmentation System (Rapid Fielding)
F-22 RP	F-22 Rapid Prototyping
LTAMDS	Lower Tier Air and Missile Defense Sensor
PTES	Protected Tactical Enterprise Service
PTS	Protected Tactical SATCOM
Next Gen OPIR Block 0 GEO	Next Generation Overhead Persistent Infrared Block 0-Geosynchronous Earth Orbit Satellites
FLRAA	Future Long Range Assault Aircraft

Source: GAO analysis of Department of Defense data. | GAO-23-106059

Notes: For programs with multiple critical technologies, the figure represents the lowest current TRL and the lowest planned TRL at program completion. F-22 Rapid Prototyping reported development plans for a new critical technology this year. This technology, intended to improve sensor capabilities, accounts for the lower current TRL and projected TRL at completion in the figure above for F-22 Rapid Prototyping. Evolved Strategic SATCOM also has critical technologies, but the program reported that the three contractors developing prototypes have different technologies at different maturity levels. Future Long Range Assault Aircraft is developing two virtual prototypes and will be unable to demonstrate its critical technologies in an operational environment (TRL 7) during MTA effort. See GAO-22-105230 and GAO-21-222 for the prior reports noted in the figure.

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[1] GAO, *Ford-Class Carriers: Lead Ship Testing and Reliability Shortfalls Will Limit Initial Fleet Capabilities*, GAO-13-396 (Washington, D.C.: Sept. 5, 2013); and *Defense Acquisitions: Decisions Needed to Shape Army's Combat Systems for the Future*, GAO-09-288 (Washington, D.C.: Mar. 12, 2009).

DOD MTA Portfolio

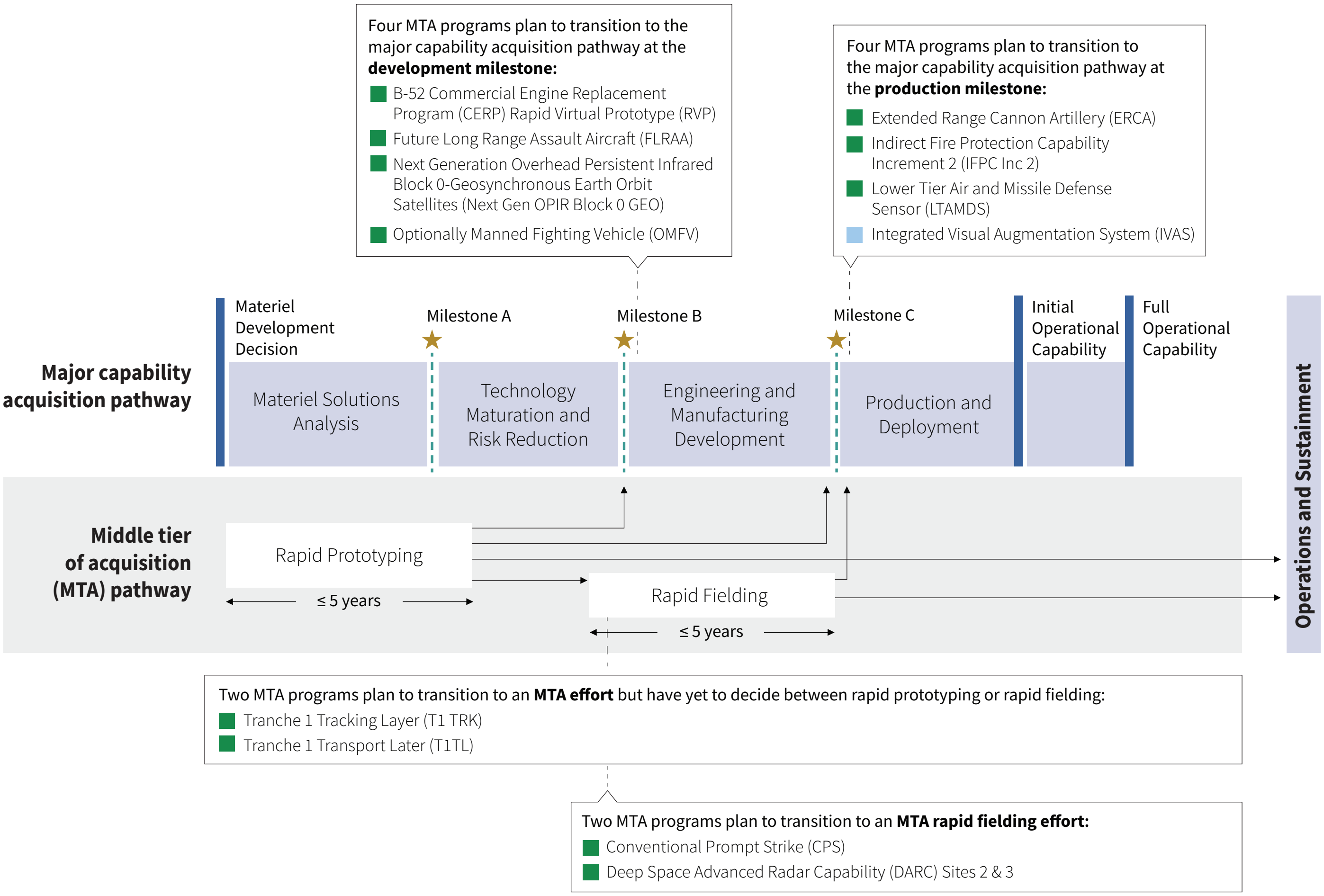
TRANSITION PLANS

Eventual capability delivery may be at least several years away for most MTA programs reporting a specific transition pathway.

Of the 14 MTA programs that identified a specific transition plan, eight expect to transition to the major capability acquisition pathway—half of which plan to enter at the development milestone. It is too soon to tell whether beginning as an MTA effort will accelerate capability delivery for programs that subsequently transition to the major capability acquisition pathway. However, monitoring the pace of progress for these programs after they transition will be critical to help DOD ensure that the MTA pathway is consistently accomplishing the goal of delivering capability to the warfighter more quickly. As noted earlier, the average expected time between program start and operational capability for MDAPs in DOD's portfolio is an estimated 11 years. If starting as an MTA does not shorten that duration, MTA programs entering the major capability acquisition pathway at development could take more than 15 years to deliver capability.

Figure 21 shows transition plans for the MTA programs we reviewed.

Figure 21: Planned Transition Pathway of Current MTA Programs That GAO Reviewed



Four MTA programs plan to transition to the major capability acquisition pathway at the **development milestone:**

- 🟩 B-52 Commercial Engine Replacement Program (CERP) Rapid Virtual Prototype (RVP)
- 🟩 Future Long Range Assault Aircraft (FLRAA)
- 🟩 Next Generation Overhead Persistent Infrared Block 0-Geosynchronous Earth Orbit Satellites (Next Gen OPIR Block 0 GEO)
- 🟩 Optionally Manned Fighting Vehicle (OMFV)

Four MTA programs plan to transition to the major capability acquisition pathway at the **production milestone:**

- 🟩 Extended Range Cannon Artillery (ERCA)
- 🟩 Indirect Fire Protection Capability Increment 2 (IFPC Inc 2)
- 🟩 Lower Tier Air and Missile Defense Sensor (LTAMDS)
- 🟦 Integrated Visual Augmentation System (IVAS)

Two MTA programs plan to transition to an **MTA effort** but have yet to decide between rapid prototyping or rapid fielding:

- 🟩 Tranche 1 Tracking Layer (T1 TRK)
- 🟩 Tranche 1 Transport Later (T1TL)

Two MTA programs plan to transition to an **MTA rapid fielding effort:**

- 🟩 Conventional Prompt Strike (CPS)
- 🟩 Deep Space Advanced Radar Capability (DARC) Sites 2 & 3

Three programs **have yet to finalize a transition pathway**:

- 🟩 Air-launched Rapid Response Weapon (ARRW)
- 🟩 Evolved Strategic SATCOM (ESS)
- 🟩 Protected Tactical SATCOM (PTS)

Two MTA programs plan to transition to the **software pathway:**

- 🟩 Protected Tactical Enterprise Service (PTES)
- 🟩 Future Operationally Resilient Ground Evolution (FORGE)

🟩 Rapid prototyping
🟦 Rapid fielding

Source: GAO analysis of Department of Defense data. | GAO-23-106059

Notes: Military GPS User Equipment Increment 2 is developing receiver cards that the individual military services will produce and field. Thus, it does not have a transition path aligned with DOD's Adaptive Acquisition Framework. F-22 Rapid Prototyping plans to transition most selected capabilities as individual programs to different pathways. DARC expects to transition Site 1 into operations & sustainment. T1 TRK and T1TL expect to transition tranche 1 into operations and sustainment, and are considering rapid prototyping or rapid fielding for subsequent tranches.

DOD MTA Portfolio

TRANSITION PLANS

Eleven MTA efforts plan to transition in 2023 or 2024.

Over half of the MTA efforts we reviewed plan to transition to a follow on effort in 2023 or 2024, as shown in figure 22. We will continue to monitor these transitions in our future assessments to provide additional insight on the effects of the MTA pathway on the overall timeliness of capability delivery.

Figure 22: Expected Transition Dates for the 19 Middle Tier of Acquisition Programs Reviewed by GAO

Quarter 2 Fiscal Year 2023	» Protected Tactical Enterprise Service (PTES)
Quarter 4 Fiscal Year 2023	» B-52 Commercial Engine Replacement Program (CERP) Rapid Virtual Prototype (RVP) » F-22 Rapid Prototyping » Protected Tactical SATCOM (PTS)
Quarter 1 Fiscal Year 2024	» Lower Tier Air and Missile Defense Sensor (LTAMDS) » Next Generation Overhead Persistent Infrared Block 0-Geosynchronous Earth Orbit Satellites (Next Gen OPIR Block 0 GEO)
Quarter 3 Fiscal Year 2024	» Future Long Range Assault Aircraft (FLRAA) » Indirect Fire Protection Capability Increment 2 (IFPC Inc 2)
Quarter 4 Fiscal Year 2024	» Conventional Prompt Strike (CPS) » Extended Range Cannon Artillery (ERCA) » Optionally Manned Fighting Vehicle (OMFV)
Quarter 4 Fiscal Year 2025	» Deep Space Advanced Radar Capability (DARC) » Evolved Strategic SATCOM (ESS) » Future Operationally Resilient Ground Evolution (FORGE) » Tranche 1 Transport Later (T1TL)
Quarter 1 Fiscal Year 2026	» Integrated Visual Augmentation System (IVAS) Rapid Fielding » Military GPS User Equipment (MGUE) Increment 2
Quarter 4 Fiscal Year 2026	» Tranche 1 Tracking Layer (T1 TRK)

Source: GAO analysis of Department of Defense data. | GAO-23-106059

Note: The Air Force has not committed to any Air-launched Rapid Response Weapon (ARRW) follow-on efforts. As such, the program did not provide an expected transition date.

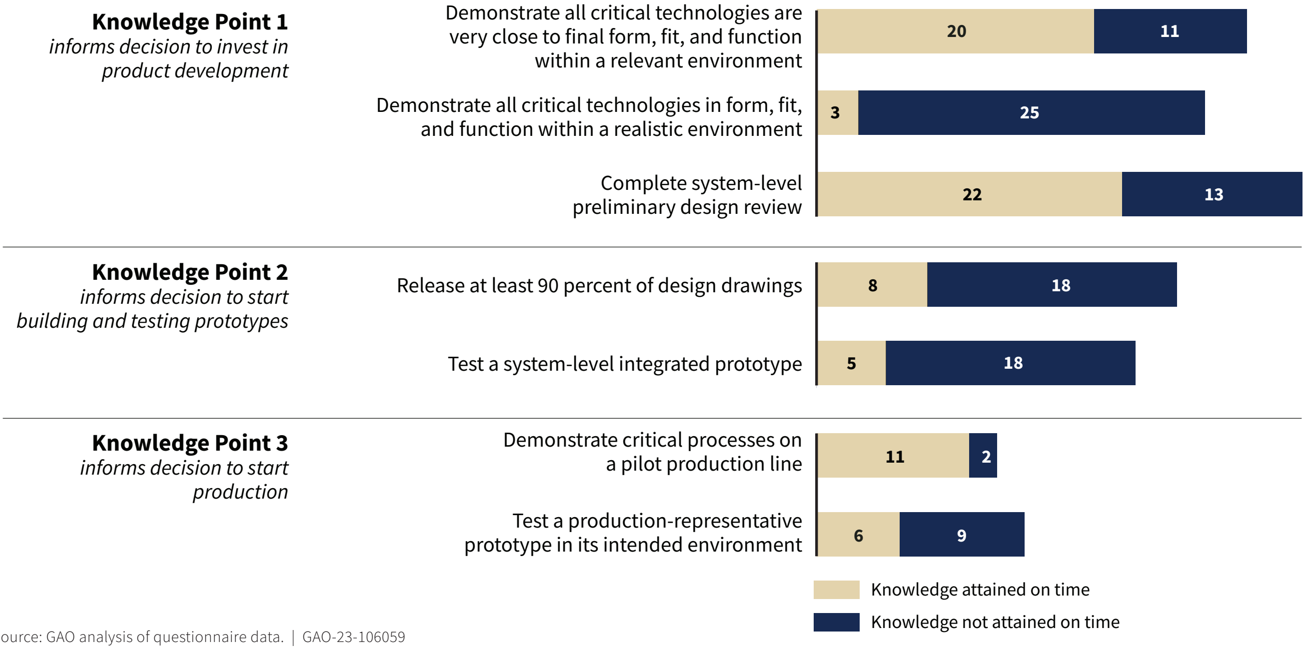
Knowledge-Based Practices

KNOWLEDGE ATTAINMENT TO INFORM MAJOR INVESTMENTS

Limited knowledge attainment poses risk for upcoming investment decisions.

MDAPs we assessed generally completed more of the seven leading acquisition practices on time since our last report. However, four of these practices had timely completion rates that remained below 50 percent, as shown in figure 23 below. Our body of work shows that attaining high levels of knowledge before making investment decisions drives positive cost and schedule outcomes. MDAPs that do not implement these practices may face greater risk of cost growth and schedule delays.

Figure 23: Major Defense Acquisition Programs Did Not Complete a Majority of Leading Acquisition Practices in Time to Inform Key Investment Decisions



Source: GAO analysis of questionnaire data. | GAO-23-106059

Note: The analysis for the figure above used the 35 MDAPs for which we completed 2-page assessments as a starting point. Knowledge attainment was assessed only for programs that had passed the relevant milestone and to which the practices applied.

Of the three MDAPs that we assessed for the first time this year, we saw differences in knowledge attainment that corresponded to where they entered in the acquisition cycle, as shown in figure 24.

The two MTA programs that transitioned to the major capability acquisition pathway in 2022—Mobile Protected Firepower (MPF) and F-15EX—entered the production phase and had the knowledge attainment to inform entry at that phase. MPF and F-15EX used the MTA pathway to select and refine mature systems prior to entering the major capability acquisition pathway, significantly reducing technical risks when entering production.

Sentinel—which started on the major capability acquisition pathway in 2020—entered development without fully maturing its critical technologies, increasing risk of costly and time-intensive rework if problems emerge later in development.

Figure 24: Knowledge Attainment at Entry into the Major Capability Acquisition Pathway for Recently Initiated Major Defense Acquisition Programs

Source: U.S. Air Force. I GAO-23-106059

Source: U.S. Army. I GAO-23-106059

Source: Northrop Grumman. I GAO-23-106059

F-15EX (Air Force)

- Program transitioned to production after a rapid fielding effort
- Mature technologies
- Stable design
- Proven production process
- Demonstrated capabilities with a production-representative prototype

Mobile Protected Firepower (Army)

- Program transitioned to production after a rapid prototyping effort
- No new technologies
- Incomplete design
- Proven production process
- Demonstrated capabilities with a production-representative prototype

LGM-35A Sentinel (Air Force)

- Program started in development
- 18 critical technologies: three are mature, 14 are approaching maturity, and one is immature
- Completed preliminary design review
- Opportunities remain to mature design, technologies, and production processes at forthcoming knowledge points

Source: GAO analysis of questionnaire data. | GAO-23-106059

Knowledge-Based Practices

PROGRAM OUTCOMES

MDAPs that made investment decisions without sufficient knowledge encountered delays.

In the past year, 18 MDAPs have reported new delays to their planned dates for achieving initial operational capability. The three programs below are examples of programs that had previously committed to major investments in system development without first completing leading practices that we have previously found reduce the risk of issues emerging later that require costly and time-intensive rework.

Infrared Search and Track (IRST)

The Navy's senior acquisition executive approved a new schedule baseline in May 2022 that **delayed planned operational capability by about 3 years** due to production quality issues on parts critical to delivering IRST capability. Officials told us that between 20 to 30 percent of the manufactured components failed to meet performance specifications.

The program completed its critical design review in 2012 **without first testing a system-level integrated prototype**, missing an opportunity to identify and address design issues before beginning production of IRST systems in 2015.

Source: U.S. Navy. | GAO-23-106059

Source: Boeing Corporation. | GAO-23-106059

T-7A Red Hawk

The program **declared a schedule breach** in June 2022, when testing determined the aircraft's ejection system did not meet airworthiness requirements. Program officials told us that, until the aircraft meets airworthiness criteria, the Air Force cannot use it for flight testing. The program is still in the process of determining the full extent of delays to its planned operational capability date.

The program entered into system development in 2018 **without first completing a preliminary design review**, missing an opportunity to identify and address this performance risk earlier in development.

VC-25B Presidential Aircraft

The Under Secretary of Defense for Acquisition and Sustainment approved a new program baseline in June 2022, which reflected a **more than 2-year delay to planned operational capability** due to technical issues with interior suppliers and designs, wiring design errors, and workforce shortages.

The program completed its critical design review in January 2020 **without first releasing at least 90 percent of design drawings**, missing an opportunity to identify and address design issues before beginning modification of the aircraft.

Source: The Boeing Company. | GAO-23-106059

Key Principles

MTA PROGRAMS AND FUTURE MAJOR WEAPON ACQUISITIONS

Programs reported using aspects of key product development principles employed by leading companies.

Our recent work on the product development approaches of leading commercial companies identified key principles of a disciplined approach to develop innovative products.[1] This year, for the first time, we asked the MTA programs and future major weapon acquisitions included in our review about whether they followed a selection of these sub-principles, which emphasize speed and innovation.

Some programs reported employing practices generally aligned with certain sub-principles of our leading companies. Yet, other programs reported not employing certain concepts, such as iterative development. See below for examples, along with additional takeaways related to implementation of the principles we identified. We have ongoing work to define metrics associated with these and other principles, which we expect will help refine our evaluation of programs' use of them in future assessments.

Principle 1, Sub-principle 3

Develop cost/schedule/performance tenets, or parameters, to define project goals before allocating initial funding.

The **Space Force's Evolved Strategic SATCOM** program outlined cost, schedule, and performance guardrails in its acquisition strategy, which the component acquisition executive approved over a year prior to obligation of funds.

Sub-Principle Takeaways

Our prior work shows that cost, schedule, and performance parameters are only useful if they are accompanied by leadership's willingness to end the program if the business case is compromised. Guardrails that exist only to trigger a program review and mitigation plan are inconsistent with key principles.

Principle 2, Sub-principle 1

Use modern design tools during both hardware and software development that enable multiple design iterations.

The **Army's Long-Range Hypersonic Weapon System** reported using 3D modeling to mature its hardware design and digital missile models and simulations to support testing. The program also employed 3D printing to produce subcomponents and iterate during design to ensure components fit together correctly.

Sub-Principle Takeaways

Our prior work shows that leading companies rely on digital engineering—specifically, digital twins—to create virtual representations of physical products to enable efficiencies during the design-build-test activities in development. Digital twins are used to exchange information and collect data to dynamically change along with the physical object in real time. Digital twin data can also be analyzed using artificial intelligence and machine learning to test different scenarios or make predictions for the physical twin.

Principle 2, Sub-principle 3

Use iterative design and testing to identify a minimum marketable product that can be followed by successive updates for both hardware and software development.

The **Army's Integrated Visual Augmentation System** program developed a series of prototypes of its augmented-reality headgear under a rapid prototyping MTA effort. The ongoing rapid fielding effort expects to release additional prototype iterations every 6 to 12 months that address feedback from user assessments and soldier touchpoints.

Sub-Principle Takeaways:

Our prior work shows that leading companies recognize the minimum capabilities needed to deliver a product to market that customers want. That product provides sufficient capability to meet users' needs in the near term and a starting point for subsequent iterations (products) that introduce new capabilities based on customer input.

Principle 3, Sub-principle 3

Off-ramp capabilities that present a risk to delivering the product on schedule.

The **Navy's MK 54 MOD 2 Advanced Lightweight Torpedo** program reported that it deferred high-altitude and vertical launch capabilities in order to deliver a minimally viable product faster. It plans to use an iterative approach to fully meet these user requirements after the initial operational capability.

Sub-Principle Takeaways

Our prior work shows that to deliver innovative products to market with speed, leading companies rely on early and ongoing customer input to help identify the capabilities most critical to a minimum marketable product. They do not approve business cases for elegant, capability packed products that necessitate long, often unpredictable, development timelines. Instead, leading companies understand that the quicker they can design and deliver a new, minimally viable product to their customers, the faster they can begin iterating to improve the capability of that product.

Principle 4, Sub-principle 2

Use customer feedback to identify challenges to address and new features to include in subsequent releases.

The **Army's Extended Range Cannon Artillery** program reported that it obtained end-user feedback through soldier touchpoints, surveys, written reports, and interviews. According to the program, this feedback has informed design upgrades, new features, and changes to make the system more effective.

Sub-Principle Takeaways

Our prior work shows that leading companies recognize that customer feedback is central to iterative development approaches. This feedback helps companies understand the needs of users and prioritize the capabilities included in minimum marketable products. Iterative development is defined by this ongoing customer input and continued revisiting of capability needs of a product. In contrast, incremental development relies on early determination of capability needs and carving up the development effort into segments matched to those needs.

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[1] GAO, *Leading Practices: Agency Acquisition Policies Could Better Implement Key Product Development Principles,* GAO-22-104513 (Washington, D.C.: Mar. 10, 2022).

Program Adoption of Modern Software Approaches and Recommended Cybersecurity Practices Is Mixed

DOD is in the process of modernizing its software development and taking actions to improve weapon systems cybersecurity. While there was a slight increase over prior years in the number of programs reporting the use of modern software development approaches, programs continue to lag in implementing recommended practices from the Defense Science Board to accelerate software development. Further, while many programs obtained frequent user feedback on software—a key feature of modern software development approaches—some programs did not start obtaining user feedback until more than a year into development. Programs also reported limited implementation of modular contracting and planned use of the software acquisition pathway, approaches that have the potential to improve software development. Lastly, most programs reported incorporating cybersecurity planning in early stages of the program. However, programs did not always report conducting or planning to conduct cybersecurity testing within recommended time frames.

Most Programs Reported Using Modern Development Approaches, but Lagged in Implementing Related Practices

Most programs reported the use of modern software development approaches (which we defined as either Agile, DevOps, DevSecOps, or an iterative approach). However, these programs did not fully implement related practices recommended by the Defense Science Board, DOD guidance, or our past work.

Use of modern software development approaches. Over each of the past 2 years, slightly more programs than during the prior year reported using at least one modern software development approach, as shown in figure 25.[40]

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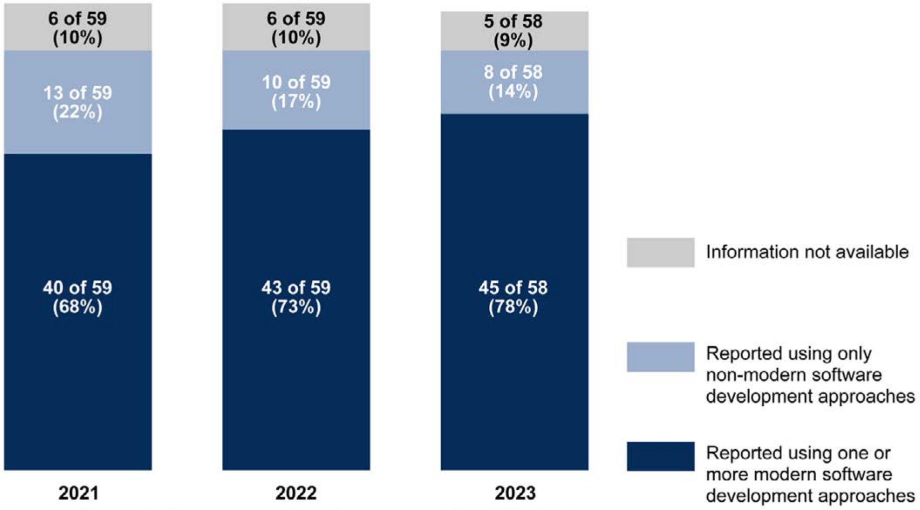
[40] In our 2022 report, we reported that 39 programs indicated the use of a modern software development approach. In our 2023 assessment, we modified our questionnaire to exclude “mixed” as one of the response options for the software development approach. We found four programs that had previously reported “mixed” to be using a modern software development approach. For these four programs, we adjusted all analyses accordingly for assessment years 2021 and 2022.

Figure 25: Slightly More Programs Reported Use of Modern Software Development Approaches in 2023 than in 2021 or 2022



Source: GAO analysis of programs' questionnaire responses. | GAO-23-106059

Note: Programs were considered to be using a modern software development approach if they reported the use of either Agile, DevOps, DevSecOps, or an iterative (other than Agile) approach. "Information not available" includes, among other responses, instances in which a program did not report a software development effort or had yet to start its software development effort.

Of the eight programs that reported only using older software development approaches, three programs reported plans to change to a modern approach in the future, while three programs reported they had no plans to switch.[41] Modern software development approaches—which hinge on rapid delivery of software to users—have been a priority for DOD to help ensure the department maintains its technological superiority and has the ability to respond to adversary advancements quickly by updating its systems accordingly.

Implementation of Defense Science Board software development recommended practices. Programs reporting the use of a modern approach continued to report limited implementation of practices recommended by the Defense Science Board. These practices are intended to help programs leverage commercial software development

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[41] Two of the eight programs that reported only using older software development approaches did not respond to our question on whether they had plans to switch to a modern approach. Reasons reported by programs on why they did not plan to switch to a modern software development approach included that their software development was nearing completion and the costs associated with modifying the existing contract.

approaches to deploy software quickly.[42] Despite DOD's continued emphasis on improving software development in acquisition programs, several practices recommended by the Defense Science Board that we included in our prior assessments show declining trends from last year (see table 5).

Table 5: Implementation of 2018 Defense Science Board Recommended Practices by Programs That Reported Using a Modern Software Development Approach

Recommended practice	2021	2022	2023	Progress from 2022
Creation of a software factory as a key source selection criterion	N/A[a]	N/A	5 of 45	N/A
	N/A	N/A	11%	
Use of software factory	8 of 40	11 of 43	9 of 45	Declined
	20%	26%	20%	
Delivery of minimum viable product, followed by next viable products	21 of 40	25 of 43	23 of 45	Declined
	53%	58%	51%	
Continuous iterative development	32 of 40	35 of 43	40 of 45	Improved
	80%	81%	89%	
Iterative development training for program manager(s) and staff	10 of 40	14 of 43	12 of 45	Declined
	25%	33%	27%	
Software documentation provided to Department of Defense at each production milestone	23 of 40	28 of 43	27 of 45	Declined
	58%	65%	60%	
Not employing any of these practices	4 of 40	3 of 43	1 of 45	Improved
	10%	7%	2%	

Source: GAO analysis of programs' questionnaire responses. | GAO-23-106059

Note: Programs were considered to be using a modern software development approach if they reported the use of either Agile, DevOps, DevSecOps, or an iterative (other than Agile) approach.

[a] The questionnaires for our assessments in 2021 and 2022 did not ask programs about the "creation of a software factory as a key source selection criterion."

Programs reported limited use of software factories, which the Defense Science Board stated are foundational to modern software development as they enable the developers, users, and management to work together on a daily basis. Nine out of the 45 programs reported the use of a software factory as part of their software development efforts. Further, five out of the 45 programs reported the use of a software factory as an evaluation criterion in the source selection process—a practice emphasized by the Defense Science Board as critical to improving DOD's

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[42] See table 2 in the report background for the recommended practices.

software development. DOD officials noted the term “software factory” has been superseded by “DevSecOps environments” in some cases, and may have been a factor in the decline of programs reporting the use of a software factory. We will continue to monitor this issue going forward for our next annual assessment.

Programs’ limited implementation of Defense Science Board recommended practices is consistent with DOD’s partial implementation of Defense Science Board recommendations at the department level. In April 2023, we reported that DOD had taken steps that partially addressed each of the Defense Science Board’s recommendations but had yet to fully implement them.[43] DOD officials stated that department-wide actions over the last several years focused on encouraging—rather than requiring—programs to adopt modern software development and acquisition practices.[44]

Modular contracting. Eleven of the 45 programs, approximately 25 percent, reported using modular contracting for their software development efforts. Modular contracting divides investments into smaller parts, and is intended to reduce program risk and incentivize contractor performance while meeting the government’s need for timely access to rapidly changing technology. It enables DOD to deliver capabilities more rapidly and permits easy adoption of newer and emerging technologies. According to DOD guidance, modular contracting is the preferred approach to acquire major software information technology systems in accordance with certain statutory and regulatory provisions.[45] Reasons cited by programs for not using modular contracting for their software development include that: it was not in accordance with the program’s

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[43] GAO-23-105611.

[44] DOD’s software acquisition pathway policy requires programs to implement some recommended practices by the Defense Science Board—such as the use of modern iterative software development methodologies. However, this policy applies only to efforts using the software acquisition pathway.

[45] Office of the Under Secretary of Defense for Acquisition and Sustainment, *Contracting Considerations for Agile Solutions: Key Agile Concepts and Sample Work Statement Language*, Version 1.0 (Washington, D.C.: Nov. 18, 2019). Modular contracting was established in title 41, section 2308 of the U.S. Code and is implemented in section 39.103 of the Federal Acquisition Regulations. Modular contracting is also identified as one of the key elements of an acquisition strategy by the software acquisition pathway guidance (DOD Instruction 5000.87).

acquisition strategy, it was not feasible due to the complex nature of the system, and it was not appropriate for classified software.

End user feedback. Nearly all programs reported obtaining or planning to obtain end user feedback on software. Specifically, 35 of the 45 programs reported obtaining end user feedback on software. Of the 10 programs that have yet to involve users, seven reported plans to do so in the future. The other three had no such plans.[46] Our previous work—as well as other DOD and industry studies—has found that user involvement is critical to successful software development efforts because it helps programs to detect deficiencies early. It is also linked to reducing risk, improving customer commitment, and improving technical staff motivation.[47]

For programs obtaining end user feedback, we asked about two aspects of that feedback—the frequency and when it began. We found that more than half of programs were obtaining feedback every 3 months or less, but we found that a substantial number of programs were not involving end users for more than a year after development started. While our past work did not include a specific time frame for end user involvement, we have reported that early and continuous involvement helps to increase the utility and effectiveness of user feedback. We will continue to monitor programs' end user engagement in the future.

- **Frequency of end user feedback.** Of the programs that reported using a modern software approach and involving end users, over half (20 of 35) reported a feedback frequency of 3 months or less.

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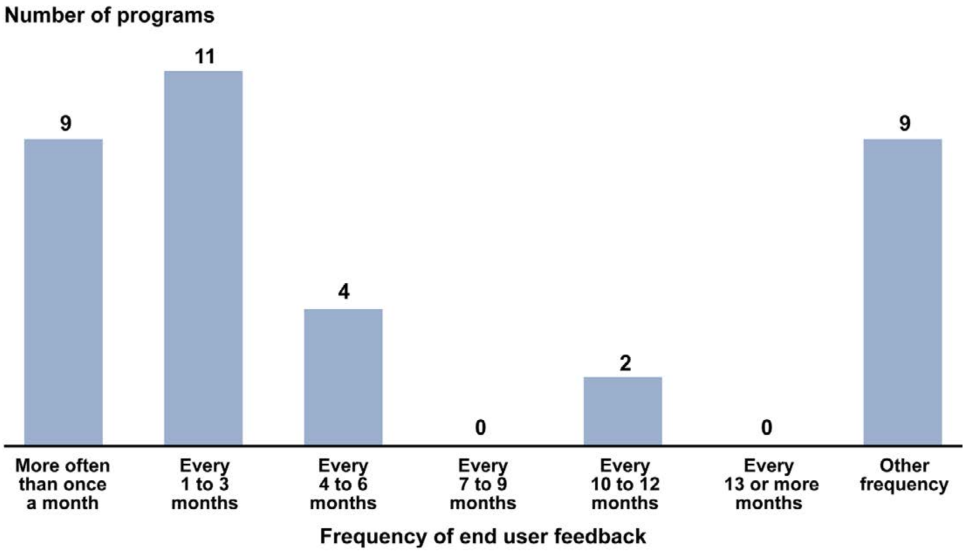
[46] Programs provided various reasons on why they did not plan to involve end users for evaluating and providing feedback on software. The Military GPS User Equipment Increment 1 program reported that the services acquiring the product were responsible for evaluating and providing feedback. The Military GPS User Equipment Increment 2 program indicated the software is embedded and has no direct user interface. The Next Generation Jammer Mid-Band program reported software is evaluated by test pilots.

[47] GAO, *Information Technology Reform: Agencies Need to Improve Certification of Incremental Development*, GAO-18-148 (Washington, D.C.: Nov. 7, 2017); *Software Development: Effective Practices and Federal Challenges in Applying Agile Methods*, GAO-12-681 (Washington, D.C.: July 27, 2012); and *Information Technology: Critical Factors Underlying Successful Major Acquisitions*, GAO-12-7 (Washington, D.C.: Oct. 21, 2011). Department of Defense, Office of the Under Secretary of Defense for Research and Engineering, Defense Science Board, *Design and Acquisition of Software for Defense Systems* (Washington D.C.: February 2018); and Software Engineering Institute, *Scaling Agile Methods for Department of Defense Programs*, Technical Note CMU/SEI-2016-TN-005 (December 2016).

Continual involvement on a regular, recurring basis throughout development is a characteristic of effective user engagement, with frequent feedback linked to reducing risk.[48] Modern software development approaches emphasize fast feedback cycles so that software is being continuously evaluated on functionality, quality, and user satisfaction. Figure 26 illustrates the frequency of end user feedback for programs that reported using a modern development approach.

Figure 26: Most Programs That Reported Using a Modern Software Development Approach Have Frequent End User Evaluation and Feedback



Source: GAO analysis of programs' questionnaire responses. | GAO-23-106059

Note: Programs were considered to be using a modern software development approach if they reported the use of either Agile, DevOps, DevSecOps, or an iterative (other than Agile) approach. "Other frequency" includes, among other things, during the test and evaluation phase, and as needed when software is available. Ten programs reported they do not currently involve end users. Seven of these programs reported plans to obtain end user feedback on software in the future, while three programs had no such plans.

- **Early end user engagement.** Nearly 40 percent of the 23 programs for which we could measure the timing of end user involvement did not involve end users until over a year after software development

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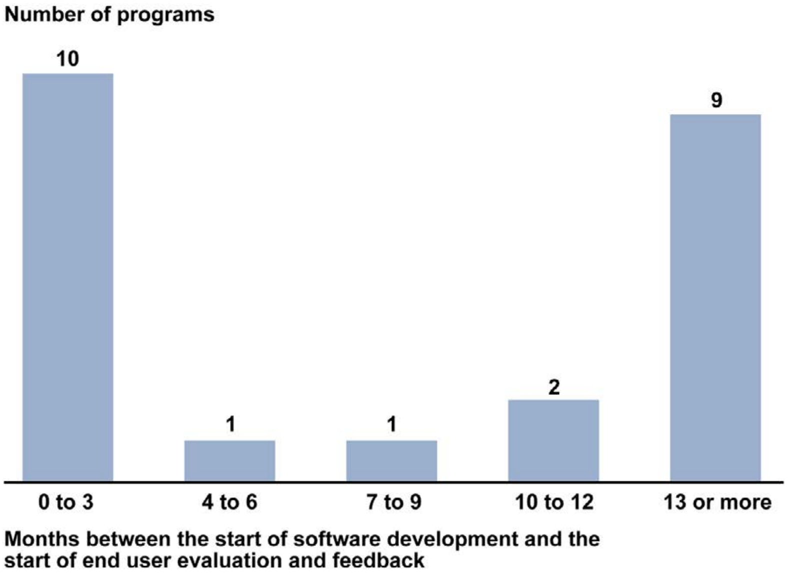
[48] GAO, *DOD Space Acquisitions: Including Users Early and Often in Software Development Could Benefit Programs*, GAO-19-136 (Washington, D.C.: Mar. 18, 2019).

started.[49] While our prior work did not identify a specific time frame for end user involvement, we reported that user involvement and feedback early in the development cycle is foundational for modern software development approaches and helps to ensure that development efforts align with user priorities.[50] Figure 27 shows the amount of time that elapsed from the start of software development to the time when end user feedback began for programs we assessed.

Figure 27: Start of End User Evaluation and Feedback Varies for Programs Reporting the Use of a Modern Software Development Approach



Source: GAO analysis of programs' questionnaire responses. | GAO-23-106059

Note: Programs were considered to be using a modern software development approach if they reported the use of either Agile, DevOps, DevSecOps, or an iterative (other than Agile) approach. Our analysis only included programs that reported both the start date for software development and the start date for end user evaluation and feedback on software. Sixteen programs did not report a start date for either software development or end user evaluation and feedback. Six programs reported a start date for end user evaluation and feedback before software development began.

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[49] Our analysis only included programs that reported both the start date for software development and the start date for end user evaluation and feedback on software. Sixteen programs did not report a start date for either software development or end user evaluation and feedback. Six programs reported a start date for end user evaluation and feedback before software development began.

[50] GAO-19-136.

Programs Reported Limited Plans to Use the Software Acquisition Pathway

Programs we assessed reported minimal use—as well as limited future plans to use—the software acquisition pathway. According to a DOD report to Congress, DOD's software acquisition pathway represents a significant component of modernizing the department's software development capabilities. It is designed to provide for the efficient and effective acquisition, development, integration, and timely delivery of secure software. Our previous work found DOD's software acquisition pathway aligned with key product development principles.[51] The pathway also requires several elements of modern software development that we assessed this year—such as the use of modern software development methodologies, as well as early and frequent end user feedback. However, these requirements only apply to efforts using the software acquisition pathway, and DOD policy does not require programs to use the software acquisition pathway to develop software.

One out of 58 MDAPs and MTA programs we assessed—the Army's Integrated Air and Missile Defense program—is using DOD's software acquisition pathway for its software development. Of the 57 programs not currently using the pathway, three reported plans to transition their software development efforts to it in the future, 28 reported no plans to transition, and 20 programs had yet to determine if they would transition.[52] For programs that had no plans to transition to the software acquisition pathway, reasons cited include:

- inability to deliver capability every year (a requirement of the pathway) due to flight testing constraints;
- completion or nearing completion of software development; and
- inefficiency of applying a separate management approach since software is a small part of the overall effort.

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[51] GAO, *Leading Practices: Agency Acquisition Policies Could Better Implement Key Product Development Principles*, GAO-22-104513 (Washington, D.C.: Mar. 10, 2022)

[52] Six programs did not provide a response on the use of the software acquisition pathway. The three programs that reported plans to transition software development efforts to the software acquisition pathway were the Space Force's Future Operationally Resilient Ground Evolution (FORGE) and Protected Tactical Enterprise Service (PTES) programs, and the Army's Future Long-Range Assault Aircraft (FLRAA) program.

As we noted last year, according to DOD officials, most hardware programs were established prior to the establishment of the software acquisition pathway, which may create a greater challenge for programs to switch their ongoing software development efforts to the software acquisition pathway.

We will continue to monitor the extent of software acquisition pathway use and have ongoing work on the extent to which DOD policies and guidance support programs using modern software development approaches.

Some Programs Lack Awareness of Potential Use of the Software Acquisition Pathway

Four programs indicated a lack of awareness that they could manage software development efforts separately on the software acquisition pathway. Two of these programs have software development efforts estimated to cost more than $100 million. These programs reported that they are not using the pathway for their software development efforts and had no plans to transition because their program was not a software-only program.

However, the software acquisition pathway includes an embedded software path for software embedded in weapon systems and other military-unique systems. This path allows the program to acquire the hardware in which the software is embedded through other acquisition pathways—for example, the major capability acquisition—while it can acquire the system software through the software acquisition pathway to achieve potential benefits associated with the pathway.

Source: GAO analysis of programs' questionnaire data and Department of Defense Instruction 5000.87. | GAO-23-106059

Programs Did Not Consistently Report Scheduling Cybersecurity Test Events before Key Milestones

Programs generally developed cybersecurity strategies and included cybersecurity in requirements documents, as required by DOD policy, but did not consistently report scheduling cybersecurity test events to ensure they happened before key program decision points. We previously reported that cyberattacks can target any weapon system that is dependent on software, potentially leading to an inability to complete military missions or even loss of life.[53] Through proper planning and timely testing, programs can reduce their cybersecurity risks.

- **Cybersecurity strategies.** Consistent with our recent assessments since 2021, all 58 programs reported either having an approved cybersecurity strategy or planning to have one in the future. DOD policy generally requires all acquisitions containing mission-critical or mission-essential IT systems to have a cybersecurity strategy.[54]
- **Cybersecurity requirements.** A majority of programs included cybersecurity provisions in key requirements documents.[55] Specifically, 45 of 58 (78 percent) programs reported that a key performance parameter, key system attribute, or MTA requirements document addressed cybersecurity.[56] Reasons cited by programs for not having cybersecurity addressed in requirements documentation include that it was addressed in another program document or that the key performance parameters had yet to be determined. We previously reported that programs that include cybersecurity in key aspects of the requirements processes help to give cybersecurity a more prominent role in key acquisition decisions.[57] Further, we also found that adding on cybersecurity late in the development cycle or after a

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[53] GAO-19-128.

[54] Department of Defense, *Cybersecurity*, DOD Instruction 8500.01 (Mar. 14, 2014) (Change 1 Effective Oct. 7, 2019); and *Information Assurance (IA) in the Defense Acquisition System*, DOD Instruction 8580.1 (July 9, 2004).

[55] We modified the question on whether cybersecurity provisions were included in key requirements documents this year to include the option of an MTA requirements document and are, thus, unable to compare results for this question with our prior assessment.

[56] Under the Joint Capabilities Integration and Development System, key performance parameters are a system's performance attributes that are considered most critical to the development of an effective military capability. Key system attributes are a system's performance attributes that are considered important to achieving a balanced solution but not critical enough to be designated a key performance parameter. See Department of Defense, *Manual for the Operation of the Joint Capabilities Integration and Development System* (Aug. 31, 2018).

[57] GAO-19-128.

system has been deployed is more difficult and costly than designing it in from the beginning.

- **Cybersecurity assessments.** Results were mixed on whether MDAPs completed or planned key cybersecurity test and evaluation assessments before certain program events occurred—the start of initial production (Milestone C), initial operational test and evaluation, or the full-rate production decision—as recommended by DOD guidance.[58] Early and regular discovery of mission-impacting system vulnerabilities makes it easier to fix vulnerabilities and reduces risk to schedule. According to the DOD *Cybersecurity Test and Evaluation Guidebook*, late testing can result in much more difficultly implementing fixes due to the time constraints and the lack of funding before fielding or deployment. Programs that do not complete these tests in a timely manner may risk discovering vulnerabilities later in the acquisition process, resulting in adverse outcomes. This is the first year we assessed the timing of cybersecurity testing in our annual assessment, and we plan to continue to examine this topic in future years to obtain additional insight. Figure 28 summarizes DOD guidance on when program cybersecurity test and evaluation activities should be conducted throughout the acquisition life cycle.

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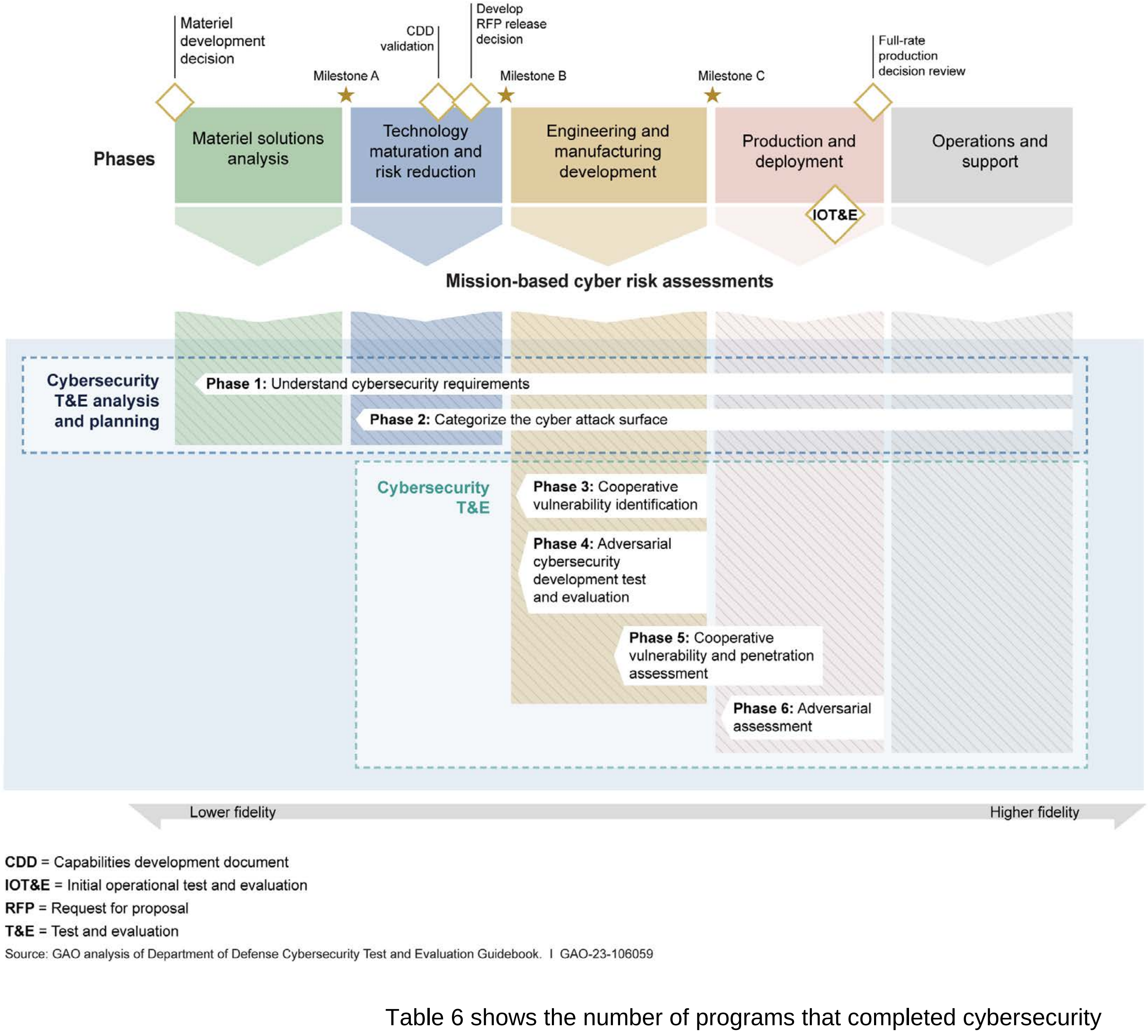
[58] All DOD acquisition programs and systems, regardless of acquisition pathway, are required by DOD Instruction 5000.89 to execute cybersecurity iterative testing and evaluation processes detailed in the DOD *Cybersecurity Test and Evaluation Guidebook* throughout the program’s life cycle. Our analysis excludes program events that occurred before DOD originally published its *Cybersecurity Test and Evaluation Guidebook* on July 1, 2015.

Figure 28: Timeline of Department of Defense (DOD) Cybersecurity Test and Evaluation Activities Recommended by DOD Guidance during the Acquisition Life Cycle



CDD = Capabilities development document
IOT&E = Initial operational test and evaluation
RFP = Request for proposal
T&E = Test and evaluation

Source: GAO analysis of Department of Defense Cybersecurity Test and Evaluation Guidebook. I GAO-23-106059

Table 6 shows the number of programs that completed cybersecurity assessments before recommended program events, among programs that have passed these events.

Table 6: Some Major Defense Acquisition Programs' Cybersecurity Assessments Did Not Occur before Key Program Events

Cybersecurity assessment	Cooperative Vulnerability Identification	Adversarial Cybersecurity Development Test and Evaluation	Cooperative Vulnerability and Penetration Assessment	Adversarial Assessment
Key program event	Start of production (Milestone C)	Start of production (Milestone C)	Initial operational test and evaluation	Full-rate production decision
Programs completing assessment before applicable program event	9 of 11	1 of 4	9 of 11	7 of 7
	82%	25%	82%	100%

Source: GAO analysis of programs' questionnaire responses. | GAO-23-106059

Note: Results shown are for programs that reported relevant dates for comparison. For example, 11 programs reported their production start date and their Cooperative Vulnerability Identification completion date, while only four programs reported their production start date and their Adversarial Cybersecurity Development Test and Evaluation completion date. Programs that did not report a completion date for a cybersecurity assessment may have yet to conduct or did not conduct the assessment. The analysis excludes program events that occurred before the Department of Defense originally published its *Cybersecurity Test and Evaluation Guidebook* on July 1, 2015.

Table 7 shows the number of programs that plan to complete cybersecurity assessments before recommended program events, among programs that have yet to reach these events.

Table 7: Some Major Defense Acquisition Programs' Cybersecurity Assessments Not Planned to Occur before Key Program Events

Cybersecurity assessment	Cooperative Vulnerability Identification	Adversarial Cybersecurity Development Test and Evaluation	Cooperative Vulnerability and Penetration Assessment	Adversarial Assessment
Key program event	Start of production (Milestone C)	Start of production (Milestone C)	Initial operational test and evaluation	Full-rate production decision
Programs planning to complete assessment before applicable program event	3 of 6	3 of 6	10 of 16	9 of 11
	50%	50%	63%	82%

Source: GAO analysis of programs' questionnaire responses. | GAO-23-106059

Note: Results shown for programs that reported relevant dates for comparison. For example, six programs reported their production start date and their planned Cooperative Vulnerability Identification date, while 16 programs reported their initial operational test and evaluation date and their planned Cooperative Vulnerability and Penetration Assessment date. The analysis excludes program events that occurred before the Department of Defense originally published its *Cybersecurity Test and Evaluation Guidebook* on July 1, 2015.

We will continue to evaluate DOD’s implementation of its cybersecurity test and evaluation guidance, among other topics, as part of our ongoing work reviewing weapon system cybersecurity.[59]

Programs Face Challenges Meeting Congress’s Increased Emphasis on Modular Open Systems Approaches

Following recent statutory provisions requiring DOD to implement a MOSA for weapon systems acquisition programs, DOD has made organizational and policy changes and is developing enhanced guidance. A majority of programs reported that they are using a MOSA. However, they noted implementation challenges such as integrating a MOSA with systems that were not developed using a MOSA, necessitating a high level of planning and coordination with other government and industry groups than other programs, and obtaining sufficient documentation from contractors to competitively upgrade components. Further, many programs using a MOSA did not report using open standards or indicate plans to test whether they have successfully implemented a MOSA—important building blocks to help ensure a MOSA achieves intended benefits.

DOD Implemented Organizational and Policy Changes in Response to Recent Legislation

The National Defense Authorization Act for Fiscal Year 2017 contained a provision requiring DOD to design and develop MDAPs with a MOSA to the maximum extent practicable.[60] The William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 expanded this requirement to include all defense programs and required USD(A&S) to issue regulations and guidance related to MOSAs.[61] In response to these and other statutory provisions, DOD has implemented organizational and policy changes and is developing additional guidance for MOSA implementation. A MOSA enables acquisition programs to more easily add, remove, and replace components as well as use a variety of suppliers over the life cycle of the system.[62]

In 2022, DOD reorganized USD(R&E) to have the Director of Systems Engineering and Architecture report directly to the Under Secretary. USD(R&E) officials told us that the purpose of this reorganization was to

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[59] The Senate report accompanying the National Defense Authorization Act for Fiscal Year 2020 included a provision for us to review DOD’s efforts to improve the cybersecurity of its major defense acquisition programs.

[60] See Pub. L. No. 114-328, § 805(a) (2016) (codified as amended at 10 U.S.C. § 4401). This provision applies to MDAPs receiving Milestone A or B approval after January 1, 2019.

[61] Pub. L. No. 116-283, § 804 (2021) (codified at 10 U.S.C. § 4401).

[62] See appendix VI for an overview of MOSA-related provisions in recent legislation.

prioritize MOSA implementation. Among other MOSA-related activities, they noted this office has convened working groups with the military departments to discuss MOSA challenges, the findings of which they have used to develop guidance. They also coordinated with the Defense Acquisition University on a November 2022 update to MOSA training for the acquisition workforce.

DOD also recently updated policy to include MOSA requirements and is working on enhanced MOSA guidance. Specifically, in 2020, DOD issued an instruction that directed lead systems engineers, under the direction of program managers, to use a MOSA to the maximum extent possible in accordance with statutory provisions and identified the military departments as the implementing organizations.[63] Further, according to officials from the Offices of the USD(R&E) and USD(A&S), DOD is developing additional MOSA regulation and guidance, including:

- A regulation to facilitate DOD's use of modular system interfaces, as required by the NDAA for Fiscal Year 2021.[64] USD(A&S) officials told us that they estimate releasing a draft for public comment in 2023.
- Detailed MOSA guidance and metrics to assess MOSA implementation, which we previously recommended.[65]

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[63] Department of Defense, *Engineering of Defense Systems*, DOD Instruction 5000.88 (Nov. 18, 2020).

[64] William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Pub. L. No. 116-283, § 804.

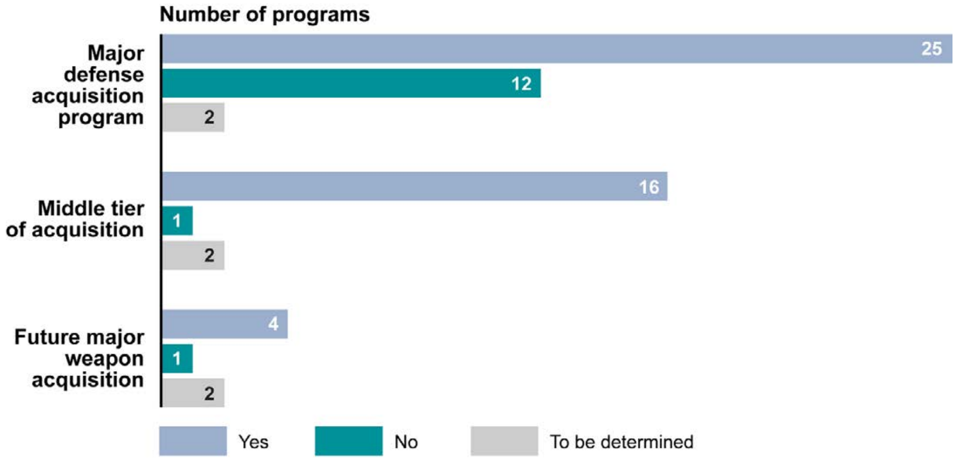
[65] GAO-13-651.

One focus of forthcoming guidance will be MOSA-related contract language, according to officials from the Office of the USD(R&E). They told us they plan to provide example contract language to assist programs. Some programs described using broad contract language that delegated decisions about the specifics of MOSA implementation to the contractor. USD(R&E) officials stated that delegating key MOSA decisions to contractors puts the program at risk of acquiring a system that is effectively proprietary and misses opportunities for program executive offices and the military departments to strategically implement a MOSA across programs.

Most Programs Reported Using a MOSA but Noted Challenges with Implementation

Most programs of all types that we assessed reported they are implementing a MOSA, as shown in figure 29.

Figure 29: Programs Reporting Implementation of a Modular Open Systems Approach by Acquisition Pathway



Source: GAO analysis of program's questionnaire responses. | GAO-23-106059

The most common reason programs cited for not incorporating a MOSA was that they were not subject to the NDAA mandate due to their

Examples of Challenges Working with Contractors to Implement a Modular Open Systems Approach (MOSA)

One major defense acquisition program (MDAP) reported that it does not anticipate receiving the documentation it needs to compete future capabilities. This may drive higher sustainment and upgrade costs over its life cycle.

Another MDAP reported that it delegated key MOSA decisions to the contractor, including selecting open standards. However, the program reported that many elements were missing from the contractor's MOSA plan, including full descriptions of all the subsystems, interface definitions, licensing, and data rights.

Source: GAO analysis of Department of Defense questionnaire responses. | GAO-23-106059 program start date.[66] Other reasons programs cited for not implementing a MOSA included concerns about increased acquisition cost and longer schedule durations. DOD officials told us that cost and schedule are such high priorities for program managers that they have little incentive to spend time implementing a MOSA if they perceive it will increase costs or cycle time. However, while implementing a MOSA may take more time and money in development, it can be a key enabler of future innovation because a variety of vendors can compete to offer upgrades on existing systems. Our prior work also shows that open systems have the potential to reduce sustainment costs—which constitutes the largest expense over a program's life cycle—to a much larger extent than the corresponding increase in development costs.[67]

Programs that reported implementing a MOSA cited challenges such as:

- integrating systems into a MOSA that were not developed using a MOSA,
- finding sufficient resources to devote to planning for which systems should be modular, and
- obtaining sufficient documentation from contractors to allow the program to work with new vendors in the future.

USD(R&E) officials noted that some programs may find it easier to implement a MOSA because they are in acquisition organizations with extensive MOSA experience that have provided guidance and prioritized MOSA across their portfolio. For example, Army Program Executive Office Aviation and the Air Force Life Cycle Management Command have both provided MOSA guidance. However, USD(R&E) officials also noted that other programs do not have as many resources and find it harder to successfully implement a MOSA.

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[66] The NDAA for Fiscal Year 2017 directed DOD to implement MOSA to the maximum extent practicable for MDAPs receiving Milestone A or B approval—program start and entering development start, respectively—after January 1, 2019. See Pub. L. No. 114-328, § 805(a)(1) (2016) (codified as amended at 10 U.S.C. § 4401). The William M. (Mac) Thornberry NDAA for Fiscal Year 2021 directed DOD to also design and develop other acquisition programs with a MOSA to the maximum extent practicable. See Pub. L. No. 116-283, § 804(b)(1) (2021) (codified at 10 U.S.C. § 4401).

[67] GAO-13-651.

Many Programs Have Yet to Implement Certain Practices for Successful MOSA Implementation

Many programs reported that they have yet to implement open standards and have yet to conduct timely verification testing for successful MOSA implementation. Statute defines a MOSA as an integrated business and technical strategy that, among other things, is subject to verification to ensure relevant modular system interfaces either (1) comply with, if available and suitable, widely supported and consensus-based standards, which we refer to as open standards; or (2) are delivered pursuant to a set of alternative statutory requirements for which DOD is currently developing regulations and guidance.[68] Implementing open standards and conducting verification testing are important building blocks to achieve the intended benefits of a MOSA. However, many programs reported that they have yet to implement these practices.

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[68] Title 10, section 4401 of the U.S. Code was originally enacted by section 805 of the NDAA for Fiscal Year 2017. This provision defined MOSA as an integrated business and technical strategy that, among other things, is subject to verification to ensure major system interfaces comply with open standards, if available and suitable. See Pub. L. No. 114-328, § 805 (a)(1) (2016) (codified as amended at 10 U.S.C. § 4401). The William M. (Mac) Thornberry NDAA for Fiscal Year 2021, amended this section to change the term "major system interfaces" to "relevant modular system interfaces," and to include, as part of the definition for a MOSA, integrated business and technical strategies that are subject to verification to ensure that relevant modular system interfaces are delivered pursuant to requirements established in section 804(a)(2)(B) of the William M. (Mac) Thornberry NDAA for Fiscal Year 2021. See Pub. L. No. 116-283, § 804(b)(1) (2021) (codified at 10 U.S.C. § 4401). Section 804(a) of the William M. (Mac) Thornberry NDAA for Fiscal Year 2021 requires OUSD(A&S) to develop regulations and guidance that include these requirements within one year following the enactment of the William M. (Mac) Thornberry NDAA for Fiscal Year 2021. As of February 2023, officials from OUSD(A&S) told us they were developing regulations and guidance.

Open Standards

Over half of programs that reported using a MOSA did not report using open standards. According to DOD guidance, appropriate selection and application of standards can be contribute to healthy competition throughout the program's acquisition life cycle.[69] We have previously reported that open standards allow for many suppliers to compete in the marketplace, and consumers no longer have to be dependent on any single supplier for parts or upgrades.[70] However, DOD guidance notes that accessing and selecting appropriate standards can be challenging because most were originally developed to solve a specific problem set. Accordingly, there can be numerous standards and each has multiple possible configurations.

Examples of Open Standards

Sensor Open Systems Architecture

Sensor Open Systems Architecture (SOSA) is an example of an open standard. SOSA was developed by a consortium of government and industry partners. Any vendor can access the SOSA standard to develop compliant sensor technologies for Department of Defense programs. In addition to the technical standard, the SOSA Consortium regularly convenes conferences.

Open Mission Systems

Open Mission Systems (OMS) is a government-owned standard developed with industry partners that allows systems to communicate using a shared data format. Using OMS, vendors can develop components without disclosing the full design, as long as they specify the external interfaces and their compliance with OMS.

Source: GAO analysis of Department of Defense documents. | GAO-23-106059

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[69] Department of Defense, Office of the Under Secretary of Defense for Research and Engineering, *Modular Open Systems Approach (MOSA) Reference Frameworks in Defense Acquisition Programs* (May 2020).

[70] GAO-13-651.

Standard Challenges

Programs reported challenges with selecting open standards and technical obstacles while developing the systems to which they conform.

A middle tier of acquisition program reported that the large number of standards available coupled with the pace of industry change made it difficult to determine the program's path forward for modular open systems implementation.

One major defense acquisition program reported that two major systems were developed using different versions of the same standard—one more recent than the other—leading to interoperability issues. The program said that reconciling the two is a continuing challenge.

Source: GAO analysis of Department of Defense questionnaire responses. | GAO-23-106059

Program responses to our questionnaire echoed these challenges. USD(R&E) officials told us that program offices may not be aware of which applicable standards are already in use, so programs with similar capabilities may not use the same standards and may not be able to interoperate. USD(R&E) officials told us that the Defense Standardization Program Office, also part of USD(R&E), is tasked with identifying MOSA standards and collecting them in a database.[71]

Verification Testing Plans

Many programs did not report plans to conduct MOSA verification tests in their responses to our questionnaire. Statute defines a MOSA as an integrated business and technical strategy that, among other things, is subject to verification to ensure compliance with open standards, if available and suitable, or are delivered pursuant to a set of alternative statutory requirements.[72] Verifying a MOSA for compliance with open standards is a necessary step to ensure that the system will be able to accept future upgrades and replacements, as expected, and interoperate with other systems that comply with the same standards. Examples of verification include running software compliance checks or plugging in a component from another system developed under the same standard.

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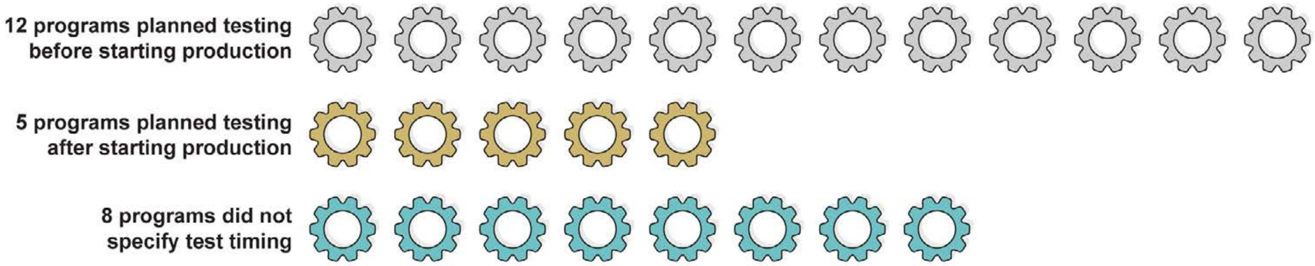
[71] The House and Senate committee reports accompanying bills for the NDAA for Fiscal Year 2023 included provisions for GAO to assess DOD's use of MOSA in developing weapon systems.

[72] 10 U.S.C. § 4401.

Most programs did not report including MOSA verification in their test plans, and most programs with production milestones did not report plans to verify a MOSA before production start. Among the 45 programs that reported implementing a MOSA, 18 reported that their test plan includes verifying conformance to the MOSA standards.[73] Further, the majority of MDAPs using a MOSA did not report plans to test conformance to standards before beginning production, as shown in figure 30.[74]

Figure 30: The Majority of Major Defense Acquisition Programs (MDAP) Using a Modular Open Systems Approach Do Not Plan to Verify Conformance before Production



Source: GAO analysis of programs' questionnaire responses; GAO (icons). | GAO-23-106059

Note: Programs that did not specify the timing of their verification plans provided varying explanations. For example, one of these programs reported verification focused on its prime contractor completing studies to mature its MOSA, while another program noted that it did not plan to conduct verification testing until a new component was funded.

We have previously found that identifying and fixing issues before starting production mitigates the risk of costly and time-intensive rework on units that are already being built. Programs that do not plan for and conduct verification testing before the start of production cannot be certain that they will achieve the intended benefits of a MOSA, such as interoperating with systems in the field and competitively seeking upgrades from new contractors.[75]

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[73] Future major weapon acquisitions are too early in development to report on their test plans, so they are not included in this analysis.

[74] Of the programs we assessed, only MDAPs have consistent milestones they must reach before production start, so we asked them to report whether they planned to verify a MOSA before or after that stage. We excluded MTA programs and future major weapon acquisitions from this analysis because they do not have consistent production milestones.

[75] GAO-04-386SP.

USD(R&E) officials told us that verification should take place before production start and that issues such as leaving a MOSA out of test plans or not planning to verify MOSA prior to critical milestones are driven, in part, by a lack of guidance. Currently, neither DOD's systems engineering policy nor MOSA guidance fully addresses when programs should complete verification testing, or how planning for the verification testing should be documented. DOD Instruction 5000.88 does not specifically address verification.[76] USD(R&E) officials stated that the policy has not been updated to reflect the MOSA-related provisions in the NDAA for Fiscal Year 2021. They explained that their priority has been coordinating with the military departments to develop implementation guidance. DOD guidance states that programs should provide a test plan, procedures, and verification methods across the program life cycle to ensure conformance to standards.[77] However, this guidance provision does not address specific timing or critical points at which testing should be completed, nor does it address specifically how programs should document MOSA verification testing plans.

USD(R&E) officials told us that they recognize that ensuring programs are adequately verifying a MOSA is a challenge, and they are working to address it by developing new guidance, informed by a verification working group established by the Office of the USD(R&E). These officials stated that, while this guidance is a first step to fully address this challenge, additional updates may need to be made to relevant DOD policies and guidance that address other aspects of the acquisition process, such as test and evaluation and the AAF.

If DOD ensures any new guidance and updates to relevant policies specify when acquisition programs should conduct MOSA verification and how they should document planning for verification testing, it could reduce the risk of programs discovering conformance problems at a later stage when fixing them could lead to cost growth and schedule delays. USD(R&E) officials told us that programs that do not meet verification requirements risk putting systems in the field that will not be capable of

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[76] Department of Defense, *Engineering of Defense Systems*, DOD Instruction 5000.88 (Nov. 18, 2020).

[77] Department of Defense, Office of the Under Secretary of Defense for Research and Engineering, *Modular Open Systems Approach (MOSA) Reference Frameworks in Defense Acquisition Programs* (May 2020).

interfacing with other mission-critical systems, will be harder to update, and will become obsolete faster.

Conclusions

The need for DOD to deliver innovative capability to the warfighter quickly remains as pressing as ever, a fact highlighted in the most recent update to the National Defense Strategy. In our last several annual assessments, we have highlighted practices that can help better position the department to achieve this goal, such as conducting effective oversight of new acquisition pathways and gaining additional insight into industrial base challenges.

This year, we identified an opportunity for DOD to strengthen its implementation of a MOSA, a key technical and business strategy that will enable the department to more effectively keep pace with technological change and save money in the sustainment phase. Most programs report that they are using a MOSA. However, to ensure that DOD is truly obtaining the benefits offered by a MOSA, programs must verify that planned approaches for individual systems work as intended. By ensuring any new guidance and updates to relevant policies specify when MOSA verification should take place and how verification plans should be documented, DOD could help ensure that programs catch any problems before they hinder interoperability in the field or create obstacles for future upgrades and replacements.

Recommendation for Executive Action

The Secretary of Defense should ensure that the Under Secretary of Defense for Research and Engineering and the Under Secretary of Defense for Acquisition and Sustainment include the appropriate times during an acquisition program’s development for programs using AAF pathways to complete MOSA verification testing and how plans for conducting that testing should be documented in new guidance and updates to relevant DOD policies. (Recommendation 1)

Agency Comments

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

We are sending copies of this report to the appropriate congressional committees and offices; the Secretary of Defense; the Secretaries of the Army, Navy, and Air Force; and the Director of the Office of Management and Budget. In addition, the report will be made available at no charge on the GAO website at http:/www.gao.gov.

If you or your staff have any questions concerning this report, please contact me at (202) 512-4841 or oakleys@gao.gov. Contact points for our offices of Congressional Relations and Public Affairs may be found on the last page of this report. Staff members making key contributions to this report are listed in appendix VIII.

Shelby S. Oakley

Shelby S. Oakley
Director, Contracting and National Security Acquisitions

List of Committees

The Honorable Jack Reed
Chairman
The Honorable Roger Wicker
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Jon Tester
Chair
The Honorable Susan Collins
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

The Honorable Ken Calvert
Chair
The Honorable Betty McCollum
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: Program Assessments

This section contains 65 assessments of weapon programs focused on the extent to which programs are following a knowledge-based acquisition approach to product development.[78]

For 35 MDAPs, we produced two-page assessments discussing cost and schedule performance, technology, design, and manufacturing knowledge obtained, software and cybersecurity efforts, as well as other program issues. The 35 MDAPs for which we developed two-page assessments are primarily in development or early production. See figure 31 for an illustration of the layout of each two-page assessment.

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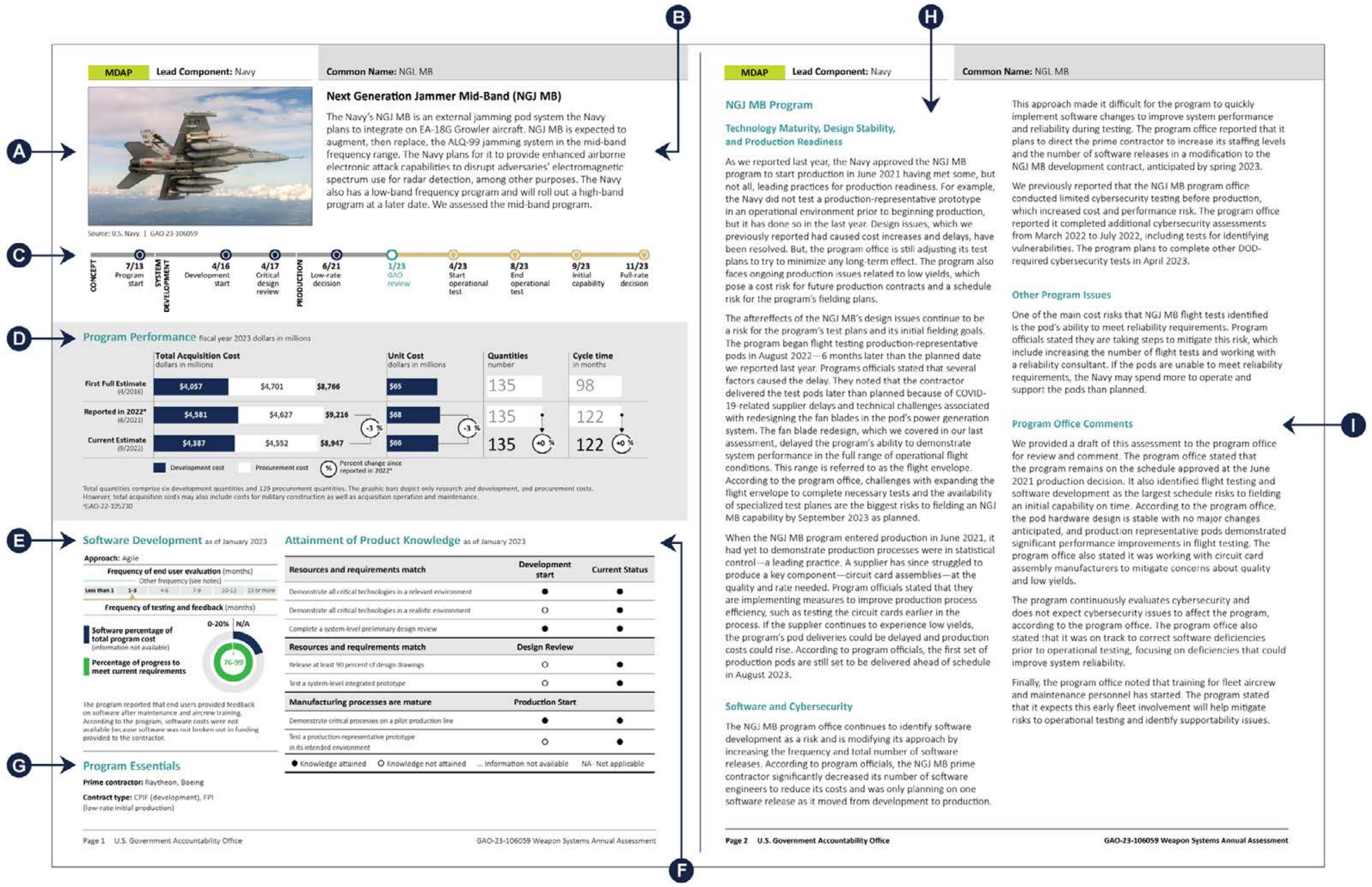
[78] The assessments also contain basic information about the program, including the prime contractor(s) or other identified contractors, and contract type(s). We abbreviated the following contract types: cost reimbursement (CR), cost-plus-award-fee (CPAF), cost-plus-fixed-fee (CPFF), cost-plus-incentive-fee (CPIF), firm-fixed-price (FFP), fixed-price-award-fee (FPAF), fixed-price incentive (FPI), and indefinite delivery/indefinite quantity (IDIQ). For some FPI contracts, we distinguished between their forms: firm target (FPIF) and successive targets (FPIS).

Figure 31: Illustration of Two-Page Major Defense Acquisition Program Assessment



MDAP **Lead Component:** Navy **Common Name:** NGL MB

Next Generation Jammer Mid-Band (NGJ MB)

The Navy's NGJ MB is an external jamming pod system the Navy plans to integrate on EA-18G Growler aircraft. NGJ MB is expected to augment, then replace, the ALQ-99 jamming system in the mid-band frequency range. The Navy plans for it to provide enhanced airborne electronic attack capabilities to disrupt adversaries' electromagnetic spectrum use for radar detection, among other purposes. The Navy also has a low-band frequency program and will roll out a high-band program at a later date. We assessed the mid-band program.

Source: U.S. Navy. | GAO-23-106059

CONCEPT
7/13 Program start
SYSTEM DEVELOPMENT
4/16 Development start
4/17 Critical design review
PRODUCTION
6/21 Low-rate decision
1/23 GAO review
4/23 Start operational test
8/23 End operational test
9/23 Initial capability
11/23 Full-rate decision

Program Performance fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions			Unit Cost dollars in millions	Quantities number	Cycle time in months
First Full Estimate (4/2016)	$4,057	$4,701	$8,766	$65	135	98
Reported in 2022ª (6/2021)	$4,581	$4,627	$9,216	$68	135	122
Current Estimate (9/2022)	$4,387	$4,552	$8,947	$66	135	122
Percent change since reported in 2022ª			-3 %	-3 %	+0 %	+0 %

■ Development cost ☐ Procurement cost (%) Percent change since reported in 2022ª

Total quantities comprise six development quantities and 129 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.
ªGAO-22-105230

Software Development as of January 2023

Approach: Agile

Frequency of end user evaluation (months)
Other frequency (see notes)
Less than 1 | 1-3 | 4-6 | 7-9 | 10-12 | 13 or more

Frequency of testing and feedback (months)

Software percentage of total program cost (information not available): 0-20% | N/A

Percentage of progress to meet current requirements: 76-99

The program reported that end users provided feedback on software after maintenance and aircrew training. According to the program, software costs were not available because software was not broken out in funding provided to the contractor.

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Resources and requirements match	**Design Review**	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

Program Essentials

Prime contractor: Raytheon, Boeing

Contract type: CPIF (development), FPI (low-rate initial production)

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MDAP **Lead Component:** Navy **Common Name:** NGL MB

NGJ MB Program

Technology Maturity, Design Stability, and Production Readiness

As we reported last year, the Navy approved the NGJ MB program to start production in June 2021 having met some, but not all, leading practices for production readiness. For example, the Navy did not test a production-representative prototype in an operational environment prior to beginning production, but it has done so in the last year. Design issues, which we previously reported had caused cost increases and delays, have been resolved. But, the program office is still adjusting its test plans to try to minimize any long-term effect. The program also faces ongoing production issues related to low yields, which pose a cost risk for future production contracts and a schedule risk for the program's fielding plans.

The aftereffects of the NGJ MB's design issues continue to be a risk for the program's test plans and its initial fielding goals. The program began flight testing production-representative pods in August 2022—6 months later than the planned date we reported last year. Programs officials stated that several factors caused the delay. They noted that the contractor delivered the test pods later than planned because of COVID-19-related supplier delays and technical challenges associated with redesigning the fan blades in the pod's power generation system. The fan blade redesign, which we covered in our last assessment, delayed the program's ability to demonstrate system performance in the full range of operational flight conditions. This range is referred to as the flight envelope. According to the program office, challenges with expanding the flight envelope to complete necessary tests and the availability of specialized test planes are the biggest risks to fielding an NGJ MB capability by September 2023 as planned.

When the NGJ MB program entered production in June 2021, it had yet to demonstrate production processes were in statistical control—a leading practice. A supplier has since struggled to produce a key component—circuit card assemblies—at the quality and rate needed. Program officials stated that they are implementing measures to improve production process efficiency, such as testing the circuit cards earlier in the process. If the supplier continues to experience low yields, the program's pod deliveries could be delayed and production costs could rise. According to program officials, the first set of production pods are still set to be delivered ahead of schedule in August 2023.

Software and Cybersecurity

The NGJ MB program office continues to identify software development as a risk and is modifying its approach by increasing the frequency and total number of software releases. According to program officials, the NGJ MB prime contractor significantly decreased its number of software engineers to reduce its costs and was only planning on one software release as it moved from development to production. This approach made it difficult for the program to quickly implement software changes to improve system performance and reliability during testing. The program office reported that it plans to direct the prime contractor to increase its staffing levels and the number of software releases in a modification to the NGJ MB development contract, anticipated by spring 2023.

We previously reported that the NGJ MB program office conducted limited cybersecurity testing before production, which increased cost and performance risk. The program office reported it completed additional cybersecurity assessments from March 2022 to July 2022, including tests for identifying vulnerabilities. The program plans to complete other DOD-required cybersecurity tests in April 2023.

Other Program Issues

One of the main cost risks that NGJ MB flight tests identified is the pod's ability to meet reliability requirements. Program officials stated they are taking steps to mitigate this risk, which include increasing the number of flight tests and working with a reliability consultant. If the pods are unable to meet reliability requirements, the Navy may spend more to operate and support the pods than planned.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that the program remains on the schedule approved at the June 2021 production decision. It also identified flight testing and software development as the largest schedule risks to fielding an initial capability on time. According to the program office, the pod hardware design is stable with no major changes anticipated, and production representative pods demonstrated significant performance improvements in flight testing. The program office also stated it was working with circuit card assembly manufacturers to mitigate concerns about quality and low yields.

The program continuously evaluates cybersecurity and does not expect cybersecurity issues to affect the program, according to the program office. The program office also stated that it was on track to correct software deficiencies prior to operational testing, focusing on deficiencies that could improve system reliability.

Finally, the program office noted that training for fleet aircrew and maintenance personnel has started. The program stated that it expects this early fleet involvement will help mitigate risks to operational testing and identify supportability issues.

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Ⓐ Illustration or photo of system

Ⓑ Program description

Ⓒ Timeline identifying key dates for the program including, the start of development, major decision reviews, production decision and planned operational capability

Ⓓ **Program Performance** Cost, quantity, and schedule data as of the program's first full estimate (baseline), one year ago (GAO's 2022 assessment), and current estimate. We depict only the program's main element of acquisition cost – research and development and procurement. However, total program costs may also include military construction and acquisition operation and maintenance. Schedule data is presented as a cycle time comparison of planned number of months from program start to initial capability.

Ⓔ **Software Developmente** Software approach employed, frequency of end user evaluation, frequency of testing and feedback, percentage of total program cost accounted for by software development, and percentage of progress to meet current requirements

Ⓕ **Attainment of Product Knowledge** Depiction of selected knowledge-based practices and the program's progress in attaining that knowledge

Ⓖ **Program Essentials** Programmatic information including prime contractor (or other identified contractors) and contract type

Ⓗ Assessment of program's technology, design, and production maturity, as well as software and cybersecurity, and other program issues

Ⓘ **Program Office Comments** General comments provided by the cognizant military service or program office

Source: GAO. | GAO-23-106059

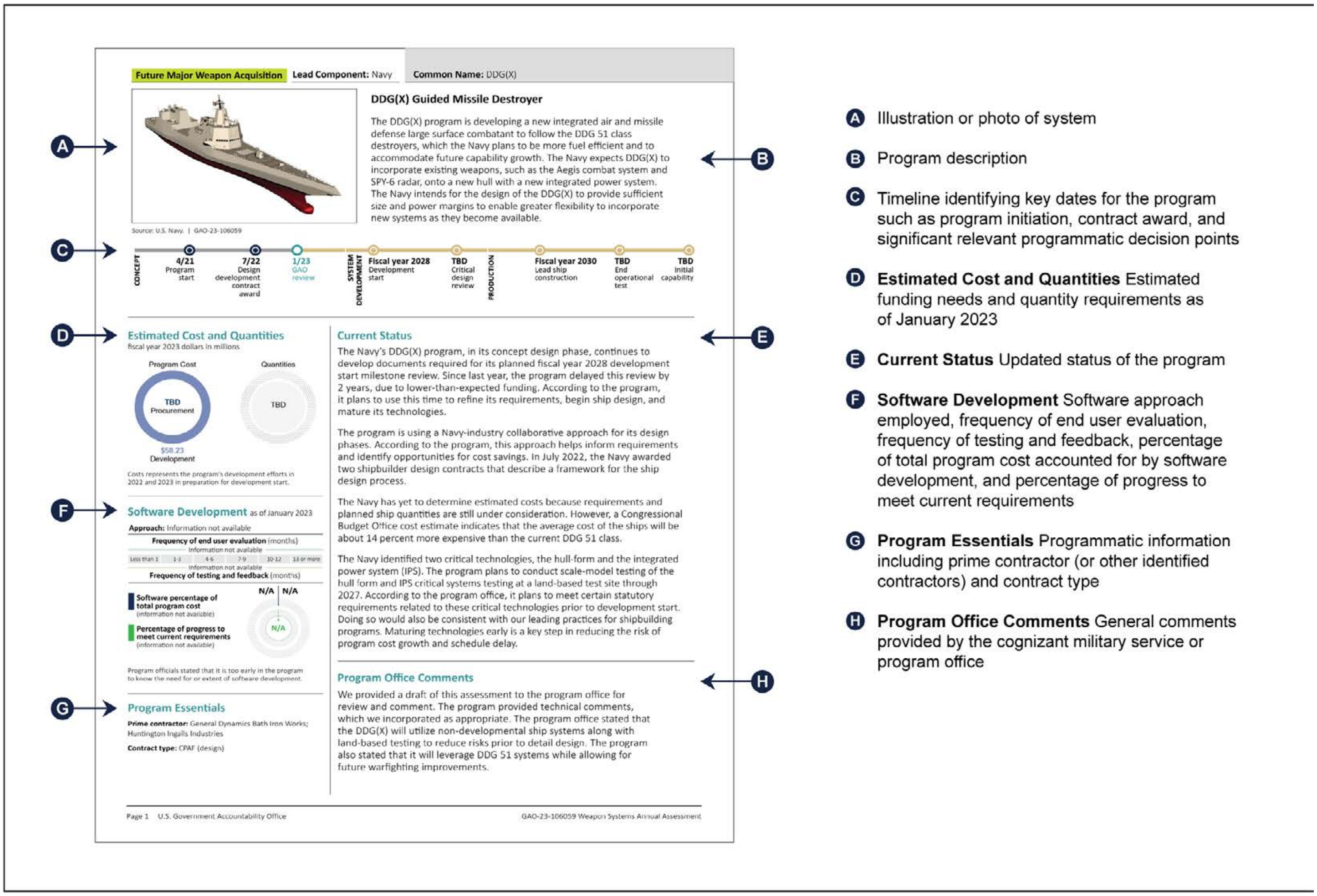
In addition, we produced one-page assessments for 11 programs:

- seven future major weapon acquisitions and

- four MDAPs that were well into production, but planned to introduce new increments of capability, which we refer to as MDAP increments.

See figure 32 for an illustration of the layout of each one-page assessment.

Figure 32: Illustration of One-Page Future Major Weapon Acquisition or Major Defense Acquisition Program Increment Assessment



Future Major Weapon Acquisition **Lead Component:** Navy **Common Name:** DDG(X)

DDG(X) Guided Missile Destroyer

The DDG(X) program is developing a new integrated air and missile defense large surface combatant to follow the DDG 51 class destroyers, which the Navy plans to be more fuel efficient and to accommodate future capability growth. The Navy expects DDG(X) to incorporate existing weapons, such as the Aegis combat system and SPY-6 radar, onto a new hull with a new integrated power system. The Navy intends for the design of the DDG(X) to provide sufficient size and power margins to enable greater flexibility to incorporate new systems as they become available.

Source: U.S. Navy. | GAO-23-106059

Estimated Cost and Quantities
fiscal year 2023 dollars in millions

Costs represents the program's development efforts in 2022 and 2023 in preparation for development start.

Software Development as of January 2023

Approach: Information not available

Frequency of end user evaluation (months)
Information not available

Information not available
Frequency of testing and feedback (months)

Software percentage of total program cost (information not available)

Percentage of progress to meet current requirements (information not available)

Program officials stated that it is too early in the program to know the need for or extent of software development.

Program Essentials

Prime contractor: General Dynamics Bath Iron Works; Huntington Ingalls Industries

Contract type: CPAF (design)

Current Status

The Navy's DDG(X) program, in its concept design phase, continues to develop documents required for its planned fiscal year 2028 development start milestone review. Since last year, the program delayed this review by 2 years, due to lower-than-expected funding. According to the program, it plans to use this time to refine its requirements, begin ship design, and mature its technologies.

The program is using a Navy-industry collaborative approach for its design phases. According to the program, this approach helps inform requirements and identify opportunities for cost savings. In July 2022, the Navy awarded two shipbuilder design contracts that describe a framework for the ship design process.

The Navy has yet to determine estimated costs because requirements and planned ship quantities are still under consideration. However, a Congressional Budget Office cost estimate indicates that the average cost of the ships will be about 14 percent more expensive than the current DDG 51 class.

The Navy identified two critical technologies, the hull-form and the integrated power system (IPS). The program plans to conduct scale-model testing of the hull form and IPS critical systems testing at a land-based test site through 2027. According to the program office, it plans to meet certain statutory requirements related to these critical technologies prior to development start. Doing so would also be consistent with our leading practices for shipbuilding programs. Maturing technologies early is a key step in reducing the risk of program cost growth and schedule delay.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program provided technical comments, which we incorporated as appropriate. The program office stated that the DDG(X) will utilize non-developmental ship systems along with land-based testing to reduce risks prior to detail design. The program also stated that it will leverage DDG 51 systems while allowing for future warfighting improvements.

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Ⓐ Illustration or photo of system

Ⓑ Program description

Ⓒ Timeline identifying key dates for the program such as program initiation, contract award, and significant relevant programmatic decision points

Ⓓ **Estimated Cost and Quantities** Estimated funding needs and quantity requirements as of January 2023

Ⓔ **Current Status** Updated status of the program

Ⓕ **Software Development** Software approach employed, frequency of end user evaluation, frequency of testing and feedback, percentage of total program cost accounted for by software development, and percentage of progress to meet current requirements

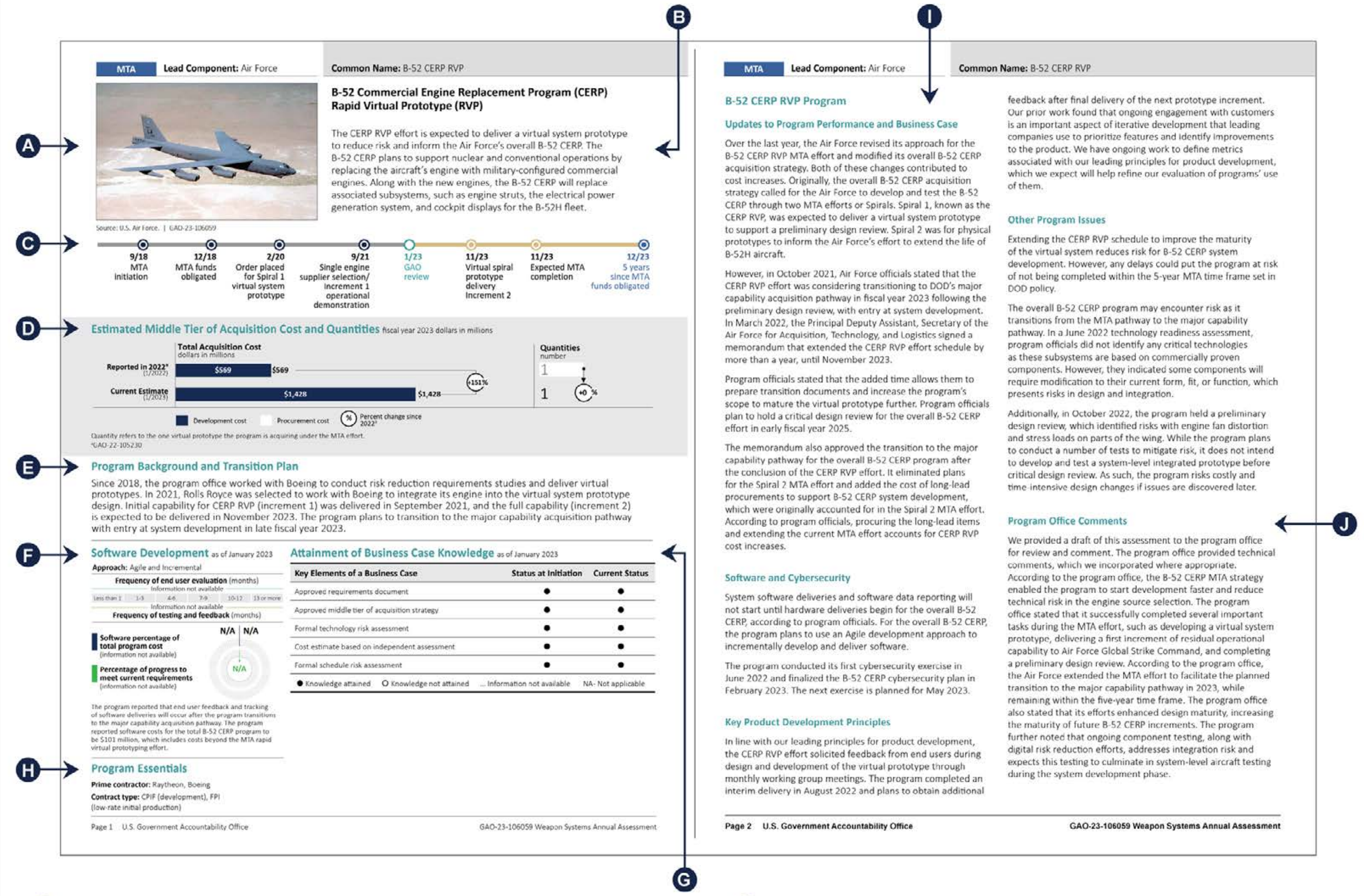
Ⓖ **Program Essentials** Programmatic information including prime contractor (or other identified contractors) and contract type

Ⓗ **Program Office Comments** General comments provided by the cognizant military service or program office

Source: GAO. | GAO-23-106059

For 19 programs using the MTA pathway, we produced two-page assessments discussing program background and transition plans, completion of or updates to key business case elements, software and cybersecurity efforts, employment of key product development principles, as well as other program issues. See figure 33 for an illustration of the layout of each two-page MTA program assessment.

Figure 33: Illustration of Two-Page Assessment of Programs Using the Middle Tier of Acquisition Pathway



MTA **Lead Component:** Air Force **Common Name:** B-52 CERP RVP

B-52 Commercial Engine Replacement Program (CERP) Rapid Virtual Prototype (RVP)

The CERP RVP effort is expected to deliver a virtual system prototype to reduce risk and inform the Air Force's overall B-52 CERP. The B-52 CERP plans to support nuclear and conventional operations by replacing the aircraft's engine with military-configured commercial engines. Along with the new engines, the B-52 CERP will replace associated subsystems, such as engine struts, the electrical power generation system, and cockpit displays for the B-52H fleet.

Source: U.S. Air Force. | GAO-23-106059

9/18	12/18	2/20	9/21	1/23	11/23	11/23	12/23
MTA initiation	MTA funds obligated	Order placed for Spiral 1 virtual system prototype	Single engine supplier selection/ increment 1 operational demonstration	GAO review	Virtual spiral prototype delivery increment 2	Expected MTA completion	5 years since MTA funds obligated

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions	Quantities number
Reported in 2022^a (1/2022)	$569	1
Current Estimate (1/2023)	$1,428	1
Percent change since 2022^a	+151%	+0%

Development cost Procurement cost (%) Percent change since 2022^a

Quantity refers to the one virtual prototype the program is acquiring under the MTA effort.

^aGAO-22-105230

Program Background and Transition Plan

Since 2018, the program office worked with Boeing to conduct risk reduction requirements studies and deliver virtual prototypes. In 2021, Rolls Royce was selected to work with Boeing to integrate its engine into the virtual system prototype design. Initial capability for CERP RVP (increment 1) was delivered in September 2021, and the full capability (increment 2) is expected to be delivered in November 2023. The program plans to transition to the major capability acquisition pathway with entry at system development in late fiscal year 2023.

Software Development as of January 2023

Approach: Agile and Incremental

Frequency of end user evaluation (months)

Information not available

Less than 1 1-3 4-6 7-9 10-12 13 or more

Information not available

Frequency of testing and feedback (months)

N/A | N/A

Software percentage of total program cost (information not available)

Percentage of progress to meet current requirements (information not available)

N/A

The program reported that end user feedback and tracking of software deliveries will occur after the program transitions to the major capability acquisition pathway. The program reported software costs for the total B-52 CERP program to be $101 million, which includes costs beyond the MTA rapid virtual prototyping effort.

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	●	●
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	●	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA- Not applicable

Program Essentials

Prime contractor: Raytheon, Boeing

Contract type: CPIF (development), FPI (low-rate initial production)

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MTA **Lead Component:** Air Force **Common Name:** B-52 CERP RVP

B-52 CERP RVP Program

Updates to Program Performance and Business Case

Over the last year, the Air Force revised its approach for the B-52 CERP RVP MTA effort and modified its overall B-52 CERP acquisition strategy. Both of these changes contributed to cost increases. Originally, the overall B-52 CERP acquisition strategy called for the Air Force to develop and test the B-52 CERP through two MTA efforts or Spirals. Spiral 1, known as the CERP RVP, was expected to deliver a virtual system prototype to support a preliminary design review. Spiral 2 was for physical prototypes to inform the Air Force's effort to extend the life of B-52H aircraft.

However, in October 2021, Air Force officials stated that the CERP RVP effort was considering transitioning to DOD's major capability acquisition pathway in fiscal year 2023 following the preliminary design review, with entry at system development. In March 2022, the Principal Deputy Assistant, Secretary of the Air Force for Acquisition, Technology, and Logistics signed a memorandum that extended the CERP RVP effort schedule by more than a year, until November 2023.

Program officials stated that the added time allows them to prepare transition documents and increase the program's scope to mature the virtual prototype further. Program officials plan to hold a critical design review for the overall B-52 CERP effort in early fiscal year 2025.

The memorandum also approved the transition to the major capability pathway for the overall B-52 CERP program after the conclusion of the CERP RVP effort. It eliminated plans for the Spiral 2 MTA effort and added the cost of long-lead procurements to support B-52 CERP system development, which were originally accounted for in the Spiral 2 MTA effort. According to program officials, procuring the long-lead items and extending the current MTA effort accounts for CERP RVP cost increases.

Software and Cybersecurity

System software deliveries and software data reporting will not start until hardware deliveries begin for the overall B-52 CERP, according to program officials. For the overall B-52 CERP, the program plans to use an Agile development approach to incrementally develop and deliver software.

The program conducted its first cybersecurity exercise in June 2022 and finalized the B-52 CERP cybersecurity plan in February 2023. The next exercise is planned for May 2023.

Key Product Development Principles

In line with our leading principles for product development, the CERP RVP effort solicited feedback from end users during design and development of the virtual prototype through monthly working group meetings. The program completed an interim delivery in August 2022 and plans to obtain additional feedback after final delivery of the next prototype increment. Our prior work found that ongoing engagement with customers is an important aspect of iterative development that leading companies use to prioritize features and identify improvements to the product. We have ongoing work to define metrics associated with our leading principles for product development, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

Extending the CERP RVP schedule to improve the maturity of the virtual system reduces risk for B-52 CERP system development. However, any delays could put the program at risk of not being completed within the 5-year MTA time frame set in DOD policy.

The overall B-52 CERP program may encounter risk as it transitions from the MTA pathway to the major capability pathway. In a June 2022 technology readiness assessment, program officials did not identify any critical technologies as these subsystems are based on commercially proven components. However, they indicated some components will require modification to their current form, fit, or function, which presents risks in design and integration.

Additionally, in October 2022, the program held a preliminary design review, which identified risks with engine fan distortion and stress loads on parts of the wing. While the program plans to conduct a number of tests to mitigate risk, it does not intend to develop and test a system-level integrated prototype before critical design review. As such, the program risks costly and time-intensive design changes if issues are discovered later.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, the B-52 CERP MTA strategy enabled the program to start development faster and reduce technical risk in the engine source selection. The program office stated that it successfully completed several important tasks during the MTA effort, such as developing a virtual system prototype, delivering a first increment of residual operational capability to Air Force Global Strike Command, and completing a preliminary design review. According to the program office, the Air Force extended the MTA effort to facilitate the planned transition to the major capability pathway in 2023, while remaining within the five-year time frame. The program office also stated that its efforts enhanced design maturity, increasing the maturity of future B-52 CERP increments. The program further noted that ongoing component testing, along with digital risk reduction efforts, addresses integration risk and expects this testing to culminate in system-level aircraft testing during the system development phase.

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- Ⓐ Illustration or photo of system
- Ⓑ Program description
- Ⓒ Timeline identifying key dates for the program such as program initiation, funds obligation, contract award, expected MTA completion, and significant relevant programmatic decision points
- Ⓓ **Estimated Middle Tier of Acquisition Cost and Quantities** Comparison of current and 2022 cost, quantity and schedule program estimate as of January 2023
- Ⓔ **Program Background and Transition Plan**
- Ⓕ **Software Development** Software approach employed, frequency of end user evaluation, frequency of testing and feedback, percentage of total program cost accounted for by software development, and percentage of progress to meet current requirements
- Ⓖ **Attainment of Business Case Knowledge** Depiction of key knowledge programs should attain prior to program initiation and the program's progress in attaining that knowledge
- Ⓗ **Program Essentials** Programmatic information including prime contractor (or other identified contractors) and contract type
- Ⓘ Assessment of program's performance and business case, software and cybersecurity, use of key product development principles, and other program issues
- Ⓙ **Program Office Comments** General comments provided by the cognizant military service or program office

Source: GAO. | GAO-23-106059

For 54 of our 65 assessments, we used scorecards to depict the extent of knowledge that a program has gained. These scorecards display key knowledge-based practices that should be implemented by certain points in the acquisition process to reduce risk, based on leading acquisition practices and our prior work on key elements of business cases.[79]

For each scorecard, we used the following scoring conventions:

- **A closed circle** to denote a knowledge-based practice the program implemented.
- **An open circle** to denote a knowledge-based practice the program did not or has yet to implement.
- **A dashed line** to denote that the program did not provide us with enough information to make a determination.
- **NA** to denote a practice that was not applicable to the program. For example, a practice may be marked “NA” for a program if it has yet to reach the point in the acquisition cycle when the practice should be implemented.

We included notes beneath the figures to explain information not available or NA scores, and added other explanatory notations for the scorecards where appropriate. Appendix II provides additional detail on our scorecard methodology. Figures 34 and 35 provide examples of the knowledge scorecards we used in our assessments.

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[79] We assessed different key points and knowledge-based practices for shipbuilding programs than for other types of programs. These shipbuilding key points— the point a design contract was awarded and at the point ship fabrication starts—and practices were informed by our prior work. See GAO, *Best Practices: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding*, GAO-09-322. (Washington, D.C.: May 13, 2009). Additionally, for MDAPs that transitioned from the MTA pathway, we assessed their knowledge attainment at the point they entered the major capability acquisition pathway.

Figure 34: Examples of Knowledge Score Cards on Two-Page Major Defense Acquisition Program Assessment

Non-shipbuilding program

Attainment of Product Knowledge as of January 2023

Resources and requirements match	**Development Start**	**Current status**
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Product design is stable	**Design review**	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	**Production start**	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	○	●

● Knowledge attained ○ Knowledge not attained ••• Information not available NA- Not applicable

Shipbuilding program

Attainment of Product Knowledge as of January 2023

Resources and requirements match	**Detail Design Contract Award**	**Current status**
Demonstrate all critical technologies in a relevant environment	○	○
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	**Fabrication start**	
Complete basic and functional design to include 3D product modeling	○	●

● Knowledge attained ○ Knowledge not attained ••• Information not available NA- Not applicable

Source: GAO analysis of DOD data. | GAO-23-106059

Figure 35: Example of Knowledge Score card for Assessments of Programs Using the Middle Tier of Acquisition Pathway

MTA

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	**Status at Initiation**	**Current status**
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	●	●
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	●	●

● Knowledge attained ○ Knowledge not attained ••• Information not available NA- Not applicable

Source: GAO analysis of DOD data. | GAO-23-106059

AIR FORCE

Program Assessments

▲ KC-46A Tanker Modernization (KC-46A)

Assessment type	Program name
MDAPs	B-52 Radar Modernization Program (B-52 RMP)
	F-15 Eagle Passive Active Warning Survivability System (F-15 EPAWSS)
	F-15EX
	HH-60W Jolly Green II (HH-60W)
	KC-46A Tanker Modernization (KC-46A)
	LGM-35A Sentinel (Sentinel)
	Long Range Standoff (LRSO)
	MH-139A Helicopter (MH-139A)
	Small Diameter Bomb Increment II (SDB II)
	T-7A Red Hawk (T-7A)
	VC-25B Presidential Aircraft Recapitalization (VC-25B)
MTA Programs	Air-launched Rapid Response Weapon (ARRW)
	B-52 Commercial Engine Replacement Program (CERP) Rapid Virtual Prototype (RVP)
	F-22 Rapid Prototyping

Source (previous page image): U.S. Air Force. | GAO-23-106059

MDAP Lead Component: Air Force

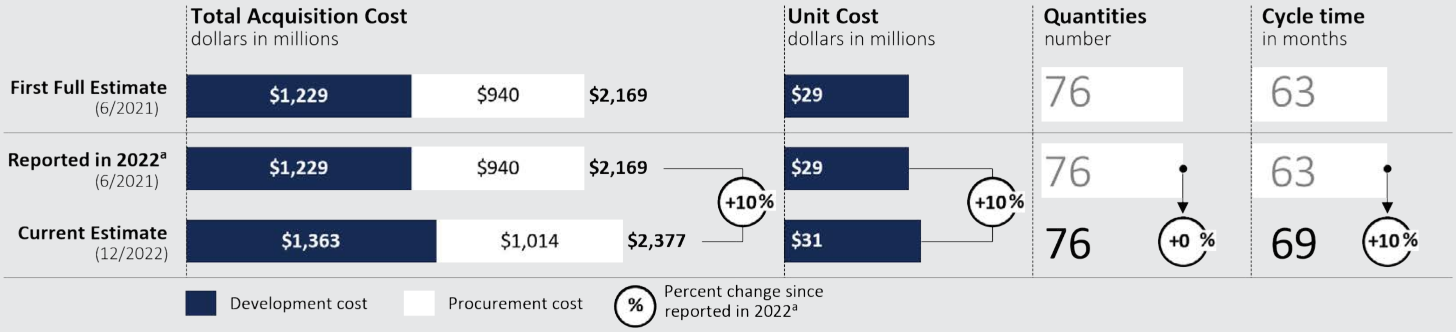
Common Name: B-52 RMP

Source: U. S. Air Force. | GAO-23-106059

B-52 Radar Modernization Program (B-52 RMP)

The Air Force's B-52 RMP plans to replace the current APQ-166 radar on all 76 B-52H aircraft with a modern off-the-shelf Active Electronically Scanned Array radar. The new radar is expected to provide improved functionality and reliability to support both nuclear and conventional B-52H missions while allowing for mission-essential aircraft navigation and weather avoidance. The Air Force plans for continued B-52H operations through the year 2050.

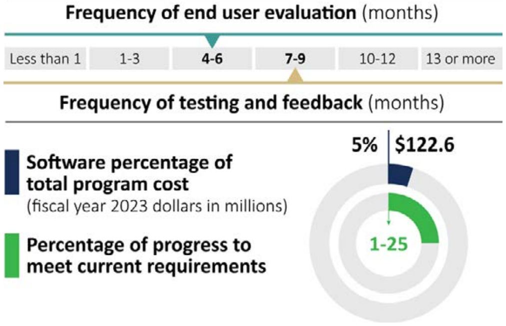
Program Performance fiscal year 2023 dollars in millions



Total quantities comprise two development quantities and 74 procurement quantities.
ᵃGAO-22-105230

Software Development as of January 2023

Approach: Agile and Incremental



Program Essentials

Prime contractor: Boeing

Contract type: CPIF

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	NA	NA
Demonstrate all critical technologies in a realistic environment	NA	NA
Complete a system-level preliminary design review	●	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	●	●
Test a system-level integrated prototype	○	○
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

We did not assess B-52 RMP critical technologies because the program office reported that the system does not have any. We also did not assess manufacturing maturity because the program has yet to reach production start.

B-52 RMP

Technology Maturity and Design Stability

B-52 RMP has identified no critical technologies. According to program officials, all planned technologies are fully mature since the program is using off-the-shelf components.

By its critical design review in February 2022, the program released over 90 percent of its drawings, a key marker of design stability. Program officials stated that they increased the number of design drawings by 20 following critical design review based on, among other things, inspection of the aircraft configuration and the need to update released drawings. Even with this increase, the number of released drawings remains over 90 percent.

Program officials stated that they plan to test a production representative unit in November 2024—over 2 years after the program's critical design review—but do not plan to test a system-level integrated prototype. They stated that they decided not to test a hardware prototype because most of the hardware is off-the-shelf. As we reported last year, this decision increases the risk of costly and time-intensive design changes if the program discovers hardware issues later.

Production Readiness

Since our last assessment, the program delayed all of its dates after critical design review by about 8 months on average. As we previously reported, program officials plan to take a tailored approach to production start, with two decision points authorizing low-rate initial production. The first decision point would provide approval for initial hardware procurement for the first 11 units. The second decision point would approve all low-rate initial production units.

According to program officials, the low-rate decision points are now planned in September 2024 and March 2025, respectively. Additionally, the program delayed its production readiness review to March 2025. Program officials stated that the schedule changes reflect supply chain issues, including delays in hardware supply chains, and discussions with the contractor that occurred after the start of system development. For example, shortages with the main supplier resulted in difficulty obtaining circuit boards. Program officials stated that the Air Force is pursuing secondary sources to obtain hardware.

Program officials reported that, after awarding the engineering and manufacturing development contract in June 2021, they met with Boeing in October 2021 to identify achievable dates for production and testing. In April 2022, the program established its performance measurement baseline with the new dates, according to program officials. They noted that the new dates fall within the original acquisition program baseline threshold dates.

Software and Cybersecurity

B-52 RMP continues to track software completion and integration as a moderate schedule risk. The program plans to manage this risk by using Agile software development processes to reduce integration time and by leveraging existing radar software modes from other aircraft.

This year, the program reported that approximately 12 percent of the software is expected to be custom, since most of the radar software comes from other government programs. Of that 12 percent, officials expect 94 percent to be new software and approximately 6 percent to be modifications of existing software. In our last assessment, B-52 RMP reported that 85 percent of its software was expected to be custom. However, this year, program officials stated that the information they provided to us last year for software type was based on a misunderstanding by the program office.

The program did not report any significant changes to its cybersecurity approach since last year's assessment. However, because of the schedule changes described above, the program delayed its developmental testing—including cybersecurity testing—to June 2024. The program completed an initial cybersecurity assessment in 2021 and plans to conduct a second assessment in March 2024. Program officials stated that they integrated cybersecurity requirements as part of software development process and, as a result, they test cybersecurity as part of ongoing development testing.

Other Program Issues

B-52 RMP reported that supply chain issues caused cost growth. Costs grew by 10 percent since the program's initial estimate in June 2021 due in part to ongoing challenges sourcing raw material and longer than expected lead times.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that it concurred with the contents of this assessment. The program office also provided technical comments, which we incorporated where appropriate.

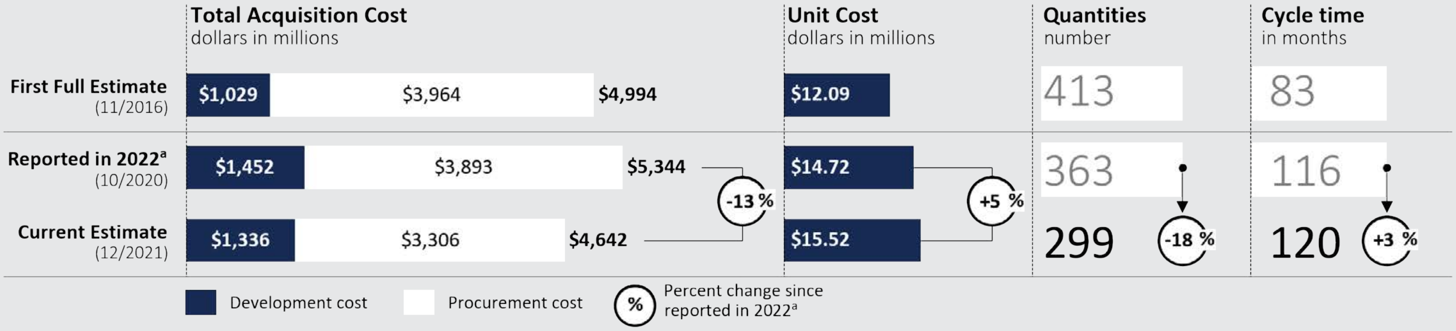
MDAP Lead Component: Air Force **Common Name:** F-15 EPAWSS

Source: U. S. Air Force. | GAO-23-106059

F-15 Eagle Passive Active Warning Survivability System (F-15 EPAWSS)

The Air Force's F-15 EPAWSS program plans to modernize the onboard F-15 electronic warfare (EW) system used to detect and identify threat radar signals, employ countermeasures, and jam enemy radars. The program uses reconfigured hardware and software from other military aircraft to address current EW threats. The Air Force developed EPAWSS Increment 1 to replace the F-15 legacy EW system. The Air Force has yet to budget for a proposed Increment 2, which adds a new towed decoy. We assessed Increment 1.

Program Performance fiscal year 2023 dollars in millions

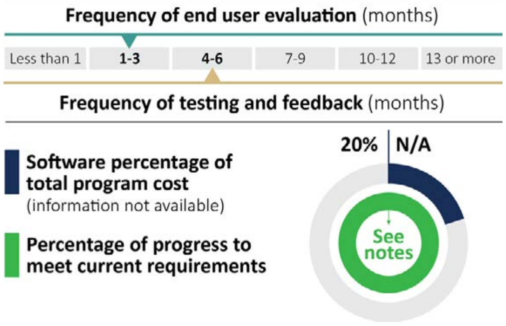


The current estimate total quantity includes two F-15C development units, 217 F-15E, and 80 F-15EX production units. Six of the F-15E production units will start as development units before they are refurbished into production units. The EPAWSS current estimate is under review such that the F-15EX quantity here does not match what is reported in the F-15EX assessment within this report.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile, Iterative (other than Agile), Waterfall, and Incremental



The program reported an estimated percentage of software costs but does not track these costs. The program indicated that software development is complete and that the contractor is integrating software and hardware.

Program Essentials

Prime contractor: Boeing

Contract type: CPIF/CPFF/FFP (development); CPFF/FFP/FPI (low-rate initial production)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	○	○

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

F-15 EPAWSS Program

Technology Maturity, Design Stability, and Production Readiness

EPAWSS's critical technologies are mature and its design is stable, as previously reported. Since our last assessment, the program completed all planned developmental test activities and addressed several risks that we noted last year. But the program delayed its planned initial operational capability (IOC) by 4 months.

The program made progress in resolving three performance and testing issues identified during developmental testing.

- We previously reported on concerns with EPAWSS performance in a dense background frequency environment. Based on improvements made through testing over the past year, program officials noted that the system is now meeting all threat identification performance measures.
- The program addressed a separate enemy radar location finding issue by obtaining Air Force approval to reduce EPAWSS requirements in certain areas**.** The Air Force determined the system's location finding ability, while less than what was planned, is operationally useful, and agreed to accept it, avoiding the need for redesign work.
- To address the risk of test asset damage when assessing the effects of indirect lightning strikes, the program used engineering analysis instead of physical testing to resolve this issue and avoid damaging assets needed for the start of operational testing.

As we reported last year, the program does not plan to test a production-representative prototype in its intended environment until the April 2023 start of operational testing, more than 2 years after entering production. This testing will also take place after the Air Force's June 2022 decision to approve the installation of EPAWSS production units on operational aircraft. Further, the Air Force plans to fund the production of approximately 73 EPAWSS units before the April 2023 prototype testing. Making production commitments without testing a production-representative prototype increases the risk of finding issues that may require costly rework on units already produced and redesigns for future production units.

Software and Cybersecurity

In February 2022, the contractor delivered the last software package containing new functional content. The program is now focused on addressing software issues identified in prior testing and refining overall system performance to prepare for operational testing.

EPAWSS completed the last of three separate cyber vulnerability tests in June 2022. Completion of all other cybersecurity testing is expected in 2023, including a full system cyber assessment. That assessment is planned for September 2023, 7 months before the planned full-rate production decision.

Other Program Issues

Since our last assessment, the Air Force reported a 4-month delay to its planned IOC date, now projected for August 2025. Program officials noted that the system remains on track to meet the required April 2025 to October 2025 timeline for IOC. The program also redefined its IOC. According to program officials, the Air Force now requires only 12 EPAWSS-equipped F-15E aircraft instead of the 24 originally planned to meet IOC after making service-wide changes to force generation and readiness models.

Despite this lower quantity, delays to IOC resulted from the Air Force's decision to prioritize specific F-15E aircraft with better engines to receive the EPAWSS upgrade first. According to program officials, these aircraft are available on a limited basis to begin the modification work, giving rise to the delay. They noted that there have been no production or aircraft installation issues encountered to date that have affected the IOC date.

Program officials cited issues with diminishing manufacturing sources and are working with the prime contractor to develop mitigation strategies. These efforts include making one-time total quantity buys for parts that will no longer be produced or buying enough of a particular part to support production and fielding until an alternative is developed. According to program officials, the first and second production lots were not adversely affected, but the need to develop alternatives for future use could result in additional costs.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office acknowledged that EPAWSS is transitioning from development to production and fielding. It noted that using two decision points—for production start and for installation—instead of the traditional single decision point expedited the expected delivery of capability by 16 months.

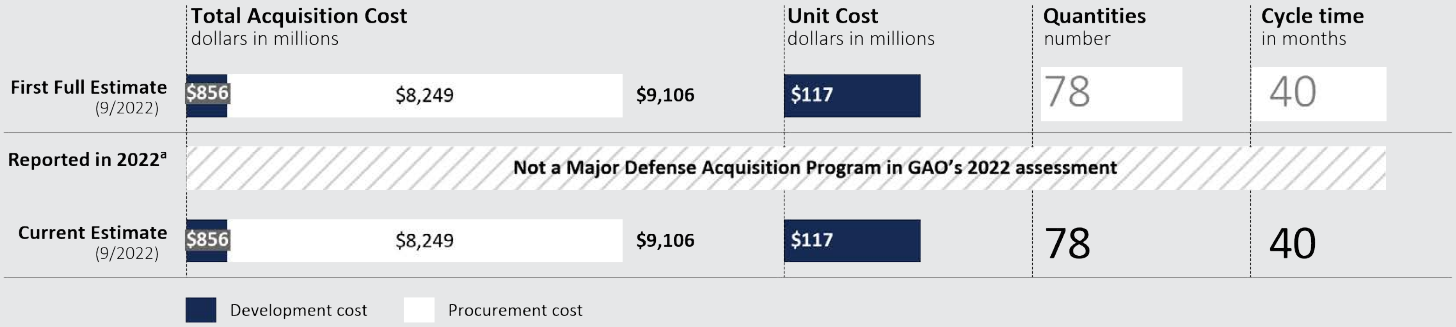
According to the program, the first two modifications of F-15E aircraft to install EPAWSS are progressing satisfactorily. It also noted the program's successful completion of various testing activities during the past year and delivery of the final iteration of the EPAWSS mission system software. According to the program, based on the system's performance in testing over the past year, it anticipates EPAWSS will be ready to start operational testing as planned in 2023.

F-15EX

Source: U. S. Air Force. | GAO-23-106059

The Air Force's F-15EX program is intended to address F-15C/D readiness challenges and eventually replace the F-15C/D fleet. The F-15EX, based on current foreign military sales aircraft, will be upgraded with capabilities unique to the U.S., including operational flight program software and Eagle Passive/Active Warning and Survivability System upgrades. The F-15EX is planned to be a complementary platform to fifth-generation F-35 and F-22 stealth aircraft operating in highly contested environments.

Program Performance fiscal year 2023 dollars in millions



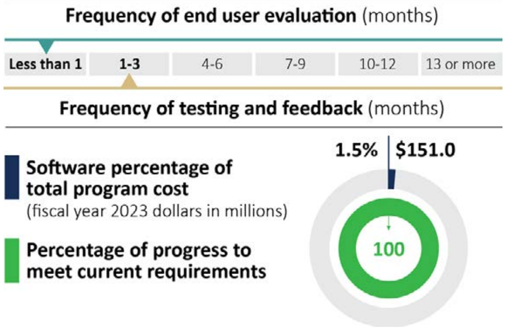
	Total Acquisition Cost dollars in millions			Unit Cost dollars in millions	Quantities number	Cycle time in months
First Full Estimate (9/2022)	$856	$8,249	$9,106	$117	78	40
Reported in 2022[a]	Not a Major Defense Acquisition Program in GAO's 2022 assessment					
Current Estimate (9/2022)	$856	$8,249	$9,106	$117	78	40

Total quantities comprise two development quantities and 76 procurement quantities. We measured cycle time from the start of the MTA rapid fielding effort to the date the program plans to achieve initial operational capability.

[a]GAO-22-105230

Software Development as of January 2023

Approach: Agile



The program reported software development for F-15EX was completed in January 2022.

Program Essentials

Prime contractor: Boeing

Contract type: IDIQ; Lot 1 definitized order; Lot 2 undefinitized order: FPI (Lot 1 and 2 orders); CPFF/CPIF/FPI/FFP (development and production support)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Status at Entry to MCA Pathway	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	●	●
Complete a system-level preliminary design review	●	●
Product design is stable		
Release at least 90 percent of design drawings	●	●
Test a system-level integrated prototype	●	●
Manufacturing processes are mature		
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	●	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable
MCA = Major Capability Acquisition

Our scores for F-15EX technology maturity reflect critical technologies being developed by the program and other entities.

F-15EX Program

Technology Maturity, Design Stability, and Production Readiness

The F-15EX program transitioned from the MTA rapid fielding pathway to the major capability acquisition pathway in September 2022. The program originally planned to transition in March 2022, but the transition was delayed by 6 months due to ongoing fiscal year 2023 budget considerations.

Air Force officials said that they reduced the planned F-15EX procurement quantities in the FY 2023 budget request from 144 to 80 in an effort to request funds for higher priority programs. They added that the F-15EX program's June 2022 cost estimate indicated that the available procurement funding was insufficient to order two of the planned aircraft. As a result, the program further reduced the planned F-15EX procurement quantities to 78.

Program officials stated that they finalized the terms and conditions for the Lot 1 production order in November 2022 and plan to finalize the Lot 2 production order terms and conditions in May 2023. The program placed undefinitized orders for these efforts in July 2020 and November 2021, respectively. Program officials attributed the delay in finalizing these orders to the Defense Contract Management Agency's (DCMA) disapproving two of Boeing's business management systems. Boeing has developed corrective action plans to address the deficiencies and is working with DCMA to obtain final approval. Program officials said that they placed an undefinitized delivery order for Lot 3 in December 2022.

All of the F-15EX's critical technologies are mature and its design is stable as it is based on an existing aircraft. Last year, we reported that the program completed tests of system-level and production representative prototypes in December 2020 and October 2021, respectively. However, the program clarified this year that both tests occurred in May 2021.

Boeing planned to deliver the first Lot 1B aircraft in December 2022 but delayed those deliveries by 6 months due to several production-related issues. The primary driver of these delays was supplier quality problems related to a critical component in the forward fuselage assembly that ensures safety of flight. Program officials said that those quality issues were corrected as of the production of the seventh and eighth aircraft.

According to a DCMA report, Boeing also used tooling that had a design error, which caused inaccurately drilled holes for the windscreen installation on the third through sixth aircraft. Boeing made adjustments to the drilling tool to address the issue. Program officials said that the issue was identified before it affected the seventh aircraft and Boeing plans to re-drill the holes on affected aircraft before beginning production of the Lot 2 aircraft. Program officials added that each Lot 2 aircraft has also been delayed 2 months due to these Lot 1B production-related issues.

Boeing now plans to deliver six Lot 1B aircraft—two aircraft per month—between May 2023 and July 2023, which program officials said is achievable. Both DCMA and Boeing schedule risk analyses, however, predict that there could be additional delays to Lot 1B aircraft deliveries. For example, DCMA's analysis indicates that the final Lot 1B aircraft deliveries will likely not take place until September 2023 due to the Lot 1B production-related issues encountered thus far. In contrast, Boeing's analysis predicts the first and second Lot 1B aircraft will likely not be delivered until July 2023 and August 2023, respectively.

According to program officials, Boeing did not use the results of its schedule risk analysis to update the timing of key F-15EX program milestone dates, such as Lot 1B aircraft delivery dates. Boeing representatives told program officials that they plan to meet the current Lot 1B delivery schedule. Additional Lot 1B aircraft delivery delays beyond July 2023 will make it challenging for the program to meet its planned milestone dates, including initial operational capability and full rate production in 2023.

Cybersecurity

The program continues to track cybersecurity vulnerabilities as its primary risk. The F-15EX design is derived from foreign military sales aircraft that, according to the program, were not designed to meet Air Force cybersecurity requirements. DOD's Cybersecurity Test and Evaluation Guidebook lays out a six-phase process for assessing vulnerabilities. Program officials stated that they completed the first two phases and identified areas to focus on during follow-on cybersecurity testing. Program officials said that they planned to complete two more phases in early 2023 and the last two phases on Lot 1B aircraft deliveries.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate.

Source: Sikorsky Aircraft Company. | GAO-23-106059

HH-60W Jolly Green II

The Air Force's HH-60W Jolly Green II program will replace the aging HH-60G Pave Hawk rescue helicopter fleet. It will provide 75 new aircraft, related training systems, and support for increased personnel recovery capability. It is a derivative of the operational UH-60M helicopter. Planned modifications to the existing design include a new mission computer and software, a higher capacity electrical system, larger capacity main fuel tanks, and armor for crew protection.

Program Performance fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions: Development cost	Procurement cost	Total	Unit Cost dollars in millions	Quantities number	Cycle time in months
First Full Estimate (6/2014)	$2,354	$7,341	$9,723	$87	112	82
Reported in 2022[a] (9/2020)	$2,326	$7,876	$10,256	$91	113	TBD
Current Estimate (9/2022)	$2,499	$5,599	$8,188	$109	75	100
Percent change since reported in 2022[a]			-20 %	+20 %	-34 %	N/A %

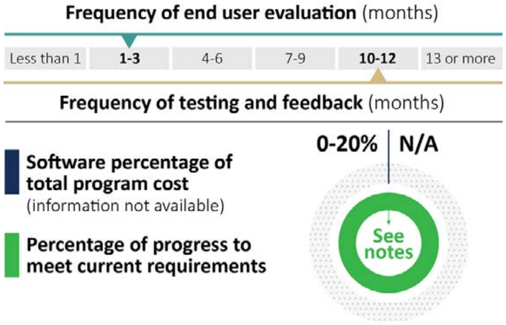
■ Development cost □ Procurement cost (%) Percent change since reported in 2022[a]

Total quantities comprise 10 development quantities and 65 procurement quantities. Since the estimate above was reported, the Consolidated Appropriations Act, 2023 appropriated funding enabling the program to procure 20 aircraft in fiscal year 2023, bringing the total to 85 [See Pub. L. No. 117-328 (2022)]. The program did not report an initial operational capability date last year and, as a result, the cycle time in 2022 could not be calculated. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile, Waterfall, and Incremental



The program reported an estimated range on software costs but does not track these costs in detail. Software development for operational testing is complete, but development continues for defect correction and enhancements, according to the program.

Program Essentials

Prime contractor: Sikorsky Aircraft Co.

Contract type: FPI/FFP/CPFF

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	○	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	○	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	...	...
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We could not assess HH-60W design drawings because the program no longer tracks these drawings; therefore, there is no total number of drawings against which to measure the program's knowledge.

HH-60W Jolly Green II Program

Technology Maturity, Design Stability, and Production Readiness

In the last year, the HH-60W program completed systems development, achieved an initial operating capability, and completed initial operational testing and evaluation, according to program officials.

Recent test performance of the HH-60W's only critical technology—the radar warning receiver—indicated no issues that might delay field use, full-rate production, or eventual future delivery of aircraft to users, according to program officials. This testing occurred prior to the start of initial operational test and evaluation in April 2022. Program officials continue to report a stable design, consistent with our last assessment.

HH-60W entered production in September 2019 without testing a production-representative prototype in its intended environment. We reported last year that the program conducted such a test as part of operational flight testing, completed in November 2021. However, program officials clarified this year that their prior response was reported to us in error. They noted that system-level developmental testing on a fully configured production-representative system with weapons in its intended environment began in April 2022—the start of initial operational test and evaluation. The Air Combat Command—the lead organization for the program—declared that the program achieved initial capability in October 2022.

Program officials noted that they are tracking production-related risks resulting from reliance on a single supplier and material obsolescence challenges, such as obsolete standby instrument system and weather radar components. They told us that they are in the process of making an initial contract award to address obsolescence issues on future aircraft deliveries. These issues are not expected to affect the full-rate production decision, currently planned for March 2023.

Software and Cybersecurity

The program's software strategy and risks are unchanged since our previous assessment, according to program officials. They told us that they completed software development and are now addressing defect corrections and enhancements. Software-related costs increased since the start of development due to software upgrades needed for initial operational test and evaluation. According to program officials, software development continues to present a moderate level of risk, partly due to increased complexity above what was originally anticipated.

Program officials completed a full system cybersecurity assessment in August 2022.

Other Program Issues

Program officials reported that the Air Force reduced total planned procurement quantities of the HH-60W due to other higher funding priorities for the Air Force. As a result, the HH-60W unit cost exceeds what was expected in the first full estimate by about 19 percent.

Aircraft availability delays affected several of the program's planned milestones over the past year. Specifically, the formal start of the HH-60W's initial operational test and evaluation was delayed by an additional month beyond the planned date reported in our last assessment—to April 2022—due to the lack of a fully operationally representative aircraft, according to program officials. As a result, the program also delayed its planned end of operational testing by about 7 months, from March 2022 to October 2022. The delay also resulted in a shift of the planned full-rate production decision from October 2022 to March 2023.

Since last year, program officials reported incurring about $4.5 million in additional costs associated with the COVID-19 pandemic because of unavailable test sites and contractor office closures.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, it achieved significant milestones and accomplishments in 2022. The program office stated that it reached training readiness in June 2022. It also noted that in October 2022, the program completed its initial operational test and evaluation and achieved initial operational capability. Further, the program office added that in 2022 the HH-60W had its inaugural deployment in which warfighters executed the first two combat saves recorded by the program. Lastly, it stated that the program is on track for a full-rate production decision in March 2023.

MDAP Lead Component: Air Force

Common Name: KC-46A

KC-46A Tanker Modernization Program (KC-46A)

Source: U. S. Air Force. | GAO-23-106059

The Air Force's KC-46A program is converting a Boeing 767 aircraft designed for commercial use into an aerial refueling tanker for operations with Air Force, Navy, Marine Corps, and allied aircraft. The program is the first of three planned phases to replace roughly a third of the Air Force's aging aerial refueling tanker fleet, comprised mostly of KC-135s. The KC-46A is equipped with defensive systems for operations in contested environments and has enhanced refueling capacity, efficiency, cargo, and aeromedical capabilities over the KC-135.

CONCEPT

SYSTEM DEVELOPMENT

2/11 Development start

7/13 Critical design review

9/15 KC-46 first flight

PRODUCTION

8/16 Low-rate decision

10/19 Start operational test

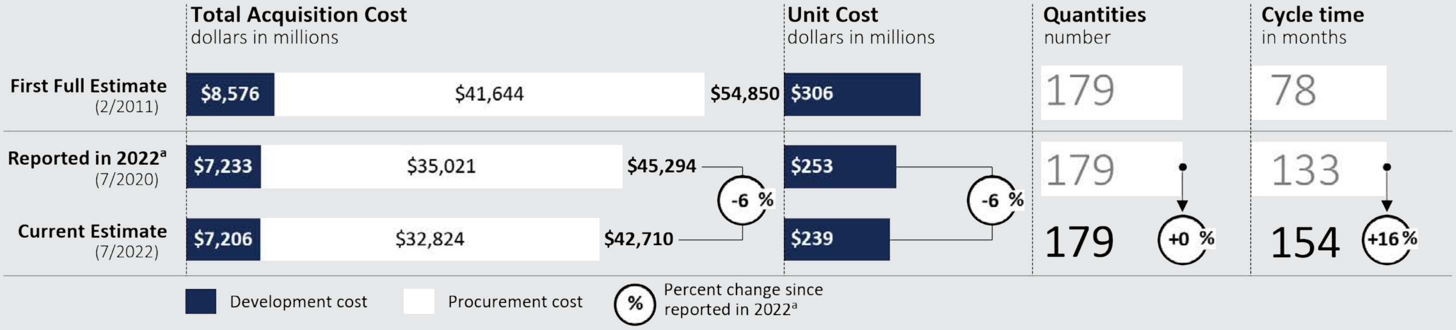
1/23 GAO review

12/23 Required assets available

12/25 End operational test

TBD Full-rate decision

Program Performance fiscal year 2023 dollars in millions



	Total Acquisition Cost dollars in millions			**Unit Cost** dollars in millions	**Quantities** number	**Cycle time** in months
First Full Estimate (2/2011)	$8,576	$41,644	$54,850	$306	179	78
Reported in 2022[a] (7/2020)	$7,233	$35,021	$45,294	$253	179	133
Current Estimate (7/2022)	$7,206	$32,824	$42,710	$239	179	154
			-6 %	-6 %	+0 %	+16 %

■ Development cost □ Procurement cost (%) Percent change since reported in 2022[a]

Total quantities comprise four development quantities and 175 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

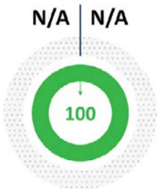
Software Development as of January 2023

Approach: Waterfall and Incremental

Frequency of end user evaluation (months)

Less than 1	1-3	**4-6**	7-9	10-12	13 or more

Frequency of testing and feedback (months)



Software percentage of total program cost (information not available)

Percentage of progress to meet current requirements (information not available)

The program reported that software costs were not tracked.

Program Essentials

Prime contractor: Boeing

Contract type: FPI (development); FFP (procurement)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	○
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	○	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	...	...
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	●	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We could not assess the status of design drawings at the KC-46A design review or currently because the program no longer tracks drawings; therefore, there is no total number of drawings against which to measure the program's knowledge.

KC-46A Program

Technology Maturity, Design Stability, and Production Readiness

KC-46A—its planned full-rate production decision delayed 7 years since its original baseline—is experiencing additional delays. These delays are largely due to continued challenges with the redesign of the remote vision system (RVS), a set of cameras and a display that a crew member uses to maneuver and insert the boom into receiver aircraft. The RVS is experiencing issues that can cause the operator to scratch stealth aircraft with the boom due to visual acuity and depth perception problems.

RVS-related delays this past year were specifically due to: 1) allowing the subcontractor time to develop hardware and complete testing and 2) addressing Federal Aviation Administration and Air Force airworthiness requirements, according to the program. The program estimates that the end of operational testing will be delayed an additional 19 months to December 2025, but it has yet to confirm a revised date for the full-rate decision.

In April 2022, the program completed the preliminary design review (PDR) for RVS despite still having three immature critical technologies—the visible camera, the long-wave infrared boom camera, and the primary display. The program also did not test a prototype integrating critical technologies on a KC-46A prior to PDR closure, as recommended by leading practices.

While Boeing is responsible for much of the cost associated with the new RVS system, the Air Force still faces cost risk. Program officials noted that Boeing is generally responsible for all development, integration, test, and retrofit costs associated with RVS design established at PDR. However, the Air Force would be financially responsible for design changes following PDR. With critical technologies still immature and untested, the program risks discovering issues later in development that require time-intensive, costly rework. In addition, program officials said that the Air Force is responsible for procuring and retrofitting another technology, the upgraded panoramic sensors, which detect and recognize certain aircraft within required distances.

Though RVS challenges are driving overall program delays, the KC-46A is also experiencing delays and cost increases related to the redesign and production of the boom, according to program officials. The Air Force is redesigning the boom because it is too stiff during refueling attempts with lighter receiver aircraft, which could damage the KC-46A aircraft.

Air Force officials told us that they now expect completion of the new boom redesign by March 2025, instead of in 2023 as reported last year. The retrofits and incorporation of the new design into production are also delayed and are now planned for fiscal year 2026. The estimated costs to redesign the boom increased since last year from $113 million to $128 million, while the estimated retrofit costs remain at about $219.2 million. Program officials noted that associated delays and cost increases are due to subcontractor difficulties meeting design specifications.

Software and Cybersecurity

The program currently uses a waterfall and incremental approach to software development but plans to adopt an Agile approach for future modifications and sustainment, according to program officials. It also plans to complete its third cooperative vulnerability and penetration cybersecurity assessment in April 2023. Program officials noted that the program and contractors had challenges attracting and retaining qualified software and cybersecurity staff.

Other Program Issues

The program procured low-rate production aircraft and began accepting them in 2019 without fully addressing the RVS and boom issues. According to the Air Force, it already purchased 124 production aircraft—over half of the total fleet—and delivered 68 of those aircraft as of January 2023. Air Mobility Command cleared the KC-46A for worldwide combat deployment in September 2022. However, the Air Force continues to restrict KC-46 refueling operations due to current RVS and boom deficiencies.

Since our last assessment, the program delayed its required assets available date—which includes 18 aircraft in final production configuration with two spare engines and nine wing aerial refueling pods—an additional 21 months to December 2023. Program officials attribute the delays to late delivery of the pods due, in part, to COVID-related shutdowns and challenges in obtaining certification related to the pods. According to the program, RVS challenges were not directly related to this current change in the required assets available date.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that accepting production KC-46s, while fixing deficiencies in parallel with operational testing, is the shortest and most cost-effective path to full operational capability. It also noted that no additional cost risk was placed on the Air Force since the closure of PDR. The program office stated that, in June 2022, it conducted a critical design review of the new RVS system to assess whether the system meets requirements and is ready for initial production. The program also added that the RVS prototype cameras were used during KC-46 aerial refueling prior to critical design review for data collection to reduce risk and support system development.

MDAP | Lead Component: Air Force | **Common Name**: Sentinel

Source: Northrop Grumman. | GAO-23-106059

LGM-35A Sentinel (Sentinel)

The Air Force's Sentinel, formerly the Ground Based Strategic Deterrent, is intended to replace the Minuteman III (MMIII) intercontinental ballistic missile system. Sentinel includes the development of a new missile, command and control and ground systems, as well as modernization of MMIII infrastructure. Sentinel is expected to enhance capability, security, and reliability of the land-based portion of the nuclear triad. Sentinel is being designed with an open systems architecture to allow for improvements to be made throughout the life of the weapon system.

Program Performance fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions			Unit Cost dollars in millions	Quantities number	Cycle time in months
First Full Estimate (9/2020)	$25,157	$52,396	$85,111	$129	659	106
Reported in 2022[a]	Program not included in GAO's 2022 assessment					
Current Estimate (7/2022)	$25,157	$52,396	$85,111	$129	659	118

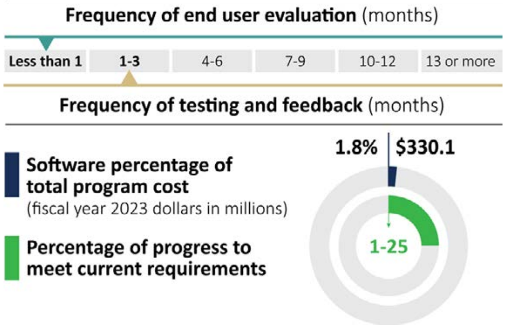
■ Development cost ☐ Procurement cost

Total quantities comprise 25 development quantities and 634 procurement quantities. Program schedule events are under review due to acquisition strategy revisions. The event schedule updates will be provided once the revisions are completed. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile and DevSecOps



Program Essentials

Prime contractor: Northrop Grumman Systems Corp.

Contract type: CPIF

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	○	○
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	NA	NA
Test a system-level integrated prototype	NA	NA
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

We did not assess Sentinel's design stability or manufacturing maturity because the program has yet to reach, respectively, critical design review or production.

Sentinel Program

Technology Maturity and Design Stability

Of Sentinel’s 18 critical technologies, three are mature, 14 are approaching maturity, and one is immature. The program plans to mature all technologies before production start, currently planned for 2026. However, our prior work found that starting development before technologies are mature can increase the risk of cost and schedule growth later in the program.

To date, the program successfully completed developmental tests of the new rocket motor and other missile components. The program expects Sentinel’s first flight and full functional tests, scheduled for fiscal year 2024 and 2025, respectively, to further validate progress.

Sentinel’s digital engineering environment (DEE), a foundational element of the program’s acquisition strategy, remains incomplete. DEE enables the digital integration of program’s data, tools, and model-based systems engineering activities to accelerate design and analysis. Use of modern design tools, such as digital engineering, is a leading practice employed by companies when using an iterative design approach. The practice increases companies’ confidence that a product will work as intended before starting production. Absence of a functional DEE is adding risk to Sentinel’s schedule, including major milestones such as system-level critical design review and first flight, both planned for fiscal year 2024. DEE is expected to achieve initial operational capability by the second quarter of fiscal year 2023.

Software and Cybersecurity

Sentinel is a software-intensive program with a compressed schedule. Software development is a high risk due to its scale and complexity and unique requirements of the nuclear deterrence mission. Sentinel continues to face limitations with data transfer between networks of different security classifications. The program reported that this is because its transfer mechanism is pending approval from the Air Force and the National Security Agency. In addition, the contractor is affected by a shortfall of cleared and appropriately skilled software workforce.

In August 2022, Sentinel completed the first incremental capability delivery of its software—IFC 0.5—which demonstrated the basic mechanical and electrical system interfaces between the missile and the command and launch module in a simulated environment. The program achieved hardware and software integration via the use of emulators due to the delayed availability of needed hardware and delayed completion of the software testing facility.

The program is currently working on IFCs 1.0 and 2.0 that include capabilities for first flight and operation of the secondary airborne launch platform of MMIII. The prime contractor projects IFC 1.0 will be completed late and over cost. According to program officials, they are in the process of determining software metrics with the contractor.

To date, Sentinel completed four cybersecurity risk reduction exercises. Implementation of cybersecurity requirements was delayed pending maturation of Sentinel’s program requirements and architecture models, resulting in schedule delays and cost growth.

Other Program Issues

Sentinel’s large program scope—development of new technologies, modification of existing systems, upgrades to property, establishment of new infrastructure—combined with its size—hundreds of facilities and operations that extend across the nation—further adds to its complexity. According to program officials, they are working closely with the Navy as well as several Air Force and Department of Energy interdependent programs to produce a new warhead, re-entry vehicle, and fuzes.

Sentinel is behind schedule due to staffing shortfalls, delays with clearance processing, and classified information technology infrastructure challenges. Additionally, the program is experiencing supply chain disruptions, leading to further schedule delays. The prime contractor is working on multiple supply chain mitigations to address the issue.

According to the program office, Sentinel’s master schedule contains many deficiencies and cannot be used to effectively manage the execution of the program. The prime contractor and the program are conducting a high-level review and discussing potential changes to the schedule.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. According to the program office, Sentinel is a total system replacement of the intercontinental ballistic missile system’s 400 missiles, 450 silos, and more than 600 facilities over a 31,900 square-mile landmass. It noted that Sentinel is one of the top priorities within the Department of Defense, and the program has the attention and focus of the department's senior leadership.

The program office further noted that Sentinel was affected by macro-economic pressures related to material shortages, long lead times for basic commodities, and staffing issues. According to the program office, DOD’s top priority for Sentinel is delivering the weapon system to the warfighter by the date it is needed, which is essential to DOD’s mission of maintaining strategic deterrence. It added that the Air Force is actively working to address current and potential future macroeconomic pressures via an updated acquisition strategy.

MDAP Lead Component: Air Force

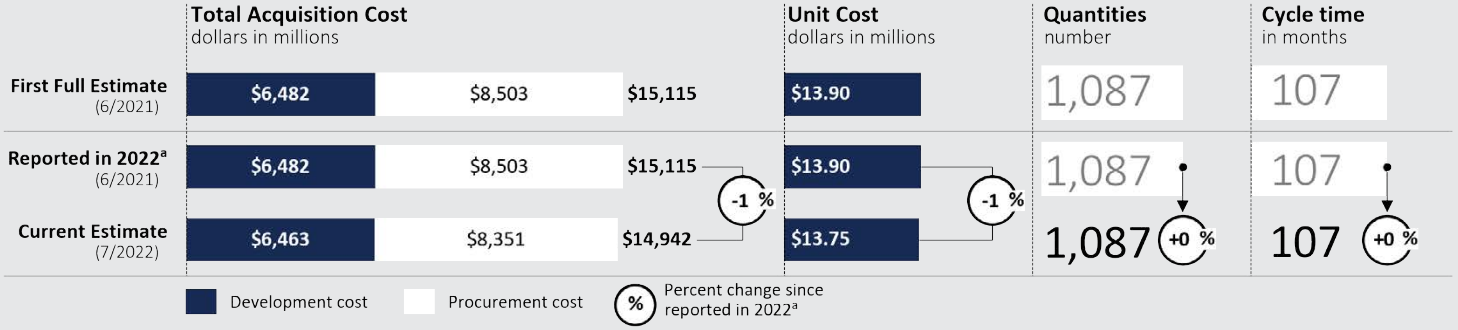
Common Name: LRSO

Long Range Standoff (LRSO)

The Air Force is designing the LRSO weapon as a long-range, survivable, nuclear cruise missile to penetrate advanced threat air defense systems. LRSO is slated to replace the Air Launched Cruise Missile. The LRSO's nuclear warhead—the W80-4—is managed by the Department of Energy (DOE) and is undergoing a life-extension program in parallel with the missile's development. Coupled with legacy and potential future bombers, the LRSO is expected to help modernize the bomber segment of the nuclear triad.

Source: U. S. Air Force. | GAO-23-106059

Program Performance fiscal year 2023 dollars in millions

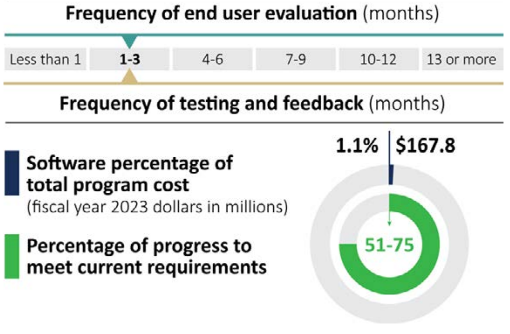


Total quantities include development and procurement missiles. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile, Waterfall, Incremental, and DevSecOps



Program Essentials

Prime contractor: Raytheon Missiles & Defense

Contract type: CPFF

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	○	○
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	●	●
Test a system-level integrated prototype	●	●
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess LRSO manufacturing maturity because the program has yet to reach production.

LRSO Program

Technology Maturity and Design Stability

LRSO started development in June 2021 with immature technologies, as we previously reported. The missile has several critical technology areas—two are considered mature, three are approaching maturity, and one is still immature. The program plans to complete testing of the immature technology, nuclear hardness, in a relevant environment by December 2023.

Additionally, DOE officials separately identified critical warhead technologies, 77 percent of which are immature. DOE reported it does not expect maturity of all these technologies until fiscal year 2025. As we reported last year, starting development without demonstrating critical technologies in a realistic environment increases the risk that issues may arise later in development that may need costly or time-consuming rework.

The LRSO missile program met two knowledge metrics that are associated with a stable design. Specifically, LRSO released 91 percent of its planned design drawings to manufacturing prior to critical design review, a marker of design stability according to leading practices. Additionally, consistent with leading practices, the program tested a system-level integrated prototype in October 2022, before the review.

DOE officials told us they held the warhead baseline design review in August 2022, which will help inform the missile critical design review. The baseline design review occurred after several delays. Overall, the program released only 40 percent of its system design drawings as of December 2022.

DOE officials told us that warhead design immaturity contributed to delays in warhead test asset availability and increases the risk that issues will emerge later in the development process that could require rework. DOE officials also told us that a recently completed DOE schedule risk assessment indicates a potential 18-month delay in warhead development. But the program office told us that warhead test asset availability delays are expected to be mitigated by utilizing surrogate warheads. As a result, it does not expect this delay to hold up the overall program’s planned fielding.

Production Readiness

The Air Force plans to demonstrate missile critical manufacturing processes on a pilot production line prior to the production decision in 2027. Our prior work found this testing provides decision makers confidence that the contractor can meet quality, cost, and schedule goals. Program officials are also planning to ensure all key characteristics of their critical manufacturing processes are either verified through statistical process control or 100 percent inspected prior to the start of production.

Software and Cybersecurity

The program identified missile software development as a medium risk, reporting challenges with hiring staff with the required experience. It plans 10 incremental software deliveries in development, four of which were delivered so far. End users of the software have been involved in providing feedback to the developer, which aligns with modern software development practices.

The LRSO program has assessed some cybersecurity risk to date, in which it identified some possible vulnerabilities. Program officials stated that these assessments will support system design. Several more assessments are planned throughout development.

Other Program Issues

Two cost estimates prepared for the start of LRSO development reflected significant procurement cost differences. An Office of the Secretary of Defense (OSD) independent cost estimate found procurement could cost $1.9 billion more than the Air Force’s estimate. Officials said the higher OSD estimate used procurement cost data from past nuclear cruise missile programs. Air Force estimators used proposed data, purchase orders, and actual cost data from parts of recently-built LRSO test missiles. The program’s milestone decision authority chose to use the higher OSD estimate, but requested that OSD conduct another estimate in 2023 using actual data from the manufacturing of additional LRSO test missiles.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, LRSO development is on track for on-time fielding. The program office stated that it will continue to focus on leading acquisition practices to support development and that it uses industry best software development processes. It added that it implemented mitigation steps to ensure the maturation of the one remaining immature technology supports future production and fielding. The program office also noted that the warhead completed a series of design reviews, along with system and flight tests and is on-track for a March 2023 entry into the phase of preparing for production. It added that DOE’s focus is continued mitigation of production risks.

MDAP Lead Component: Air Force **Common Name:** MH-139A

Source: U. S. Air Force. | GAO-23-106059

MH-139A Gray Wolf Helicopter (MH-139A)

The MH-139A program will replace the Air Force's fleet of 63 UH-1N utility helicopters. The MH-139A helicopter's missions will include securing intercontinental ballistic missile sites and convoys and transporting senior government officials in the National Capital Region. The MH-139A program is acquiring a militarized version of a commercial helicopter to be integrated with previously developed systems. In addition to the helicopters, the program plans to acquire an integration laboratory, a training system, and support and test equipment.

Program Performance fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions				Unit Cost dollars in millions		Quantities number		Cycle time in months	
First Full Estimate (9/2018)	$643	$2,738	$3,739		$45		84		60	
Reported in 2022[a] (7/2020)	$673	$2,757	$3,695		$44		84		TBD	
Current Estimate (7/2022)	$670	$2,571	$3,520	-5 %	$44	+0 %	80	-5 %	77	N/A %

■ Development cost □ Procurement cost (%) Percent change since reported in 2022[a]

Total quantities comprise six development quantities and 74 procurement quantities. The program reduced the total quantity to 80 after a mission requirement was removed. The program did not report an initial operational capability date last year and, as a result, the cycle time in 2022 could not be calculated. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile

Frequency of end user evaluation (months)

Information not available

Less than 1	1-3	4-6	7-9	10-12	13 or more

Information not available

Frequency of testing and feedback (months)

Software percentage of total program cost (information not available)

Percentage of progress to meet current requirements

The program reported that it does not have insight on software costs since they are included in the overall firm-fixed-price contract. The program also reported that software development for the aircraft was completed and the software for the training systems is nearly complete.

Program Essentials

Prime contractor: Boeing

Contract type: FFP (development)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	NA	NA
Demonstrate all critical technologies in a realistic environment	NA	NA
Complete a system-level preliminary design review	NA	NA
Product design is stable	Design Review	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	NA	NA
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess MH-139A critical technologies because the program office reported that it does not have any. We also did not assess completion of a preliminary design review or system-level integrated prototype testing because the program office reported that these were not applicable. Further, we did not assess manufacturing maturity because the system had yet to reach production at the time of our cut-off date for new information.

MH-139A Program

Technology Maturity and Design Stability

During the past year, the program successfully completed some of the testing that it had previously delayed. Specifically, according to officials, the program completed the first three of five levels of supplemental certification testing required by Federal Aviation Administration (FAA) in July 2022. This testing was completed after several delays that contributed to a schedule breach in April 2021. The program office attributed the delays to unanticipated challenges integrating previously developed military systems onto the commercial platform. FAA is reviewing test reports and documentation before certifying the aircraft and the program anticipates completing certification by May 2023.

The program office reported that the aircraft design is starting to stabilize due to several developments over the past year. Program officials stated that the completion of the first three levels of supplemental testing increased design stability, which also reduced the likelihood that the weight of the aircraft would have to be modified. Further, as of January 2023, the program reported that it released at least 90 percent of expected drawings to manufacturing, a key marker of design stability. Last year, we reported that the program had not met this leading practice because of a significant increase in the total number of expected design drawings over a 2-year period.

Production Readiness

The program plans an initial low-rate production purchase of 13 aircraft at production start. Program officials stated that the program is currently scheduled to reach the production start milestone in February 2023, 17 months later than previously scheduled due to the delays in obtaining FAA certification testing.

According to program officials, they plan to start production prior to the planned May 2023 completion of supplemental certification. This certification involves the sustainability of an external case for infrared sensors and the closed circuit refueling mechanism, which allows refueling under pressure to shorten refueling times. Until this certification is completed, the program is at risk of incurring additional cost due to later design changes. The program expects these certification updates will drive retrofits of previously delivered aircraft, which will also include capabilities certified in fiscal year 2023.

The program reported that, to date, Boeing absorbed the cost growth resulting from schedule delays. The program told us that it plans to exercise an option on an existing contract to purchase the first low-rate initial production lot.

Software and Cybersecurity

According to program officials, the program's baseline aircraft software development was completed in July 2022. However, the program also noted that the aircraft's training systems software development is ongoing. The program office anticipates completing this software development during the third quarter of fiscal year 2023.

The program conducted developmental adversarial cyber testing in October 2022 to identify potential cyber vulnerabilities beyond those found in earlier cyber test activities. Program officials stated that they plan to mitigate previously identified cyber risks through policy and procedural controls.

Other Program Issues

Program officials reported that in 2020, the total production quantity was reduced by four aircraft. This reduction occurred because the Pacific Air Forces Command removed its requirements for this aircraft. Program costs were updated to account for this decrease. In addition, the program delayed initial operational capability for 13 months from our prior assessment due to delays completing supplemental certification testing.

Program officials told us that they are not pursing a modular open systems approach for MH-139's incremental systems development because the program largely integrates existing capabilities. However, the officials noted that some of the capabilities integrated into the aircraft, such as a selective availability anti-spoofing module-based global positioning receiver, used this approach. They plan to leverage the benefits offered by those capabilities.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program, it recovered from schedule delays in 2022 with the issuance of long-awaited FAA certifications that led to the acceptance of the first four MH-139A helicopters. It noted that the program accomplished significant developmental testing, such as exercising the integrated military capabilities and expanding range of flight conditions. The program office added that the program is expected to meet all requirements.

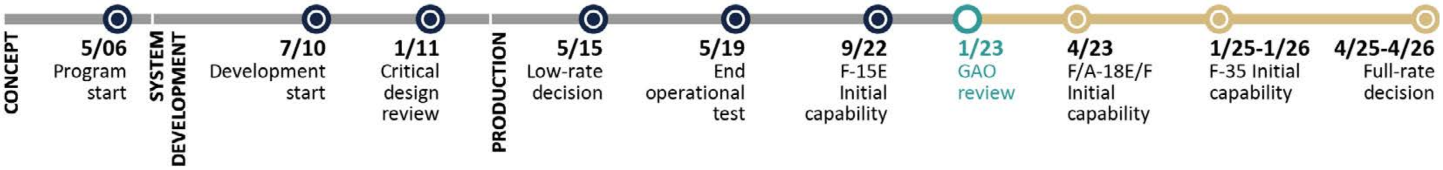
The program further stated that it is positioned to enter into low-rate initial production in February 2023, when the Air Force plans to purchase 13 aircraft and the remaining training systems. The program stated that, for the remainder of 2023, it will focus on continued developmental testing and readiness for initial operational test and evaluation.

MDAP | Lead Component: Air Force | **Common Name**: SDB II

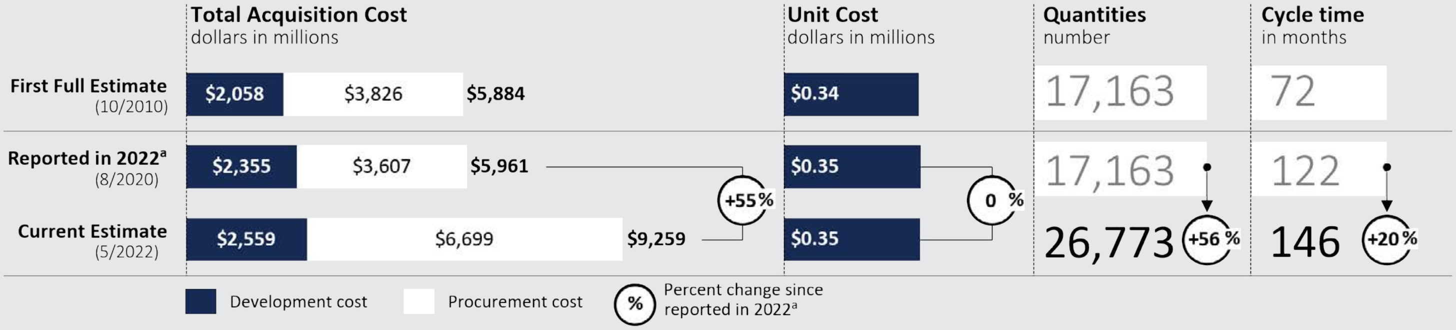
Source: © 2009 Raytheon Company. | GAO-23-106059

Small Diameter Bomb Increment II (SDB II)

The Air Force's SDB II StormBreaker is a joint-interest program with the Navy that is designed to provide attack capability against mobile targets in adverse weather from extended range. It combines radar, infrared, and semiactive laser sensors to acquire, track, and engage targets. It uses airborne and ground data links to update target locations, as well as a GPS and an inertial navigation system to ensure accuracy. SDB II will be integrated with various Air Force and Navy aircraft.



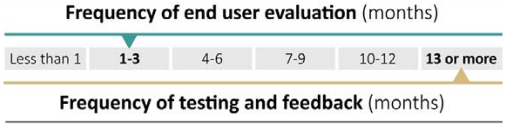
Program Performance fiscal year 2023 dollars in millions

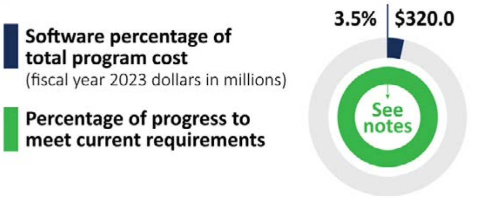


Total quantities comprise 163 development quantities and 26,610 procurement quantities.
[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile and Iterative (other than Agile)





The program reported initial software development was completed for fielding on the F-15E. Software is continually updated for enhanced capability and fielding on other aircraft.

Program Essentials

Prime contractor: Raytheon Missiles and Defense

Contract type: FPI/FFP (procurement)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	...	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	●	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We could not assess SDB II design drawing stability at design review because the program implemented design changes after this event but did not track these changes in such a way that we could assess the effect on design stability at the program’s design review.

SDB II Program

Technology Maturity, Design Stability, and Production Readiness

As we reported last year, SDB II has mature critical technologies and a stable design. Over the past year, the program finished addressing production challenges we previously reported on related to the clip holding the bomb's fins and the guidance component. The contractor incorporated a redesigned fin clip into production for lot 5 units, which started delivery in June 2021, and retrofitted delivered units from the first four lots to address these issues.

Lot 6 deliveries began in July 2022, after delays due to subcontractor production issues, according to program officials. Specifically, supplier shortfalls and workforce shortages during the COVID-19 pandemic exacerbated production issues. The program brought on an additional supplier to minimize further delays and expects to resolve delays with delivery of all 1,228 lot 6 units by the end of lot 8 production in 2025. Delivery of lot 7 units is scheduled to begin in September 2023.

Program officials indicated that incorporation of the military code (M-code) chip is no longer a major technical risk because they determined that it met critical design and production requirements. M-code is a stronger, encrypted GPS signal intended to help military users overcome signal jamming. In September 2022, the program purchased the M-code chips needed for production. It began M-code chip integration in the fall of 2022 and will conduct verification testing through the fourth quarter of fiscal year 2024. The program expects to incorporate the M-code chip into production for lot 11 deliveries in 2027. According to officials, the program has a waiver that does not require M-code integration on lots 6-10.

Software and Cybersecurity

The program is experiencing several challenges related to software development efforts. For example, the program is working with the National Security Agency to correct problems with receiving modernized cryptographic keys after retiring the legacy keys, according to officials. These keys help to improve information security. Further, officials told us that they experienced delays in receiving the operational flight software, which included system upgrades to address multiple deficiencies. Although the program is working through operational key issues, it successfully tested cryptographic modernization using test keys on the F-15 and F-18 aircraft. Program officials expect the upgraded software capabilities to be on the F-15 and F-18 in April 2023, and on the F-35B in September 2023.

The program does not currently have a cybersecurity requirement, according to officials. They noted, however, that Raytheon implemented cybersecurity features and capabilities. Further, officials told us that the program completed four phases of DOD's Cybersecurity Test and Evaluation process. As of January 2023, the program is working with the Director of Operational Test and Evaluation and the Navy to define cybersecurity test requirements.

Other Program Issues

Since our last assessment, the program's estimated total acquisition costs increased by approximately 55 percent, due to an increase in procurement quantity from 17,000 to 26,610 weapons. Our past work suggests that it is reasonable to expect that unit costs will decrease as more units are produced due to cost reductions achieved through economies of scale. For SDB II, however, unit costs did not decrease. To increase the inventory to meet the new production quantity, the program will have to complete a costly technical redesign of the weapon's seeker because of obsolete parts.

The program breached schedule thresholds for the weapon's initial operational capability on the F-35 and for full-rate production. While SDB II is ready for testing on the F-35, the F-35 program encountered software development delays that held up the completion of SDB II integration and testing. According to the program, the change in procurement quantity and the F-35 delays led to a May 2022 update of the program's baseline. The initial operational capability delay for the F-35 to January 2025 caused the SDB II full-rate production date to slip to at least April 2025. As of January 2023, SDB II is on track to meet the revised costs and planned dates, according to program officials.

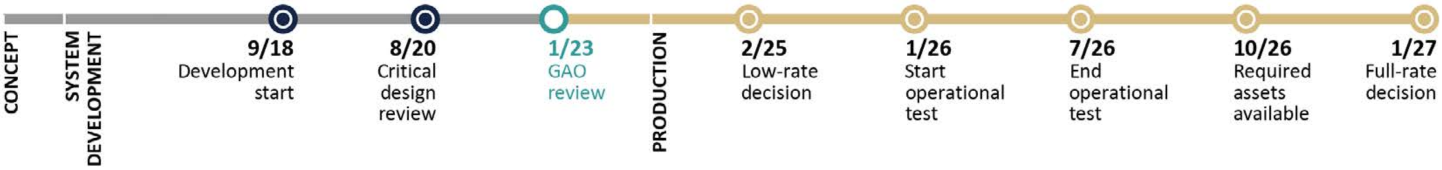
Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that SDB II reached a significant milestone this year when the Air Force declared initial operational capability on the F-15E and is on track for early operational capability on the F-35B in fiscal year 2025. Further, the program office stated that it completed a lifetime buy of over 85,000 Raytheon M-code chips, addressing a provision in the Ike Skelton National Defense Authorization Act for Fiscal Year 2011.

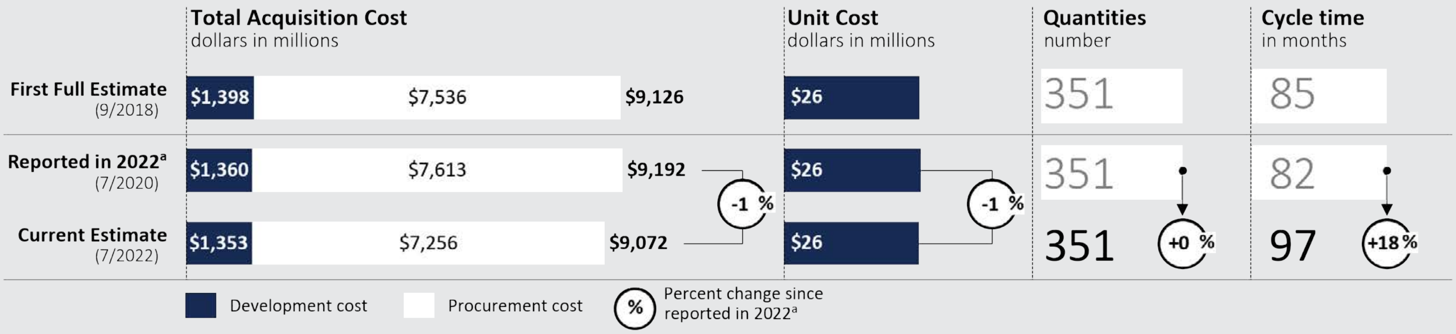
Source: Boeing Corporation. | GAO-23-106059

T-7A Red Hawk

The Air Force's T-7A Red Hawk program, formerly the Advanced Pilot Training program, is expected to replace the Air Force's legacy T-38C trainer fleet and related ground equipment by developing and fielding newer, more technologically advanced trainer aircraft. The program is developing two major components for the T-7A: the air vehicle and an associated ground-based training system. T-7A program seeks to address the Air Force's advanced fighter pilot training needs and close training gaps that the T-38C cannot fully address.



Program Performance fiscal year 2023 dollars in millions

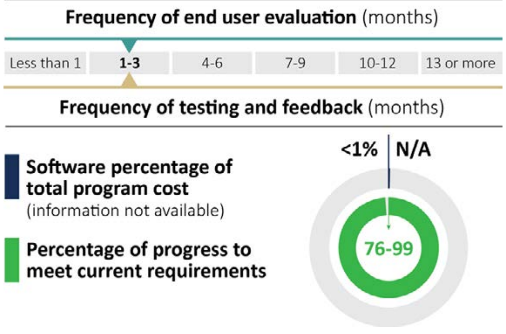


Total quantities comprise five development quantities and 346 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance. The required assets available date is scheduled about 90 days ahead of the program's planned initial operational capability date of January 2027.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile



The program reported an estimated percentage on software costs but stated that it does not track these costs.

Program Essentials

Prime contractor: Boeing

Contract type: FPI/FFP (development)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	○	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	●	●
Test a system-level integrated prototype	○	○
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess T-7A's manufacturing maturity because the system has yet to reach production.

T-7A Program

Technology Maturity and Design Stability

Program officials declared a schedule breach in June 2022 after assessing program risks and determining that the baseline schedule for low-rate production was unachievable. Health and safety concerns with the escape system are the most significant factors driving program delays. The program reported the canopy fracturing system—one of the program's two critical technologies—as mature. But Air Force data from testing in 2021 showed that it does not meet airworthiness requirements, based on the likelihood of injury during ejection.

Health and safety concerns raised by members of Congress, as well as the Air Force's low risk tolerance for student pilots, increased the sensitivity of this issue. The program and Boeing disagree on how to measure the probability of serious injury, particularly in the case of cockpit pressure created from the controlled explosion that fractures the canopy. To help resolve these issues, program officials said that they placed an order with Boeing for $3.8 million to study ways to improve escape system performance beyond the current contract, and to become fully compliant with Air Force airworthiness standards.

Program officials told us that they cannot proceed with developmental flight testing until the T-7A program reduces risks associated with safety and airworthiness. The program tested some changes to the escape system in February 2023, which reduced some safety risks. Based on the test results, the program plans to seek approval from the Air Force Acquisition Executive to begin developmental flight testing at higher risk while it resolves remaining issues.

The program's other critical technology, the 8K projector for the Ground-Based Training Systems (GBTS), is approaching maturity. The program office, however, reported that integration of the 8K projector remains a risk because of defective pixels and image stability. The projector subcontractor indicated it cannot correct these issues until it establishes a production assembly line. Boeing expects to assess a sample projector for improvements in June 2023.

Last year, we reported that the program was tracking a risk related to protecting the pilot in the event of hitting a 4-pound bird during certain flight conditions. Since then, the program identified the necessary improvements to the blast shield and windshield and plans to complete final qualification tests for this fix by 2023.

Production Readiness

Boeing is nearing completion of the program's planned five developmental aircraft. However, with the recent schedule breach, the program postponed the planned date for the low-rate initial production decision from November 2023 to February 2025. The Air Force's decision to delay production until the program resolves key technology issues may help reduce the potential for costly rework during production.

Boeing designed and built the first five T-7A aircraft using full size determinant assembly, an innovative manufacturing method expected to provide certain benefits for production and sustainment. In the full size determinant assembly process, suppliers deliver digitally engineered parts with the holes precisely and accurately drilled at connection points, eliminating the need for manual drilling for more than 65,000 fasteners on each aircraft.

According to Boeing, using the full size determinant assembly method is expected to reduce drilling mistakes and nonconformities during production by as much as 98 percent. Boeing successfully assembled the five developmental aircraft in a relatively short amount of time using this method, which supports the Air Force's expectations that Boeing will produce T-7A aircraft more quickly and accurately than previous aircraft.

Software and Cybersecurity

T-7A uses a mix of commercial and custom software and hardware. Additionally, both the aircraft and GBTS use the same software, which program officials expect to enable simultaneous updates and more consistent training. Program officials reported that, as of November 2022, Boeing expects to deliver the final software version in 2023 for developmental aircraft. However, these officials also noted that the program may need additional software deliveries to resolve any critical deficiencies identified in subsequent testing.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that it is focused on delivering the T-7A Red Hawk to the Air Force Air Education and Training Command for training the Air Force's future fighter and bomber pilots.

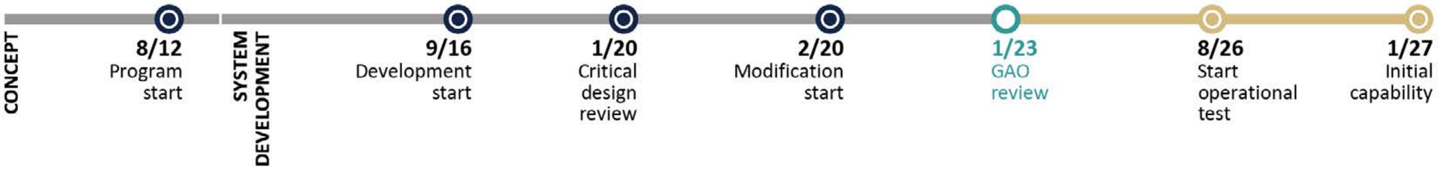
MDAP Lead Component: Air Force

Common Name: VC-25B

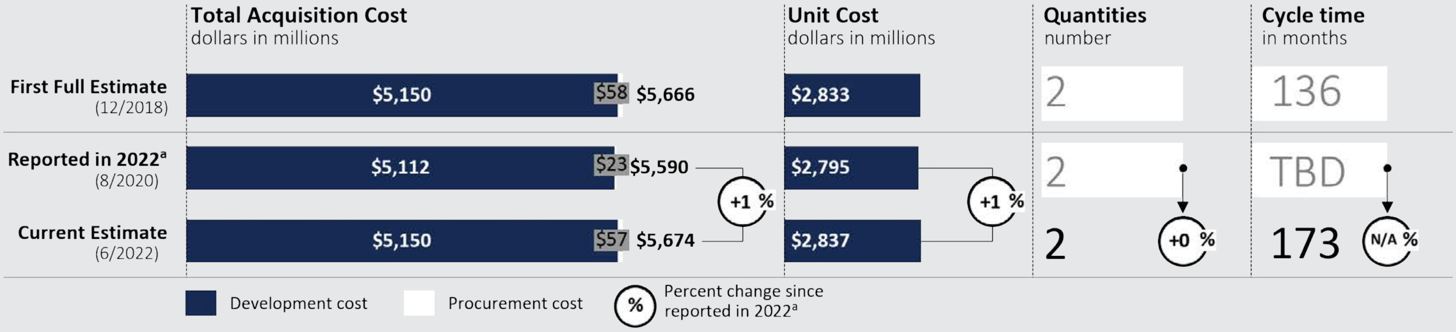
Source: The Boeing Company. | GAO-23-106059

VC-25B Presidential Aircraft Recapitalization (VC-25B)

Through its VC-25B program, the Air Force is replacing the current two VC-25A presidential aircraft with two modified Boeing 747-8 aircraft. The Air Force plans to modify the commercial aircraft to provide the U.S. President, staff, and guests with safe and reliable air transportation, with the same level of security and communications available in the White House. Aircraft modifications will include structural modifications, electrical power upgrades, a mission communication system, military avionics, executive interiors, and other systems.



Program Performance fiscal year 2023 dollars in millions



	Development cost	Procurement cost	Total Acquisition Cost	Unit Cost	Quantities	Cycle time
First Full Estimate (12/2018)	$5,150	$58	$5,666	$2,833	2	136
Reported in 2022[a] (8/2020)	$5,112	$23	$5,590	$2,795	2	TBD
Current Estimate (6/2022)	$5,150	$57	$5,674	$2,837	2	173
Percent change since reported in 2022[a]			+1 %	+1 %	+0 %	N/A %

Total quantities comprise two development quantities and zero procurement quantities. Cycle time is calculated using the required assets available date. The program did not report a planned initial capability date last year and, as a result, the cycle time in 2022 could not be calculated. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile, Iterative (other than Agile), and Waterfall

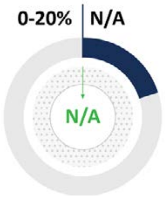
Frequency of end user evaluation (months)

Information not available

Less than 1	1-3	4-6	7-9	10-12	13 or more

Information not available

Frequency of testing and feedback (months)



Software percentage of total program cost (information not available)

Percentage of progress to meet current requirements

The program reported an estimated percentage for software costs, but it does not track software deliveries or costs under the firm-fixed-price contract.

Program Essentials

Prime contractor: Boeing

Contract type: FFP (development)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	NA	NA
Demonstrate all critical technologies in a realistic environment	NA	NA
Complete a system-level preliminary design review	○	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	○
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

We did not assess VC-25B critical technologies because the program told us that the system does not have any. We also did not assess manufacturing maturity because the program stated that these metrics are not applicable due to its plan to modify fully-mature commercial aircraft.

VC-25B Program

Technology Maturity, Design Stability, and Production Readiness

VC-25B will integrate mature technology into two existing commercial aircraft.

Boeing began modifying both aircraft in 2020. According to VC-25B officials in 2022, Boeing completed major structural modifications and continued secondary modifications, including floor/cargo track modification, on the first aircraft. It also began preparations for wiring installation, planned to start in May 2023. Boeing is completing the major structural modifications, expected to finish in February 2023. Secondary structural modifications for the second aircraft have been ongoing since early 2022.

The program office continues to track four major schedule risks we reported on last year, though progress has been made in some areas:

First, program officials stated that Boeing's transition of the interior subsystem work to the new supplier took more time than Boeing originally scheduled. They noted that delays were due to the work needed to resolve technical and certification issues in the previous supplier's design. They also said that Boeing updated the master schedule in October 2022.

Second, wiring design and fabrication was slower than planned. According to program officials, Boeing identified a large number of unexpected design errors, which led to suspension of wiring fabrication in March 2022. Program officials stated that Boeing is increasing the number of wiring suppliers to prevent delays in fabricating the volume of wiring needed once the wiring design is final.

Third, Boeing experienced aircraft mechanic workforce limitations due to a competitive labor market, according to program officials. In addition to needing to possess specific skills, employees must also meet stringent security requirements to work on the VC-25B program because of its presidential support mission.

Program officials stated that with help of the Air Force, Boeing has taken recent steps to mitigate workforce limitations. As of January 2023, they noted that Boeing met hiring targets for structural mechanics and was on course for other specialties. They said that Boeing increased hiring rates over the past year to account for attrition. Further, in 2022, the Air Force began a formal prescreening process for applicants to help mitigate the lower-than-planned security clearance approval rates for skilled workers needed to modify the aircraft. Program officials also stated that Boeing created additional onboarding skills training to ensure mechanics had the required skills prior to performing on-aircraft work.

Lastly, program officials reported that Boeing's test plans will likely not be completed by first flight—currently scheduled for April 2024. This increases the risk of testing delays. If testing takes longer than expected, the program may experience additional delays to future milestones.

Software and Cybersecurity

The program reported that there are no significant software or cybersecurity related issues at this time.

Other Program Issues

The Under Secretary of Defense for Acquisitions and Sustainment approved the new VC-25B program baseline in June 2022. This reflects a more than 2-year delay from the original program baseline delivery dates of the two aircraft, from September 2024 to January 2027 and February 2025 to April 2027, respectively. According to program officials, they have ongoing negotiations with Boeing to update the contracted delivery dates. The Air Force's Air Mobility Command, in consultation with the White House Military Office, will determine when the aircraft has reached initial operational capability. VC-25B schedule delays will likely delay retirement of the VC-25A, fielded in 1990 and currently scheduled to retire in 2025. The VC-25A will be maintained until the two VC-25Bs are fielded.

Program officials also stated that numerous stress-corrosion cracks on certain aircraft support structures were discovered on the 747-8 commercial fleet—including crack locations on each VC-25B—that require repair. According to VC-25B officials, about half of the cracks have already been repaired as of December 2022, and the remaining cracks will be repaired by summer 2023. Program officials said that an Independent Review Team consisting of Air Force, Boeing, and Federal Aviation Administration experts noted that the cracks do not present any safety issues to the VC-25B aircraft, as long as planned inspections are conducted during scheduled VC-25B maintenance periods.

Program Office Comments

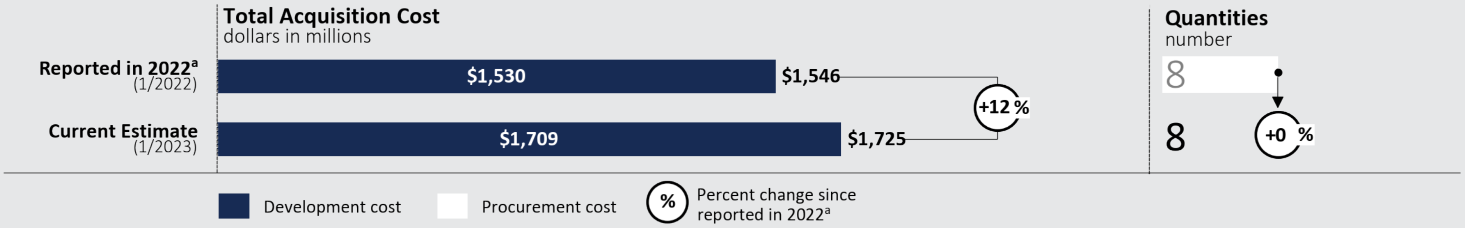
We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that it will continue to work with Boeing to manage all program risks to modify, test, and deliver presidential mission-ready VC-25B aircraft.

Source: U. S. Air Force. | GAO-23-106059

Air-launched Rapid Response Weapon (ARRW)

The Air Force's ARRW, an MTA rapid prototyping effort, is developing a conventional, long-range, air-launched hypersonic missile that can be carried on a B-52H bomber aircraft. The program leveraged the Defense Advanced Research Projects Agency's tactical boost glide effort to develop the missile's hypersonic-speed glider component. The program plans to produce eight missiles with up to four intended as spares.

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

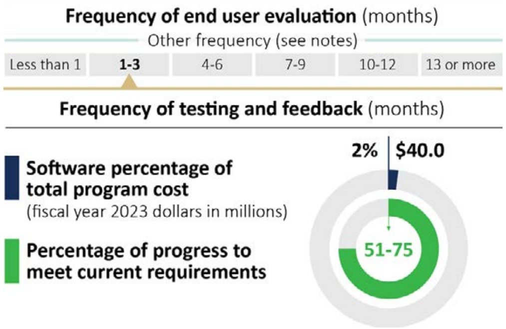
[a] GAO-22-105230

Program Background and Transition Plan

The Air Force initiated ARRW as an MTA rapid prototyping effort in 2018 with an objective to complete it by September 2022. The schedule was delayed by more than a year after numerous delays and a booster test failure in 2021. The program successfully completed two of three booster tests and its first missile test in 2022. The program plans to complete three more flight tests in an operational environment in 2023, but it is now likely to exceed the 5-year period established in DOD policy for MTA programs. The Air Force has not committed to any ARRW follow-on efforts and additional missile procurements.

Software Development as of January 2023

Approach: Agile



The program reported that end users evaluate and provide feedback when software is released and implemented.

Program Essentials

Prime contractor: Lockheed Martin

Contract type: CPFF (development)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	○	●
Formal technology risk assessment	○	●
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	○	○

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

ARRW Program

Updates to Program Performance and Business Case

Since our last assessment, ARRW had increased testing success. But its remaining schedule is compressed and its costs continued to grow. After multiple delays and one failure in 2021, the program completed its booster testing program with two successful tests in 2022. The first flight test of a missile in an operational environment was successfully completed in December 2022, and a second is planned for early 2023.

The program plans to complete three more missile flight tests in 2023, but it is likely to exceed the 5-year MTA period established in DOD policy. The program estimated that the last test will take place by the end of 2023, up to 4 months beyond the 5-year period. According to program officials, the contractor projected that it would deliver some test missiles later than planned. The delay left the program with a single missile for the first two tests but will not likely affect subsequent tests where two missiles should be available. According to officials, using a single missile does not affect the planned test but does limit their ability to learn more about a configuration where two missiles fly on the B-52 at the same time.

If the program does not successfully complete the planned tests by the end of the 5-year MTA period, program officials said that they must seek a waiver from the Defense Acquisition Executive to extend the program or complete the program with fewer planned tests.

ARRW's estimated costs increased for the fourth consecutive year. This year's increase was due to booster testing delays and failures and the schedule extending into fiscal year 2023. Overall, the Air Force Cost Analysis Agency's annual independent cost assessment increased by almost 85 percent from its first assessment in April 2018 to its latest in April 2022.

Software and Cybersecurity

ARRW experienced several software development challenges. Program officials stated that software costs increased because the contractor provided more software releases than planned to support booster flight tests and address failures. The program also reported challenges hiring contractor and government staff.

ARRW successfully completed a cyber test on its software in September 2022 and has not identified any repeated cybersecurity vulnerabilities in any of its assessments.

Key Product Development Principles

ARRW reported that it focused on obtaining customer feedback, a practice in line with leading principles for product development. Specifically, the program identified its end users and involved them early. For example, program officials said that munitions loaders provided feedback as the procedures for equipping the aircraft with the missile were developed and improved. We previously found that ongoing engagement with customers is an important aspect of iterative development that leading companies use to prioritize features and identify product improvements.

We have ongoing work to define metrics associated with our leading principles, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

As of October 2022, ARRW officials told us that Air Force leadership has yet to determine future production and any additional development of ARRW in a follow-on effort. We reported last year that the Air Force planned to initiate a new MTA rapid fielding effort in fiscal year 2022, but booster test failures prolonged the MTA rapid prototyping effort. The program took several steps to prepare for the transition to a rapid fielding MTA effort if it is approved. Program officials stated that they will complete a production readiness review in early 2023.

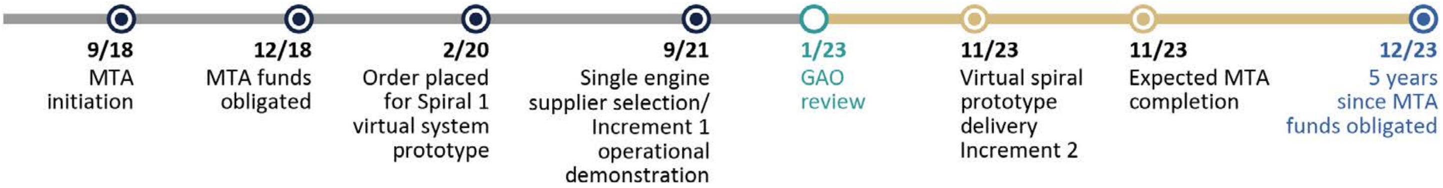
Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program provided technical comments, which we incorporated where appropriate.

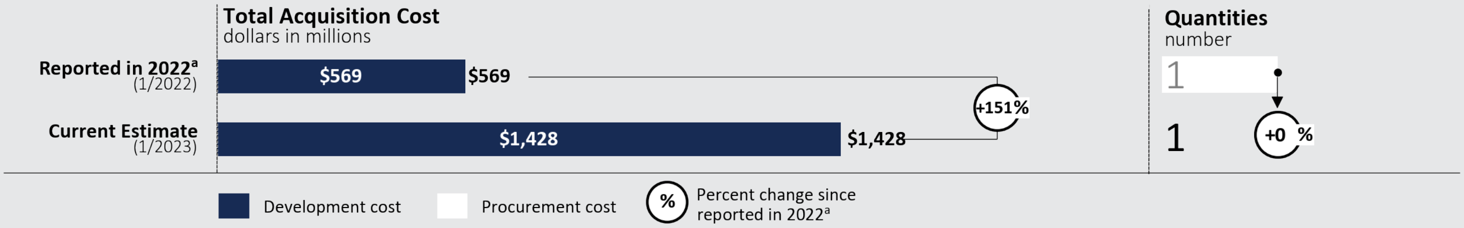
Source: U. S. Air Force. GAO-23-106059

B-52 Commercial Engine Replacement Program (CERP) Rapid Virtual Prototype (RVP)

The CERP RVP effort is expected to deliver a virtual system prototype to reduce risk and inform the Air Force's overall B-52 CERP. The B-52 CERP plans to support nuclear and conventional operations by replacing the aircraft's engine with military-configured commercial engines. Along with the new engines, the B-52 CERP will replace associated subsystems, such as engine struts, the electrical power generation system, and cockpit displays for the B-52H fleet.



Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



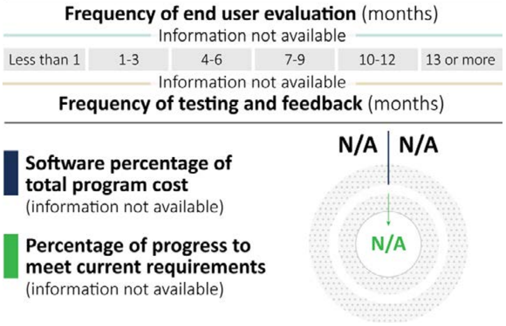
Quantity refers to the one virtual prototype the program is acquiring under the MTA effort.
[a]GAO-22-105230

Program Background and Transition Plan

Since 2018, the program office worked with Boeing to conduct risk reduction requirements studies and deliver virtual prototypes. In 2021, Rolls Royce was selected to work with Boeing to integrate its engine into the virtual system prototype design. Initial capability for CERP RVP (increment 1) was delivered in September 2021, and the full capability (increment 2) is expected to be delivered in November 2023. The program plans to transition to the major capability acquisition pathway with entry at system development in late fiscal year 2023.

Software Development as of January 2023

Approach: Agile and Incremental



The program reported that end user feedback and tracking of software deliveries will occur after the program transitions to the major capability acquisition pathway. The program reported software costs for the total B-52 CERP program to be $101 million, which includes costs beyond the MTA rapid virtual prototyping effort.

Program Essentials

Prime contractors: Boeing: Rolls Royce

Contract type: CPIF, FFP

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	●	●
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	●	●

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

B-52 CERP RVP Program

Updates to Program Performance and Business Case

Over the last year, the Air Force revised its approach for the B-52 CERP RVP MTA effort and modified its overall B-52 CERP acquisition strategy. Both of these changes contributed to cost increases. Originally, the overall B-52 CERP acquisition strategy called for the Air Force to develop and test the B-52 CERP through two MTA efforts or Spirals. Spiral 1, known as the CERP RVP, was expected to deliver a virtual system prototype to support a preliminary design review. Spiral 2 was for physical prototypes to inform the Air Force's effort to extend the life of B-52H aircraft.

However, in October 2021, Air Force officials stated that the CERP RVP effort was considering transitioning to DOD's major capability acquisition pathway in fiscal year 2023 following the preliminary design review, with entry at system development. In March 2022, the Principal Deputy Assistant, Secretary of the Air Force for Acquisition, Technology, and Logistics signed a memorandum that extended the CERP RVP effort schedule by more than a year, until November 2023.

Program officials stated that the added time allows them to prepare transition documents and increase the program's scope to mature the virtual prototype further. Program officials plan to hold a critical design review for the overall B-52 CERP effort in early fiscal year 2025.

The memorandum also approved the transition to the major capability pathway for the overall B-52 CERP program after the conclusion of the CERP RVP effort. It eliminated plans for the Spiral 2 MTA effort and added the cost of long-lead procurements to support B-52 CERP system development, which were originally accounted for in the Spiral 2 MTA effort. According to program officials, procuring the long-lead items and extending the current MTA effort accounts for CERP RVP cost increases.

Software and Cybersecurity

System software deliveries and software data reporting will not start until hardware deliveries begin for the overall B-52 CERP, according to program officials. For the overall B-52 CERP, the program plans to use an Agile development approach to incrementally develop and deliver software.

The program conducted its first cybersecurity exercise in June 2022 and finalized the B-52 CERP cybersecurity plan in February 2023. The next exercise is planned for May 2023.

Key Product Development Principles

In line with our leading principles for product development, the CERP RVP effort solicited feedback from end users during design and development of the virtual prototype through monthly working group meetings. The program completed an interim delivery in August 2022 and plans to obtain additional feedback after final delivery of the next prototype increment.

Our prior work found that ongoing engagement with customers is an important aspect of iterative development that leading companies use to prioritize features and identify improvements to the product. We have ongoing work to define metrics associated with our leading principles for product development, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

Extending the CERP RVP schedule to improve the maturity of the virtual system reduces risk for B-52 CERP system development. However, any delays could put the program at risk of not being completed within the 5-year MTA time frame set in DOD policy.

The overall B-52 CERP program may encounter risk as it transitions from the MTA pathway to the major capability pathway. In a June 2022 technology readiness assessment, program officials did not identify any critical technologies as these subsystems are based on commercially proven components. However, they indicated some components will require modification to their current form, fit, or function, which presents risks in design and integration.

Additionally, in October 2022, the program held a preliminary design review, which identified risks with engine fan distortion and stress loads on parts of the wing. While the program plans to conduct a number of tests to mitigate risk, it does not intend to develop and test a system-level integrated prototype before critical design review. As such, the program risks costly and time-intensive design changes if issues are discovered later.

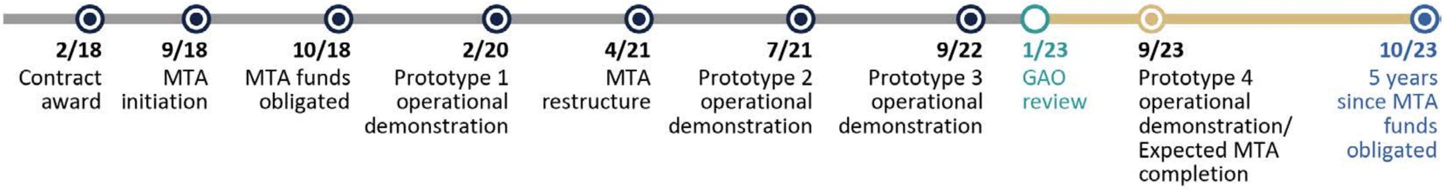
Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, the B-52 CERP MTA strategy enabled the program to start development faster and reduce technical risk in the engine source selection. The program office stated that it successfully completed several important tasks during the MTA effort, such as developing a virtual system prototype, delivering a first increment of residual operational capability to Air Force Global Strike Command, and completing a preliminary design review. According to the program office, the Air Force extended the MTA effort to facilitate the planned transition to the major capability pathway in 2023, while remaining within the five-year time frame. The program office also stated that its efforts enhanced design maturity, increasing the maturity of future B-52 CERP increments. The program further noted that ongoing component testing, along with digital risk reduction efforts, addresses integration risk and expects this testing to culminate in system-level aircraft testing during the system development phase.

Source: Defense Visual Information Distribution Service. | GAO-23-106059

F-22 Rapid Prototyping

The Air Force's F-22 program, utilizing the MTA rapid prototyping and fielding pathways, intends to develop, integrate, and deliver hardware and software capabilities to F-22 aircraft. This assessment focuses on the F-22 rapid prototyping effort, which is expected to develop enhanced capabilities, including for tactical information transmission, combat identification, navigation, sensors, fuel tanks, and electronic protection.



Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions	Quantities number	
Reported in 2022	Not approved for public release by the Air Force	4	
Current Estimate (1/2023)	Not approved for public release by the Air Force	4	+0 %

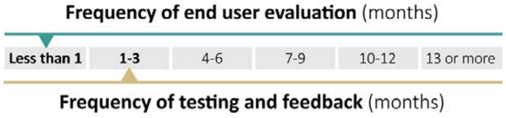
Quantities represent the planned number of prototype demonstrations during the MTA effort.

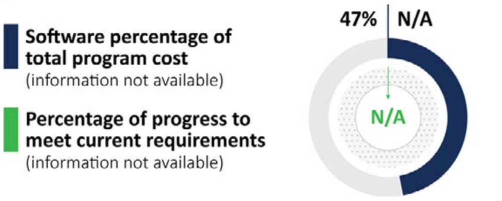
Program Background and Transition Plan

F-22 Rapid Prototyping partly replaced a prior MTA effort, the F-22 Capability Pipeline. The Air Force restructured the Capability Pipeline in April 2021 into separate rapid prototyping and rapid fielding efforts. F-22 Rapid Prototyping expects to demonstrate four prototypes of enhancements to the six capabilities by September 2023. It already demonstrated the first three prototypes. The program plans for most capabilities demonstrated to transition as individual programs to the major capability acquisition pathway, with entry at system development or production. The program also continues to assess potential use of other acquisition pathways as appropriate based on the capabilities under development.

Software Development as of January 2023

Approach: Agile, DevOps, and DevSecOps





The program reported that the percentage of progress to meet current requirements was unknown. The Air Force did not approve the public release of the software cost in dollars.

Program Essentials

Prime contractor: Lockheed Martin

Contract type: CPFF/CPAF/FFP (development)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	○	●
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

F-22 Rapid Prototyping Program

Updates to Program Performance and Business Case

F-22 Rapid Prototyping remains on track to demonstrate its last prototype before the expected MTA completion in September 2023, according to program officials. The program noted that it successfully demonstrated prototype 3 in September 2022, which featured updated electronic protection capability.

The program expects to demonstrate prototype 4 in fiscal year 2023, although the demonstration is not expected to include a fully tested tactical information transmission capability. The program originally developed this capability for prototype 1, but program officials said that it has yet to be fully demonstrated. They noted that the program is working with other agencies, such as the Federal Aviation Administration, to obtain necessary certifications to complete testing of the capability. They added that they now expect the testing to occur in the follow-on major capability acquisition effort. Program officials stated that issues with this capability have not presented any limitations on the development of the other five capabilities.

The program office reported a new critical technology for sensor enhancements this year, the Infrared Search and Track (IRST) capability. Currently the technology is approaching maturity, and the program expects it to be mature at MTA completion. The Navy has a separate program to develop IRST technology, which we also assess in this report.

F-22 Rapid Prototyping's other critical technology, Open Systems Architecture (OSA), is mature. In August 2022, for the first time in a flight test, OSA enabled third-party software to integrate with F-22 aircraft. Program officials told us that the expected benefits of using open systems include increased innovation and more affordable future capability deliveries.

Software and Cybersecurity

The program continued to report software development as a high risk. The completion of software to finish operational testing is a new factor the program reported as contributing to software development risk this year. Program officials stated that close collaboration across the test community mitigates this risk by prioritizing capabilities for testing.

The program office stated that the Air Force approved the F-22 cybersecurity strategy in August 2021, as well as an updated strategy in August 2022.

Key Product Development Principles

F-22 Rapid Prototyping reported approaches in line with our leading principles for product development. For example, the program is implementing processes to:

- develop minimum viable products that enable improvements on subsequent releases. Our prior work found that leading companies use iterative design and testing to identify a minimum marketable product that can be followed by successive updates to that product.
- defer planned capabilities to subsequent releases to meet schedule goals, which the program did for the tactical information transmission capability. Our prior work found that leading companies make an intentional decision to off-ramp capabilities that present a risk to delivering, on schedule, the capability prioritized by customers.

We have ongoing work to define metrics associated with these leading principles, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

Previously, we reported at the start of prototype development F-22 used level-of-effort contracts, which require the contractor to perform a specified amount of work during a stated time period. We reported that the program transitioned further development to a firm-fixed price contract after prototype content matured and continued through operational demonstration.

However, program officials stated that they changed the contracting strategy over the past year and plan to use level-of-effort contracts for the remainder of the MTA effort. Officials noted challenges with the former strategy, such as predicting the amount of content that would mature before the firm-fixed price contract would have begun. They also noted that the firm-fixed price contract for one of the prototypes did not ensure a higher level of product quality and schedule commitment as intended.

Program officials told us that part of the new contracting strategy is an incentive structure that helps retain the delivery and schedule requirements of a firm-fixed price contract. The program office anticipates this shift in strategy can lead to decreases in staff hours, fewer contract actions, and cost savings.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, in October 2022, it recommended fielding prototype 2 for the second annual Agile capability release. The program office stated that it continues to mature technologies across the six approved capabilities and remains committed to releasing capabilities on a scheduled cadence. The program office also noted that the program is currently executing within its respective cost parameters and is on track to meet its commitment of four operationally relevant demonstrations within the 5-year time frame.

ARMY

Program Assessments

▲ Integrated Visual Augmentation System (IVAS)

Assessment type	Program name
MDAPs	CH-47F Modernized Cargo Helicopter (CH-47F Block II)
	Integrated Air and Missile Defense (IAMD)
	Improved Turbine Engine Program (ITEP)
	Mobile Protected Firepower (MPF)
	Precision Strike Missile (PrSM)
MTA Programs	Extended Range Cannon Artillery (ERCA)
	Future Long Range Assault Aircraft (FLRAA)
	Indirect Fire Protection Capability Increment 2 (IFPC Inc 2)
	Integrated Visual Augmentation System (IVAS)
	Lower Tier Air and Missile Defense Sensor (LTAMDS)
	Optionally Manned Fighting Vehicle (OMFV)
Future Major Weapon Acquisitions	Future Attack Reconnaissance Aircraft Program (FARA)
	Long Range Hypersonic Weapon (LRHW)

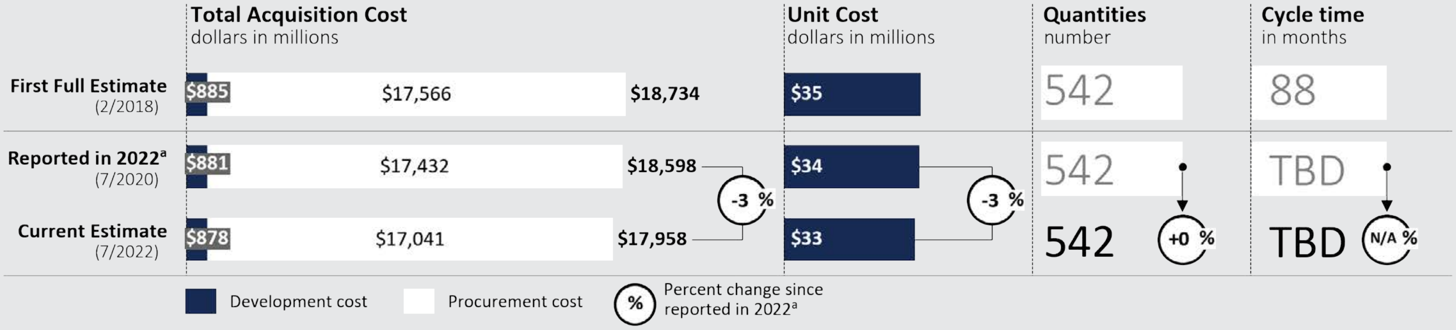
Source (previous page image): U.S. Army. | GAO-23-106059

Source: U. S. Army. | GAO-23-106059

CH-47F Block II Modernized Cargo Helicopter (CH-47F Block II)

The Army's CH-47F Block II program upgrades the CH-47F aircraft and is intended to provide additional capability, greater reach, and increased payload capacity. Improvements include a strengthened airframe and drive train, improved flight controls, and upgraded fuel and electrical systems to increase lift in hot weather conditions. The Army expects the CH-47F Block II fuel and rotor system improvements to reduce operating and support costs. CH-47F helicopters provide the Army's only heavy-lift capability and are scheduled to remain in service through 2060.

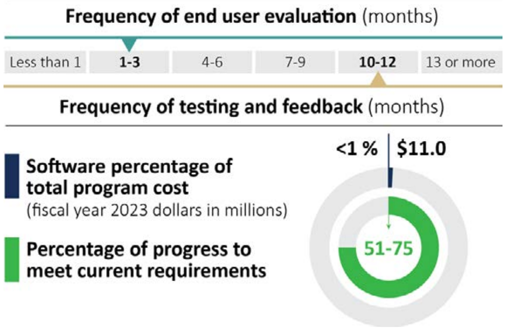
Program Performance fiscal year 2023 dollars in millions



Total quantities comprise three development quantities and 539 procurement quantities, including 69 MH-47G Block II aircraft for Special Operations Forces. Program performance data may change as a result of the ongoing rebaselining effort. The program did not report an initial capability date last year and, as a result, the cycle time in 2022 could not be calculated. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.
[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile, Iterative (other than Agile), and DevSecOps



Program Essentials

Prime contractor: Boeing

Contract type: CPIF (development); FPI/IDIQ (production before low-rate production decision)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

We did not assess CH-47F Block II manufacturing maturity because the program has yet to reach the production phase. The program stated that, in response to direction by congressional conferees, it contracted to procure six Block II aircraft prior to the production decision.

CH-47F Block II Program

Technology Maturity and Design Stability

The CH-47F Block II program reports that its one critical technology is fully mature. However, as we reported last year, this technology was susceptible to increased risks. The program completed the first of three planned tests since our last report, with results expected in the third quarter of fiscal year 2023. Program officials told us that they are not pursuing further risk mitigation efforts because initial results from testing appear favorable.

The program previously reported another critical technology it considered to be fully mature—a new rotor technology. However, as a result of technical and safety concerns found in developmental testing, the program removed it as a critical technology and plans to use currently fielded fiberglass rotor blades. However, issues encountered during development of the new rotor blade technology already delayed the program's original schedule by approximately 2 years and will likely result in cost increases.

Despite reporting a stable design since its December 2017 design review, the program had to redesign its fuel system doors as a result of test failures that occurred in qualification testing in April 2021. The redesigned doors successfully completed the first phase of testing, allowing them to proceed to the next phase, with anticipated completion in fiscal year 2024. Currently, development of the doors is on schedule. However, increased costs or further delays may occur in the event that issues discovered during continued testing result in any additional redesign to the fuel system test asset. The program office noted that no fuel system redesign is anticipated as of March 2023.

Production Readiness

The production decision, originally planned for the fourth quarter of fiscal year 2021, has been delayed since our last assessment. The Army noted that a new planned date has yet to be determined and is dependent upon a decision by Army leadership, which is expected in the first quarter of fiscal year 2024. The delay is a result of the technical issues and funding shortfalls.

Schedule delays raised concerns within the Army about the program's ability to maintain production, which could increase future production and support costs. The Army reported awarding a contract to Boeing in September 2021 and placed orders in September 2021 and 2022 for four and two aircraft, respectively, to maintain the production line.

The CH-47F Block II program completed an updated manufacturing readiness assessment in May 2022, after the September 2021 procurement. Our prior work showed that beginning production without a sufficient level of manufacturing maturity can increase the risk of subsequent rework and associated cost growth. Results of the assessment were also not available at the time of the September 2022 procurement but according to the Army have since shown that the program can produce low quantities of aircraft—less than seven per year.

Software and Cybersecurity

Since our last review, the program began employing iterative and DevSecOps software development approaches. According to the program, its new software development strategy allows the contractor to perform continuous security testing and processes within development and may result in reduced cost and schedule risks. However, the program reported that software poses a cost risk due to difficulties finding experienced and available staff, hardware design changes, and completing the software needed for testing.

The program continues to conduct cybersecurity assessments such as cooperative vulnerability and penetration assessments. The program reported vulnerability and penetration testing identified some medium to low risks. According to the program office, it is working with the contractor to address these risks.

Other Program Issues

The program is in the process of establishing a new cost and schedule baseline due to the delays caused by technical and safety concerns found during development testing. Current costs are based on the previous baseline and system configuration. The program will not know the full cost and schedule effect until the new program baseline is complete—pending a decision from Army leadership on the program's path forward.

Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated as appropriate. According to the Army, the program procured two additional CH-47F Block II aircraft with fiberglass rotor blades along with necessary logistical support and initial spares required for fielding. Additionally, the Army stated that it conducted a developmental test to validate the performance parameters under operationally relevant conditions. It also noted that the program plans to complete system verification qualification testing prior to a production decision.

MDAP Lead Component: Army

Common Name: IAMD

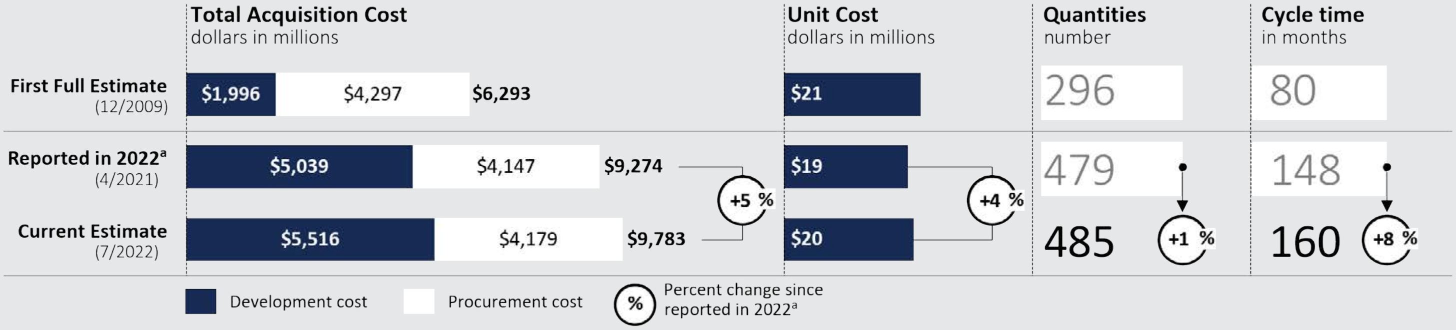
Integrated Air and Missile Defense (IAMD)

Source: Dynetics. | GAO-23-106059

The Army's IAMD program links sensors, weapons, and a common battle command system across an integrated fire control network to support the engagement of air and missile threats. The IAMD battle command system provides the Army the capability to control and manage specific sensors and weapons—such as the Sentinel radar and Patriot launcher and radar—through an interface module that supplies data and networked operations.

CONCEPT	2/06	Technology development start
SYSTEM DEVELOPMENT	12/09	Development start
	5/12	Critical design review
PRODUCTION	1/21	Low-rate decision
	1/22	Start operational test
	10/22	End operational test
	1/23	GAO review
	1-3/23	Full-rate decision
	4-6/23	Initial capability

Program Performance fiscal year 2023 dollars in millions



	Total Acquisition Cost (dollars in millions): Development cost	Procurement cost	Total	Unit Cost (dollars in millions)	Quantities (number)	Cycle time (in months)
First Full Estimate (12/2009)	$1,996	$4,297	$6,293	$21	296	80
Reported in 2022[a] (4/2021)	$5,039	$4,147	$9,274	$19	479	148
Current Estimate (7/2022)	$5,516	$4,179	$9,783	$20	485	160
Percent change since reported in 2022[a]			+5 %	+4 %	+1 %	+8 %

Total quantities comprise 25 development quantities and 460 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction and acquisition as well as operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

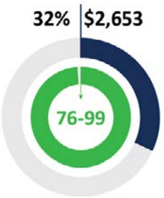
Approach: Agile

Frequency of end user evaluation (months)

Other frequency (see notes)

Less than 1	1-3	4-6	7-9	10-12	13 or more

Frequency of testing and feedback (months)



Software percentage of total program cost (fiscal year 2023 dollars in millions)

Percentage of progress to meet current requirements

The program reported end users are continuously involved in software development through participation in planning and demonstration events.

Program Essentials

Prime contractor: Northrop Grumman

Contract type: FPIF (production)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	●	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess IAMD's demonstration of critical processes on a pilot production line because the program office reported that there are no such processes since the program's hardware is primarily integrating commercial off-the-shelf items.

IAMD Program

Technology Maturity, Design Stability, and Production Readiness

The IAMD program has mature technologies and a stable design, and it awarded its production contract in December 2021. The program completed its initial operational testing in the first quarter of fiscal year 2023. This was later than originally planned because Army leadership restructured initial operational testing into two phases in January 2022. According to IAMD officials, this restructure enabled the program to insert software updates between the two phases.

As of the first quarter of fiscal year 2023, Army Test and Evaluation Command and the Director, Operational Test and Evaluation (DOT&E) were evaluating the data and results from both phases, according to IAMD and DOT&E officials. The program expects a final report from DOT&E in the second quarter of fiscal year 2023 to inform its full-rate production decision planned for the same quarter. IAMD officials said that they received Army Test and Evaluation Command's assessment during the first quarter of fiscal year 2023, which they expect will allow them to address any issues discovered during testing.

The program now expects to deliver the initial operational capability in the third quarter of fiscal year 2023—a year later than the program reported last year—because of the restructured operational testing. IAMD officials stated that the initial operational capability is ready for delivery. However, the delay gives the program time to review the results of operational testing and release the newest software increment, according to the officials.

Software and Cybersecurity

IAMD is using the software acquisition pathway to conduct its software development efforts and, according to the program, awarded a contract for this work in April 2022. IAMD officials stated that the program continues to use an Agile software development approach.

The program conducted a second cybersecurity penetration test in April 2022, as well as a survivability and resilience exercise in July 2022. According to the program, the April 2022 test demonstrated that the program addressed the most critical finding from its penetration and adversarial cybersecurity assessments in 2021.

Other Program Issues

IAMD officials attributed nearly $500 million in developmental cost increases since our last assessment to capabilities intended to address threats in the Pacific.

The program office said a truck redesign was completed as a result of transportability issues discovered during testing. It also completed transportability and mobility testing on the redesigned truck in the first quarter of fiscal year 2023. However, the program office stated that it will transition to a newer version of the truck when quantities are available from the vendor. It further noted that the Integrated Battle Command System equipment mounted in the bed of the truck will remain in the same configuration. The program plans to conduct qualification testing on the newer version when it receives trucks from the vendor.

According to officials, IAMD is proactively monitoring supply chain risks with a new DOD-sponsored risk management tool. IAMD officials said that, to date, the prime contractor absorbed cost and schedule effects from these supply chain issues.

Lastly, the program is working with stakeholders to determine the most efficient way to navigate the process used to ensure that the system is safe and suitable for the warfighter. The program is anticipating a continuous cycle of this process, which can be lengthy and complex, for its multiple software and hardware releases. As a result, the program stated that it established a working group to discuss the issue further and identify an alternative process that can still meet the intent of the materiel release process but in a more streamlined manner.

Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated where appropriate. According to the Army, the IAMD program is currently within cost, schedule, and performance parameters. It also stated that the program obtained valuable information and learned important lessons throughout its operational testing program, resulting in a more effective, suitable, and survivable capability for the warfighter. The Army also reiterated that the program is on schedule to meet planned dates for its full-rate production decision and initial operational capability.

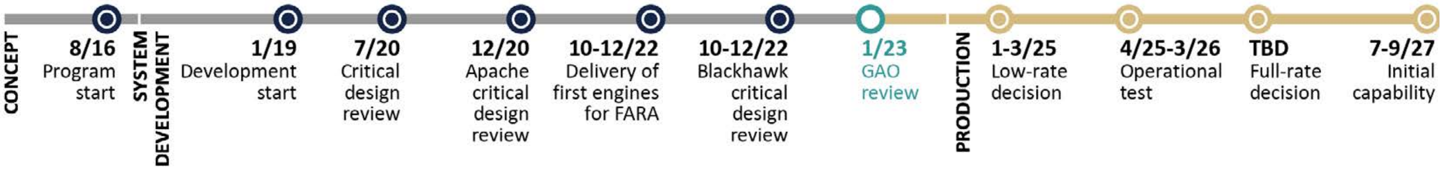
MDAP Lead Component: Army

Common Name: ITEP

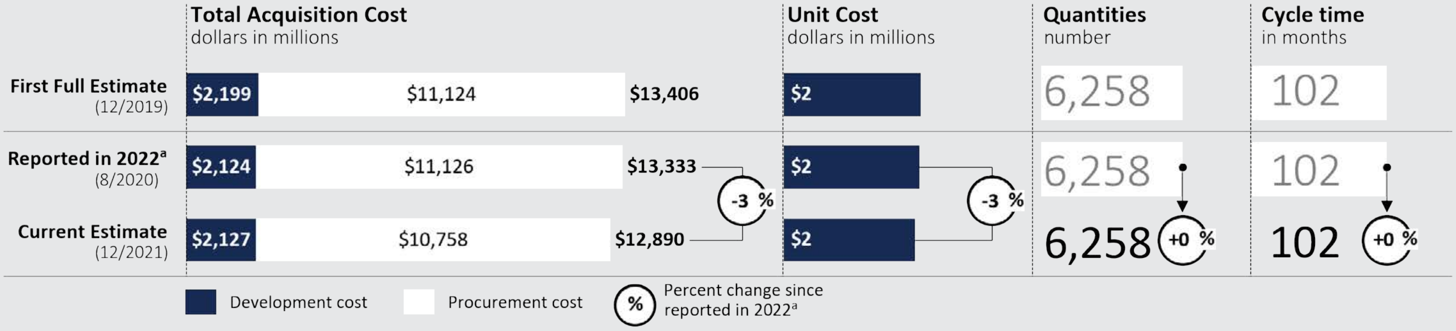
Improved Turbine Engine Program (ITEP)

The Army's ITEP is developing a next generation turbo-shaft engine for the Black Hawk, Apache, and Future Attack Reconnaissance Aircraft (FARA) fleets. The improved turbine engine is needed to fit inside the existing engine compartments of Black Hawk and Apache helicopters and to integrate with FARA. It is also expected to provide an increase in power, improved fuel efficiency, enhanced reliability, and lower sustainment costs. The Army plans to field the new engine for all platforms by fiscal year 2027.

Source: U. S. Army. | GAO-23-106059



Program Performance fiscal year 2023 dollars in millions



	Total Acquisition Cost dollars in millions				Unit Cost dollars in millions		Quantities number		Cycle time in months	
	Development cost	Procurement cost	Total	%		%		%		%
First Full Estimate (12/2019)	$2,199	$11,124	$13,406		$2		6,258		102	
Reported in 2022[a] (8/2020)	$2,124	$11,126	$13,333		$2		6,258		102	
Current Estimate (12/2021)	$2,127	$10,758	$12,890	-3 %	$2	-3 %	6,258	+0 %	102	+0 %

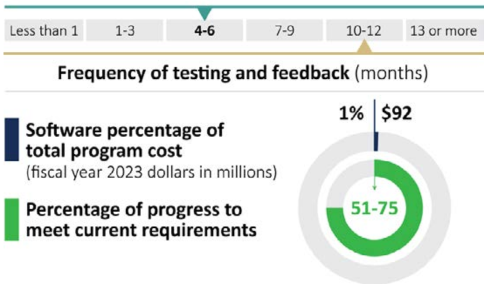
▇ Development cost ☐ Procurement cost % Percent change since reported in 2022[a]

Total quantities comprise 69 development quantities and 6,189 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-10523

Software Development as of January 2023

Approach: Agile and Incremental



Program Essentials

Prime contractor: General Electric Aviation

Contract type: CPIF

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	●	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess ITEP's manufacturing maturity because the program has yet to reach production.

ITEP

Technology Maturity and Design Stability

Four years after development start, ITEP's three critical technologies have yet to reach maturity. Last year, the program told us it planned to verify maturity of its critical technologies during a system-level engine test, conducted between March 2022 and June 2022. This test recorded over 100 hours of engine run time, and the program office reported successful validation of engine performance. This year, program officials stated that ITEP's critical technologies are approaching maturity and will not further mature until the engine completes substantial flight testing in an operational environment.

The engine design is currently stable, with over 98 percent of drawings released to date. In June 2022, ITEP completed its first test of a system-level prototype, another key marker of design stability. Nevertheless, until the program fully matures its technologies, ITEP risks issues emerging in testing that could require redesigns, further disrupt engine testing and aircraft integration schedules, and potentially delay engine certification.

ITEP is conducting separate engine integration critical design reviews for the Apache and the Black Hawk platforms. ITEP is on track to conduct the Blackhawk critical design review in the second quarter of fiscal year 2023. The Apache critical design review was completed in October 2021 and a Blackhawk engine integration preliminary design review in December 2021.

Production Readiness

ITEP's engine production start date, originally planned for the fourth quarter of 2024, was delayed for a second year in a row, and is now planned for the second quarter of fiscal year 2025. Program officials attributed these delays to COVID-19 manufacturing effects, prior-year funding cuts, and developmental flight test delays.

Relatedly, mitigations for ITEP's longstanding additive manufacturing risk have yet to achieve their intended effects. ITEP's goal is to use additive manufacturing in place of traditional processes in order to enhance performance and achieve weight savings for component designs. Lack of additive manufacturing machines has increased production time for the engine's front frame. As a result, the program delayed the planned delivery of FARA's first engines from January 2022 to November 2022. ITEP continues to work to address this risk. Officials told us that the program ordered more machines and incorporated design improvements to reduce production cycle times. Additionally, officials noted that engine control issues have further delayed FARA engine deliveries to spring 2023.

Software and Cybersecurity

All but one of ITEP's five planned software releases have been late. Releases one and two, which contain less than 25 percent of ITEP's planned software, were delivered in 2021. Releases three and four, a ground test and a safety of flight release, scheduled for delivery in March 2022 and September 2022, are delayed to the second quarter of fiscal year 2023 and the first quarter of fiscal year 2024. Program officials said that since last year, ITEP added two additional FARA related software releases, which will also be delivered in the second quarter of fiscal year 2023 and the first quarter of fiscal year 2024, for a new total of seven releases.

Three of ITEP's four planned cybersecurity tests are scheduled for the second and third quarter of fiscal year 2023, with two—the developmental adversarial and the operational vulnerability assessments—scheduled to run concurrently. While the concurrent approach preserves test asset availability, it, along with the compressed test schedule, limits ITEP's ability to resolve issues and conduct regression testing of any deficiencies identified. The fourth test, ITEP's operational adversarial assessment, planned for the first quarter of fiscal year 2025, will assess its cyber survivability and resilience.

Other Program Issues

ITEP is monitoring defense industrial base risks related to its prime contractor's global engine supply chain. Program officials stated that over 20 percent of engine parts are manufactured internationally.

Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated as appropriate. The Army stated that it continues to manage cost, schedule, and performance of ITEP to field the new engine for platforms by fiscal year 2027. It also stated that the Army's Aviation Turbine Engines project management office, of which ITEP is a part, continues to aggressively assess the delivery dates amid global supply chain issues.

In March 2023, after our cut-off date for new information, the Army announced that due to parts manufacturing challenges, FARA's first engines will be delivered in early fiscal year 2024.

Source: U. S. Army. | GAO-23-106059

Mobile Protected Firepower (MPF)

The Army intends MPF to provide a new direct fire capability for support of infantry units across a range of military operations. One key requirement is that MPF be air-transportable to enable initial entry operations. In June 2022, MPF transitioned from the MTA rapid prototyping pathway to the major capability acquisition pathway for production.

Program Performance fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions			Unit Cost dollars in millions	Quantities number	Cycle time in months
First Full Estimate (8/2022)	$1,211	$4,656	$6,628	$18	377	108
Reported in 2022[a]	Not a Major Defense Acquisition Program in GAO's 2022 assessment					
Current Estimate (8/2022)	$1,211	$4,656	$6,628	$18	377	108

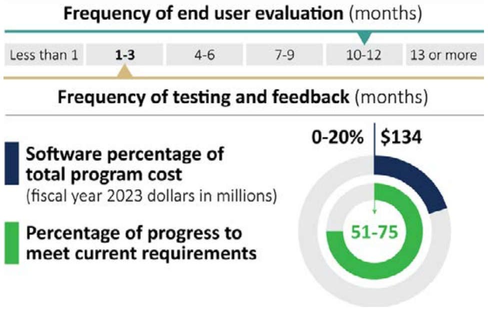
■ Development cost □ Procurement cost

Total quantities comprise 27 development quantities and 350 procurement quantities. We measured cycle time from the start of the MTA rapid prototyping effort to the date the program plans to achieve initial operational capability. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a]GAO-22-105230

Software Development as of January 2023

Approach: Iterative (other than Agile) and Incremental



Program Essentials

Prime contractor: General Dynamics Land Systems

Contract type: FFP/ FPIF/ CPFF

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Status at Entry to MCA Pathway	Current Status
Demonstrate all critical technologies in a relevant environment	NA	NA
Demonstrate all critical technologies in a realistic environment	NA	NA
Complete a system-level preliminary design review	●	●
Product design is stable		
Release at least 90 percent of design drawings	○	○
Test a system-level integrated prototype	●	●
Manufacturing processes are mature		
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	●	●

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

MCA = Major Capability Acquisition

The Army stated that multiple assessments, including a technology readiness assessment organized by the Office of the Under Secretary of Defense for Research and Engineering, determined that MPF did not have critical technologies.

MPF Program

Technology Maturity, Design Stability, and Production Readiness

Following testing of 14 MTA prototype vehicles, the Army reported that it conducted a competitive source selection and exercised contract options for production in June 2022. The program subsequently entered the major capability acquisition pathway at production start in June 2022. As we previously reported, the Army determined that MPF does not have any critical technologies, consistent with the results of a technology risk assessment organized by the Office of the Secretary of Defense.

During its MTA effort, the program released over 90 percent of its design drawings for the prototype vehicles, a key marker of design stability. By June 2022, when the program entered the major capability acquisition pathway, the number of releasable design drawings dropped to 88.5 percent. This decrease was due to changes to the number and types of drawings for production vehicles based on prototype test results completed in January 2022. The program office expects to have these drawings updated by the second quarter of fiscal year 2023.

The program also addressed leading acquisition practices related to design stability and production readiness through its prototype tests during the MTA phase. According to program officials, the prototype vehicles produced and tested during the MTA phase were production representative designs for both hardware and software.

The program does not plan to demonstrate critical manufacturing processes on a pilot production line, an important aspect of ensuring product processes are mature. Instead, program officials told us that they gained equivalent knowledge using an alternative manufacturing approach known as “stall builds”—a manufacturing process in which all parts are brought to one location and pieces are assembled before being moved to a different stall for further assembly.

Program officials stated that they chose this approach because the low rate of production did not support a traditional production line. The contractor used this approach to begin low-rate initial production of up to 25 vehicles in fiscal year 2022. Program officials told us that they plan to build approximately two vehicles per month, with the first two scheduled to complete production in the first quarter of fiscal year 2024.

The program is moving production to Anniston, Alabama from Warren, Michigan—where the prototypes were produced—as originally planned. Vehicle production will occur concurrently at both sites until the second quarter of fiscal year 2024. Program officials told us that the stall build set-up will remain the same to help avoid learning loss. They also said that they are training subcontractors to ensure tools and knowledge remain in place following the MTA effort.

Software and Cybersecurity

The program largely used software from the Abrams vehicle, which has been modified for the MPF vehicle. It expects to continue using this same software for production vehicles with modifications incorporated using an iterative incremental software development approach. According to the program, this approach is expected to help control software costs.

The program has yet to deliver any modified software but plans to release two to three versions of software during the low-rate initial production phase. End users began evaluating and providing feedback on the software in April 2021, according to the program.

The DOD Chief Information Officer approved the program’s cybersecurity strategy in March 2022. During the rapid prototyping phase, the program identified cybersecurity vulnerabilities and program officials stated that they plan to make software changes to address those vulnerabilities. The program plans to conduct a system-level cybersecurity assessment in the second quarter of fiscal year 2024.

Other Program Issues

The program is monitoring schedule risks related to vehicle testing. The program plans to refurbish eight prototypes to the low-rate initial production configuration for use during production qualification testing during the first quarter of fiscal year 2024. Program officials told us that, if the program cannot refurbish the prototypes as planned, it would conduct this testing on other low-rate initial production vehicles from the production line. However, delivery of these other vehicles is also scheduled for the first quarter of fiscal year 2024. Consequently, should delivery of the low-rate production vehicles be delayed, the testing may also have to be delayed.

Program Office Comments

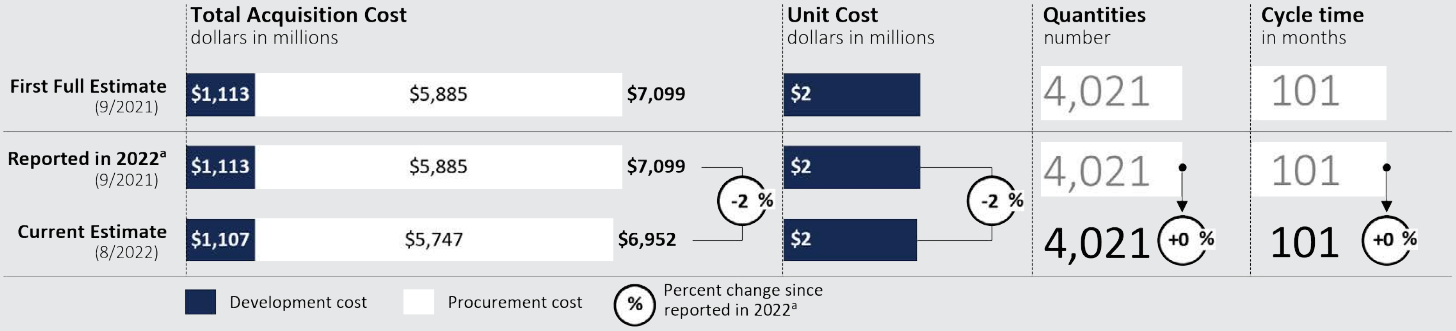
We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated where appropriate. The Army stated that the MPF program is executing within cost, schedule, and performance parameters. According to the Army, the program is well underway with the refurbishment of the prototype vehicle and is using this activity to train the manufacturing team in Alabama. The Army also noted that, to further mitigate risk, a prototype vehicle is being separately modified to the low-rate initial production decision design. The Army further stated that it anticipates testing results by the second quarter of fiscal year 2023.

Source: Lockheed Martin. | GAO-23-106059

Precision Strike Missile (PrSM)

The Army's PrSM is a ballistic missile designed to attack area and point targets at distances ranging from 70 kilometers to more than 400 kilometers. Each PrSM missile container will hold two missiles, double the current missile container's capacity. The Army designed PrSM as one of a family of munitions for compatibility with existing rocket launcher systems and to comply with statutory requirements for insensitive munitions and DOD policy on cluster munitions.

Program Performance fiscal year 2023 dollars in millions

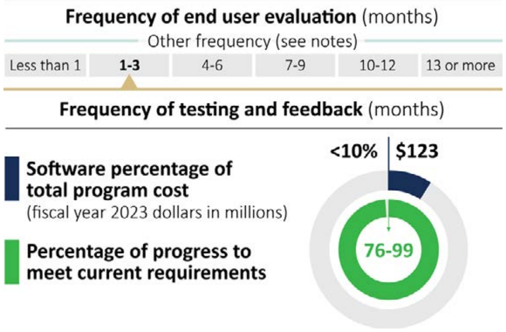


Total quantities comprise 35 development quantities and 3,986 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a]GAO-22-105230

Software Development as of January 2023

Approach: Agile and Waterfall



The program reported that end user feedback on software occurs during limited user tests.

Program Essentials

Prime contractor: Lockheed Martin

Contract type: FFP

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	○	○
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	●	●
Test a system-level integrated prototype	●	●
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

Critical technologies being developed by the program have been demonstrated in a relevant environment. However, necessary critical technologies being developed outside the program have yet to reach that level of maturity. We did not assess PrSM's manufacturing maturity because the program has yet to reach production.

PrSM Program

Technology Maturity and Design Stability

About a year after starting system development, PrSM has yet to fully mature any of its 10 critical technologies. In August 2022, PrSM reported that seven of these technologies have been demonstrated in a relevant environment, which program officials noted met the DOD requirement for beginning system development. This reporting is a change from last year, when the program reported that six technologies were mature at system development. Program officials corrected the administrative reporting error this year.

Of the three remaining critical technologies, two will be fully assessed during qualification testing, currently planned to start in the fourth quarter of fiscal year 2023. The final critical technology is under development by a separate program. Army officials said that PrSM will be in production before the technology is available for testing. Program officials told us that these three technologies will, therefore, not be a part of the initial product configuration.

Although a May 2021 independent technical risk assessment determined PrSM to be low risk, we continue to be concerned about the program's technology maturity levels. Our prior work showed that until all critical technologies are mature, programs risk costly and time-intensive redesign work if problems are found later in testing.

The program planned to complete sub-assembly testing by December 2021. However, issues during testing delayed the release of final results. The program now plans to complete sub-assembly qualification testing by the first quarter of fiscal year 2024. The program plans to begin system-level ground and flight testing in summer 2023.

In October 2022, program officials reported that all drawings were released as of critical design review in November 2021. They stated that their response last year that indicated the program released only 82 percent of drawings at critical design review was an administrative error in reporting by the program. We updated our Attainment of Product Knowledge table to reflect this clarification. The program plans to conduct a design completion review by the first quarter of fiscal year 2024 to fully establish the design configuration and ensure that requirements are met. However, without having fully matured its critical technologies, the program risks further changes to design subsequent to this review.

Production Readiness

The program started production for an early operational capability fielding before demonstrating production readiness. Specifically, in September 2021, the program modified a contract with Lockheed Martin to produce up to 26 missiles. Later that same month, the Army authorized the procurement of up to almost 400 missiles—pending further approvals. In 2021 and 2022, the Army approved procurement of 26 and 54 missiles, respectively.

As we reported last year, the program office plans to finalize the design and demonstrate critical manufacturing processes on a pilot production line by mid-2024. By committing to limited production of an initial quantity before technologies and manufacturing processes are mature and the design is stable, the program risks discovering issues in testing that may require rework on missiles in production.

Software and Cybersecurity

Cybersecurity requirements for PrSM were not finalized until after initial system design, increasing costs and requiring software changes. The program used draft cybersecurity requirements as the basis for the performance specifications provided to the contractor. Program officials stated that changes in cybersecurity requirements between draft and final requirements are projected to result in a number of software changes and related cost growth. They told us that the effect of these changes will be reflected in future cost estimates.

Program officials are implementing software changes to meet the new cybersecurity requirements for the first increment. However, it will postpone hardware changes until the second increment in order to meet timelines for early delivery. As a result, the Army expects to have two versions of the missiles. Program officials stated that this approach would enable them to provide the early capability to the user, while providing full cybersecurity capabilities when the program goes to full-rate production.

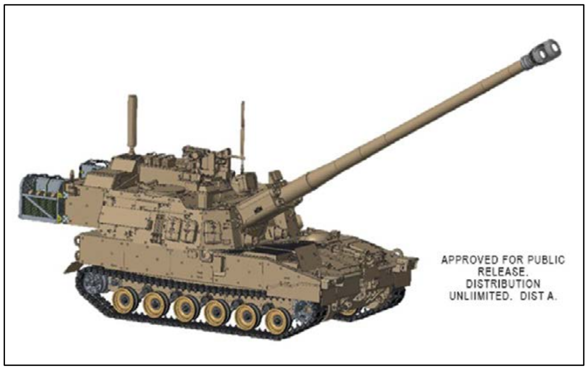
Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments which we incorporated where appropriate. According to the Army, PrSM is executing within cost, schedule and performance parameters. The Army stated that, to counter existing threats, Army leaders authorized production of a version of the missile concurrent with system development. It noted that the program demonstrated critical technologies that are part of the initial production configuration in a relevant environment. It also stated that all major subsystems are qualified or in qualification testing.

The Army added that, prior to system-level testing scheduled to begin in the fourth quarter of fiscal year 2023, the program plans to confirm design maturity. It noted that the assembly and production of early operational capability missiles will support initial capability no later than the fourth quarter of fiscal year 2023, but the bulk of early operational capability missile deliveries will occur after system testing is complete.

MTA | Lead Component: Army | **Common Name:** ERCA

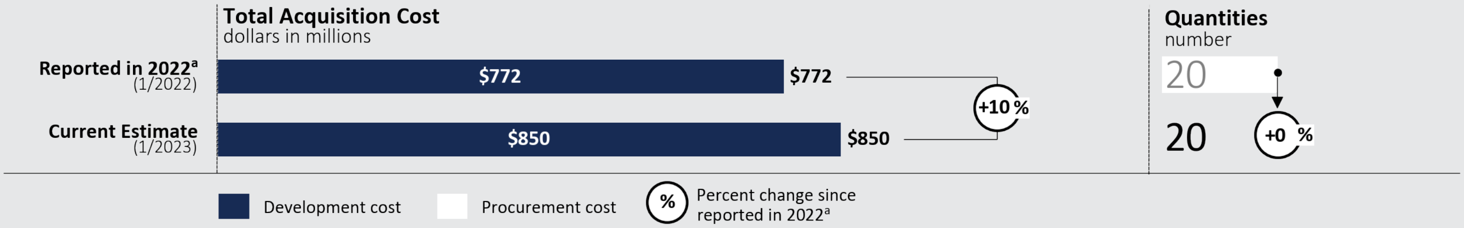
Extended Range Cannon Artillery (ERCA)



Source: U. S. Army. | GAO-23-106059

The Army's ERCA program is developing an upgrade to the M109 self-propelled howitzer intended to improve lethality, range, and reliability. The ERCA program, using the MTA rapid prototyping pathway, plans to add armament, electrical systems, and other upgrades to the existing vehicle. Subsequent to the rapid prototyping effort, the program plans to deliver future improvements, such as increasing the number of rounds fired per minute.

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



Quantities include two vehicles for use during developmental testing and 18 vehicles that will be used for the program's operational demonstration.

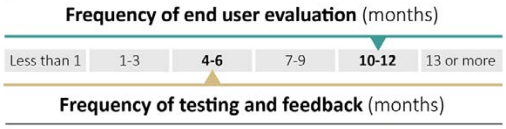
[a] GAO-22-105230

Program Background and Transition Plan

The Army initiated ERCA using the MTA rapid prototyping pathway in September 2018. The Army planned to complete operational testing and transition to the major capability acquisition pathway at production within the 5-year time frame established in DOD policy for the MTA pathway. Due to delays in development, the Army now plans to assess the system's ability to perform key capabilities at the end of the MTA pathway in late fiscal year 2023 and field up to 18 prototypes. The Army plans to transition to the major capability acquisition pathway after completion of operational testing in late fiscal year 2024.

Software Development as of January 2023

Approach: Agile



The program reported an estimated percentage of software costs but did not provide a specific dollar value.

Program Essentials

Prime contractor: Army's Development Command, Armaments Center, supported by BAE Systems

Contract type: CPFF (development) (using other transaction authority)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	○	●
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	○	○
Formal schedule risk assessment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

ERCA Program

Updates to Program Performance and Business Case

ERCA made some progress in addressing its technical challenges over the past year, but schedule delays persist and program costs increased. During this time, the Army implemented design changes and conducted some developmental testing, in part, to address technical challenges identified during ERCA's July 2021 technology readiness assessment with a critical subcomponent of the cannon assembly.

The program planned to complete subsystem developmental testing in December 2022, which officials told us that they expected would assess the fixes to the cannon assembly, among other things. However, Army officials reported that additional technical challenges were identified during the test event that required them to pause test activities. According to these officials, the Army has yet to determine the effect of these issues on the program's schedule.

Due to delays, the Army now plans to complete the MTA effort by outfitting an artillery battalion with up to 18 ERCA prototypes and conducting an operational assessment in late fiscal year 2023. The operational assessment will collect soldier feedback and inform further development. The program's cost increased by approximately $78 million (10 percent) over the past year due, in part, to the program's schedule changes.

ERCA did not have all elements of its business case at program initiation in 2018. While it has since made some progress, it still lacks a formal technology risk assessment and a cost estimate based on an independent assessment. Completing these elements earlier could have helped decision makers identify whether the program was well positioned to deliver the planned capability within 5 years. Program officials stated that they are developing a plan to conduct a formal technology risk assessment and working with Army cost analysts to develop a life-cycle cost estimate to inform the program's transition to the major capability acquisition pathway.

Army officials also said that the program initiated efforts during the past year to update ERCA's acquisition strategy and schedule to account for technical challenges, schedule delays related to COVID-19, and the availability of weapons for testing. As of the second quarter of fiscal year 2023, the Army had yet to approve the updated acquisition strategy.

Software and Cybersecurity

The program completed two software deliveries in fiscal year 2022, for a total of four since program initiation, according to program officials. Program plans currently call for one additional delivery before the completion of the MTA effort.

The Army is conducting cybersecurity assessments during the MTA effort and the program plans to finalize a cybersecurity strategy before the program's transition to the major capability acquisition pathway.

Key Product Development Principles

ERCA took some actions aligned with leading principles for product development we identified in recent work. For example, it established processes to solicit end users' feedback through multiple soldier touchpoints, surveys, and reports. Army officials reported that they use simulators to conduct soldier touchpoints. We previously found that ongoing engagement with customers is an important aspect of iterative development that leading companies use to prioritize features and identify improvements to the product.

We have ongoing work to define metrics associated with our leading principles, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

We previously reported that ERCA planned to pursue a waiver to extend the effort beyond the 5-year MTA time frame established by DOD policy. However, according to Army officials, the Under Secretary of Defense for Acquisition and Sustainment denied the request. These officials reported that the Army Acquisition Executive subsequently determined that following the rapid prototyping effort, he would oversee the program's progress as it completes the development, documentation, and operational testing required to transition to the major capability acquisition pathway, currently planned for late fiscal year 2024.

The James M. Inhofe National Defense Authorization Act for Fiscal Year 2023 directed the Army to limit the production of ERCA prototypes to no more than the 20 planned vehicles and to compare the cost and value of certain production approaches.

Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated as appropriate.

The Army stated that ERCA continues to make improvements to deliver capability to the user through iterative system development, testing, and engagement with users. It also reiterated that the program plans to continue to execute the effort on the MTA pathway and transition to the major capability acquisition pathway.

Further, according to the Army, the program continues to mature its government-owned technical data package and ensure its package is adequate to support competition for production. It also noted that the program will perform a business case analysis to further inform the acquisition strategy.

MTA Lead Component: Army

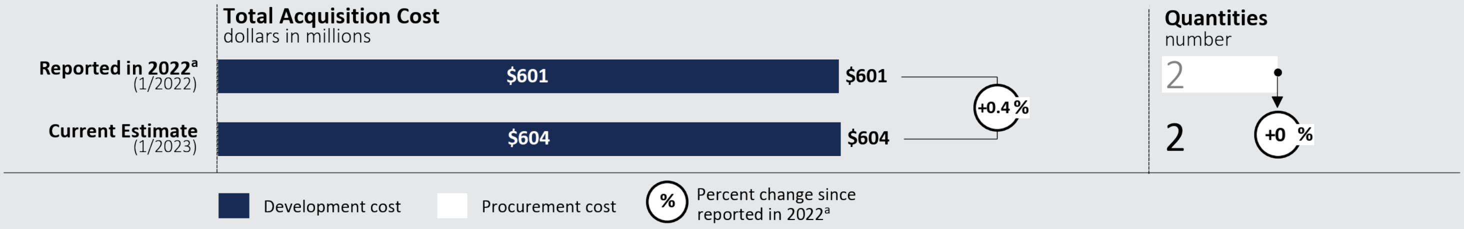
Common Name: FLRAA

Future Long Range Assault Aircraft (FLRAA)

FLRAA is part of the Future Vertical Lift portfolio of systems, a top modernization priority for the Army. It is intended to be a medium-sized assault and utility rotorcraft, to deliver speed, range, agility, endurance, and sustainability improvements as compared with current Black Hawk helicopters. The Army also expects the program to provide combatant commanders with tactical capabilities at operational and strategic distances. The Army initiated FLRAA using the MTA rapid prototyping pathway in October 2020 to develop two virtual prototypes.

Source: U. S. Army. | GAO-23-106059

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



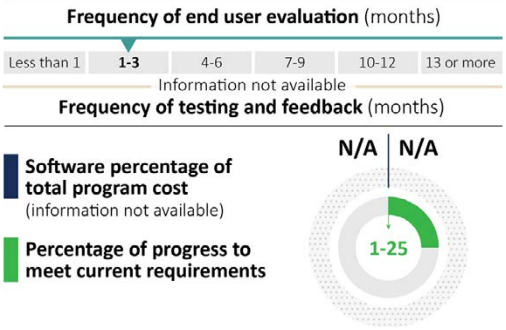
ªGAO-22-105230

Program Background and Transition Plan

In March 2020, the Army selected two contractors for project awards to develop FLRAA conceptual prototype designs under an other transaction agreement. In December 2022, the Army reported awarding a weapons system development contract to Bell Textron, Inc. The contract is expected to support completion of virtual prototype development, as well as system development and low-rate initial production. The Army plans to transition FLRAA to the major capability acquisition pathway with entry at system development during the third quarter of fiscal year 2024.

Software Development as of January 2023

Approach: Agile, Incremental, and DevSecOps



The program did not provide estimated software costs specific to the MTA effort.

Program Essentials

Contractors: Bell Textron, Inc. and Sikorsky Aircraft Corp.-Boeing Co. (competitive demonstration and risk reduction); Bell Textron, Inc. (development)

Contract type: cost reimbursable with cost share (competitive demonstration and risk reduction) (using other transaction authority); CPIF/FPI (development)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	○	○

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

FLRAA Program

Updates to Program Performance and Business Case

FLRAA continues to lack formal technology and schedule risk assessments, but, according to the Army, the program intends to develop them. Specifically, the program expects to have a technology risk assessment, a formal schedule risk assessment, and an independent cost estimate approved by DOD's Office of Cost Assessment and Program Evaluation prior to the transition to the major capability acquisition pathway and the start of system development in the third quarter of fiscal year 2024. The Army also expects to update its October 2020 abbreviated capability development document. The Army reported that it took other risk reduction activities related to technology, such as conducting an informal technology assessment in 2019. It also noted that DOD completed an independent preliminary design review assessment during the first quarter of fiscal year 2023.

FLRAA officials reported that the program's two critical technologies are approaching maturity. According to the Army, preliminary design work planned as part of the MTA efforts will continue to mature these technologies. Program officials stated that they plan to demonstrate the maturity of these critical technologies in a relevant environment prior to the start of system development.

While the program reported that it plans to mature these technologies to a level required at development start, their maturity at that point will not conform to the level recommended by leading practices. These practices call for demonstration in an operational environment. FLRAA plans to develop only virtual system prototypes during its MTA rapid prototyping effort. Without a physical prototype, FLRAA will not be able to fully mature its critical technologies. Our prior work found that entering system development without mature technologies exposes programs to more risk of costly and lengthy rework if issues are discovered later in development.

FLRAA's acquisition strategy identified its constrained schedule as a high risk. The strategy noted that, if FLRAA did not award its contract to a single vendor by February 2022, the planned first unit equipped date of fiscal year 2030 would be unachievable. In December 2022, the Army reported awarding this contract to Bell Textron, Incorporated—representing at least a 10-month delay from the date noted in the acquisition strategy. FLRAA officials plan to conduct an analysis of schedule risks in fiscal year 2023 after the contract award, in association with the establishment of an integrated master schedule.

Software and Cybersecurity

FLRAA plans to use a mixture of development approaches—including Agile, DevSecOps, and incremental—to deliver off-the-shelf and custom software. Program officials reported an increase in the anticipated amount of custom software due to the lack of available existing software to meet FLRAA flight critical and mission critical software certification requirements. The program office noted that it plans to begin cybersecurity assessments starting during the first quarter of fiscal year 2023, when it expects to complete architectural vulnerability assessments.

Key Product Development Principles

The program reported that it solicited and received feedback from end users during the design and development process, which we found is a leading practice to help inform iterative product development. End users identified by the program include experimental test pilots, test engineers, and operational users.

The program has yet to establish parameters for tracking cost, schedule, and performance, another leading practice for product development. Leading companies use these parameters as guideposts and continuously evaluate them to increase confidence that the product can meet the targets. We have ongoing work to define metrics associated with our principles for product development, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

According to the program, it is implementing a modular open systems architecture approach in an effort to achieve several goals, including more rapid integration of new technologies and capabilities, lower costs, adaptability to cyber threats, and goals for intellectual property rights. The program is coordinating this effort through the Modular Open Systems Approach Transformation Office established at Program Executive Office, Aviation. The program plans to verify the effectiveness of the architecture through its test strategy.

After the reported award of the FLRAA contract to Bell Textron, Sikorsky Aircraft Corporation filed a bid protest in December 2022.

Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated where appropriate. The Army stated that it awarded a contract in December 2022 to Bell Textron, Inc. The Army noted that the FLRAA program strategy meets Army modernization objectives for capability development and deployment through rapid prototyping. It added that FLRAA has a robust acquisition strategy, an approved requirements document, and a draft Army cost estimate to support budget planning. It stated that it is committed to a modular open systems approach, which it expects will provide faster fielding of innovative, threat-based capability, as well as affordability and commonality across different systems. The Army also noted that the program plans to look for opportunities to inform technology readiness and to mitigate risk to equip the first unit in 2030.

MTA Lead Component: Army

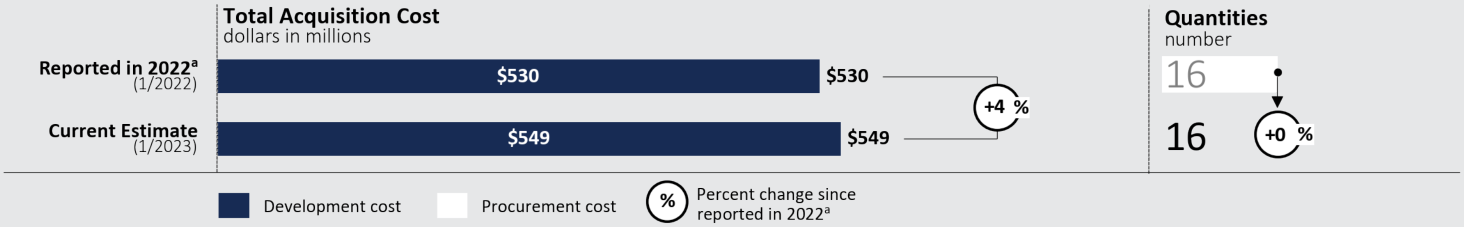
Common Name: IFPC Inc 2

Source: Dynetics. | GAO-23-106059

Indirect Fire Protection Capability Increment 2 (IFPC Inc 2)

The Army's IFPC Inc 2 is intended to enhance and extend the range of the first IFPC increment, which provided a short-range capability to counter threats from rockets, artillery, and mortars. IFPC Inc 2 consists of four subsystems—an existing sensor, a fire control system, an interceptor missile, and a new air defense launcher.

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



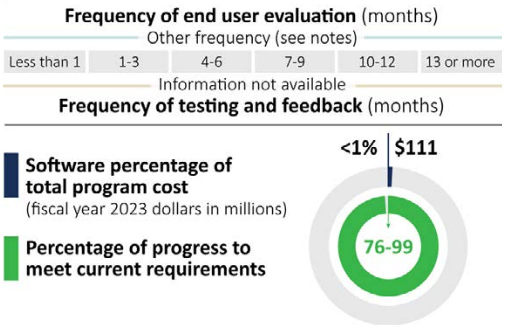
[a]GAO-22-105230

Program Background and Transition Plan

IFPC Inc 2 was designated as an MTA rapid prototyping effort in August 2021, which the Army concluded was necessary to meet a statutory fiscal year 2023 deadline for deploying two batteries of the interim missile defense capability. The Army awarded a prototype project other transaction agreement in September 2021 to Dynetics, Inc. to develop 16 prototypes of the air defense launcher. Several of these launchers will be consumed during testing and the remaining are expected to be evaluated as a battery in the operational assessment in early fiscal year 2024. The program plans to transition to the major capability acquisition pathway at production at the conclusion of the rapid prototyping effort.

Software Development as of January 2023

Approach: Agile



The program reported end user evaluation will occur during verification, validation, and training for the software.

Program Essentials

Prime contractor: Dynetics, Inc.

Contract type: FFP (using other transaction authority)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	○	○

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

IFPC Inc 2 Program

Updates to Program Performance and Business Case

Several key elements of IFPC's business case were approved prior to initiation. However, the program has yet to complete a formal schedule or technology risk assessment, as we previously reported. Neither is planned until the third quarter of fiscal year 2023, about a year before the planned completion of the MTA effort. The absence of both assessments continues to present risk to the program. We previously reported that these assessments help provide decision makers with the data needed to make well-informed choices.

IFPC continues to have an aggressive timeline for fielding capability and faces ongoing technology integration risks, especially with respect to two of the four subsystems that comprise an IFPC battery.

The Army considers IFPC to be one of many priorities with respect to the Army's Integrated Air and Missile Defense (IAMD) architecture. IFPC program officials stated that their program schedule is aligned with IAMD, which is managed as a separate program. However, they added that they have little insight into the status of the IAMD development effort—in particular the fire control system on which IFPC relies. According to these officials, IFPC will use the most recent version of IAMD's fire control system available during planned developmental testing in late fiscal year 2023 and the planned operational assessment in fiscal year 2024. They noted that this version of the fire control system may not be the one that is ultimately deployed.

The program continues to experience ongoing technical issues with one subsystem and is working with the subsystem's contractor to resolve them. The program plans to verify any mitigations with that contractor.

Software and Cybersecurity

IFPC finalized the details of its software development plan since our last assessment. The program is using an Agile development approach for software and plans two full system software releases approximately 3 months apart.

The program received approval for its cybersecurity strategy in March 2022. We previously reported that program officials expected an update to the IFPC requirements document to include protection against cybersecurity as a key performance parameter. An updated requirements document is pending approval, which program officials expect in fiscal year 2024.

Key Product Development Principles

The IFPC program implemented some key product development principles that our prior work found leading companies employ. For example, soldiers from the 188th Air Defense Brigade participated in design reviews. Program officials stated that Dynetics, Inc.—the prime contractor for the air defense launcher—made design changes for reloading the AIM-9X interceptor based on feedback from these reviews. We previously found that leading companies collect user feedback to inform improvements to a product as part of the product development process.

In addition, program officials stated that Dynetics, Inc. is using digital engineering and 3D modeling to gain fidelity on the launcher design. Leading companies employ modern design tools, such as digital engineering, in their product development process. These design tools are used as part of an iterative design approach that results in a minimum viable product in order to maintain schedule. The IFPC program is in the process of identifying a set of capabilities that would comprise a minimum viable product in order to meet the program's tight schedule.

We have ongoing work to define metrics associated with our leading principles for product development, which we expect will help refine our evaluation of programs' use of them.

Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated where appropriate. According to the Army, the program is managing IFPC Inc 2 within its cost, schedule, and performance targets, and it is on path to deliver a battery of systems. The Army also stated that various testing, including the planned operational assessment, will inform the Army's plans to transition the program to the major capability acquisition pathway at production and future procurement decisions.

MTA Lead Component: Army

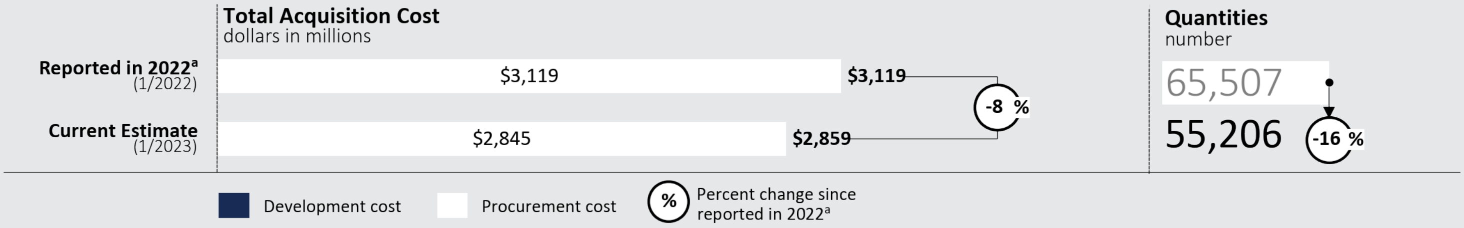
Common Name: IVAS

Source: U. S. Army. | GAO-23-106059

Integrated Visual Augmentation System (IVAS)

The Army's IVAS program seeks to improve warfighter close combat capabilities by providing a single platform that allows the warfighter to fight, rehearse, and train using augmented-reality head gear. The system includes a heads-up display, sensors, on-body computer, and other elements intended to improve warfighter sensing, decision-making, target acquisition, and target engagement via a 24/7 situational awareness tool. IVAS has rapid prototyping and rapid fielding efforts ongoing. This assessment focuses on the rapid fielding effort.

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



Cost and quantity reflect only the IVAS rapid fielding effort. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

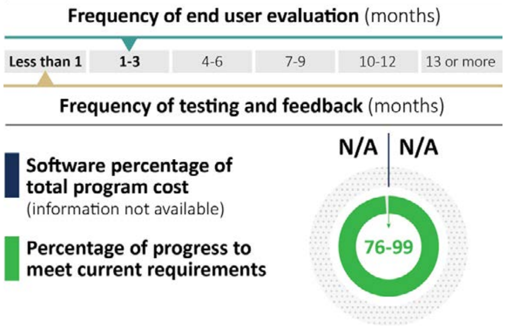
ªGAO-22-105230

Program Background and Transition Plan

The Army initiated IVAS as an MTA rapid prototyping effort in 2018. After developing and testing a prototype, the Army approved a follow-on rapid fielding effort in 2020. In 2021, the Under Secretary of Defense for Acquisition and Sustainment conditionally approved the rapid fielding effort pending correction of known technical deficiencies. As a result, the program conducted a replan in the same year to address the issues. Prior to the conclusion of the rapid fielding effort in 2025, the program plans to transition to the major capability acquisition pathway.

Software Development as of January 2023

Approach: Agile, DevOps, and DevSecOps



The program reported that cost data is unavailable because the firm-fixed price agreement and cost model do not separate out software costs.

Program Essentials

Prime contractor: Microsoft

Contract type: FFP (production) (using other transaction authority)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	○	●
Cost estimate based on independent assessment	○	○
Formal schedule risk assessment	○	●

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

IVAS Program

Updates to Program Performance and Business Case

During the past year, the program took delivery of the first IVAS systems, referred to as version 1.0. The systems are to be used in training formations. Fielding was originally scheduled for September 2021. However, due to ongoing technical issues with both hardware and software and plans to implement fixes, the program now plans to complete fielding in 2024.

IVAS plans two additional versions:

- Version 1.1 has the same form as Version 1.0 and adds an improved low-light sensor that will improve camera quality and an updated software that will improve software reliability.
- Version 1.2 incorporates a new design, allowing the goggles to be helmet mounted. This design is expected to improve overall user comfort and warfighter acceptance.

The program took delivery of approximately 5,000 of the 1.0 systems and reported being under contract for approximately 5,000 of the 1.1 systems. According to the Army, it awarded a task order for the development of 1.2 systems in the first quarter of fiscal year 2023.

The National Defense Authorization Act for Fiscal Year 2022 limited DOD from obligating or expending a portion of funding made available for fiscal year 2022 until the Army submitted to the congressional defense committees a report that included, among other things, a certification that IVAS is sufficiently reliable to meet certain operational needs. A demonstration in support of this certification occurred from May 2022 to June 2022. The Director, Operational Test and Evaluation highlighted challenges during the demonstration with system reliability and display low-light performance, as well as continued issues with its wearability and warfighter acceptance. Army testers also conducted a technology assessment during this demonstration and noted similar concerns. System updates included in 1.1 and 1.2 systems are intended to address these issues.

Last year, we reported that the Office of the Deputy Assistant Secretary of the Army-Cost and Economics developed an independent cost estimate that was pending final approval. This year, the program office stated that this estimate was put on hold due to the program replan and is now estimated to be completed in the third quarter of fiscal year 2023. We updated our Attainment of Business Case Knowledge table to show that IVAS clarified that its previous cost estimate did not reflect the current program and that the program does not have an estimate at this time.

Software and Cybersecurity

The program reported that it encountered software reliability issues during user testing. It developed related software updates, which are expected to be included in the next software release. The program stated that these updates should rectify the reliability issues.

As of October 2022, IVAS received an Authority to Operate—their cybersecurity certification—for version 1.0, and was pursuing it for 1.1 and 1.2. Following the award of the task order for 1.2, the program is now developing a comprehensive cybersecurity strategy that the Army stated it expects to be completed prior to the fourth quarter of fiscal year 2023.

Key Product Development Principles

IVAS reported using certain approaches in line with product development principles employed by leading companies. For example, the program solicits feedback on the design from operational combat units during user assessments and soldier touchpoints. It expects to release prototype iterations for additional user testing and feedback every 6 to 12 months. We previously found that ongoing engagement with customers is an important aspect of iterative development that leading companies use to prioritize features and identify improvements to the product.

We have ongoing work to define metrics associated with our leading principles, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

Since our last assessment, the program reported quantity and cost decreases of 16 percent and 8 percent, respectively. According to the program, the Army is adjusting the IVAS program plan to field a limited number of IVAS 1.0 and IVAS 1.1 systems while moving forward with development, production, and fielding of IVAS 1.2. The program noted that it assumed unit cost increases due to inflation and version 1.2 updates.

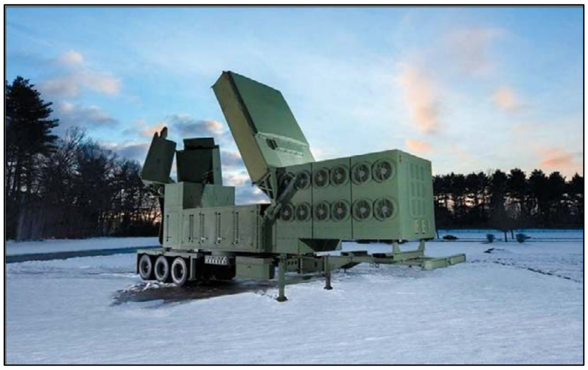
Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated as appropriate. The Army stated that it continues to work with its IVAS industry partner, Microsoft, to execute the IVAS program in a rapid and innovative manner.

MTA | Lead Component: Army

Common Name: LTAMDS

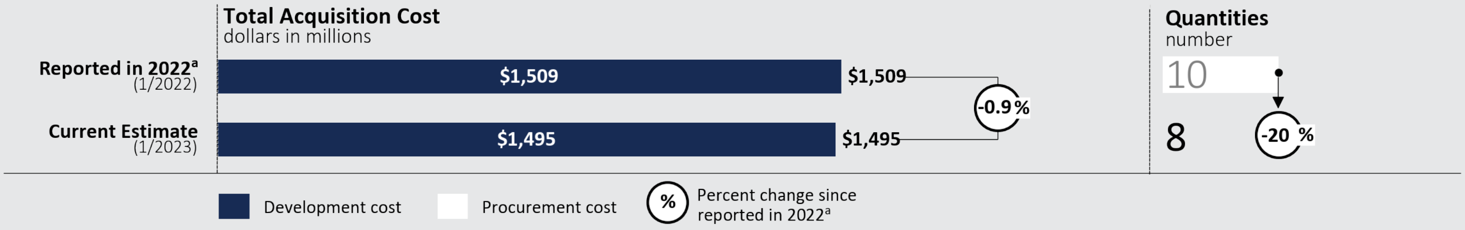
Lower Tier Air and Missile Defense Sensor (LTAMDS)



Source: Copyright 2020 Raytheon Company. |GAO-23-106059

The Army's LTAMDS, an MTA rapid prototyping effort, is planned as a multifunction radar that will replace the current Patriot radar. The Army expects that LTAMDS, as a lower-tier component of the Army's Integrated Air and Missile Defense Battle Command System architecture, will enhance radar performance, modernize technology, and improve reliability and maintainability, to better address emerging threats. The Army plans to test and field six representative LTAMDS prototypes by the end of the MTA effort.

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



The program plans to acquire six urgent material release (UMR) prototypes and two Pre-Planned Product Improvement (P3I) sensors. The program clarified that, as of our prior report, those plans included six UMRs and four P3Is. According to the program, the P3I quantity was reduced because its current planned funding can only support two.

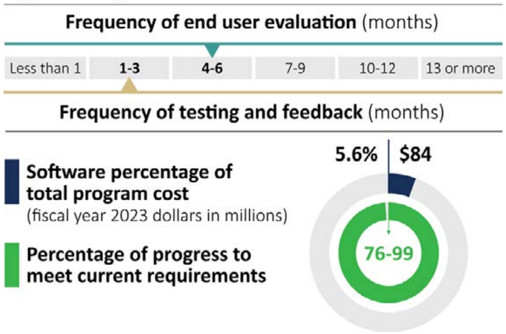
[a] GAO-22-105230

Program Background and Transition Plan

The Army pursued the MTA rapid prototyping pathway for LTAMDS in 2018 in response to an analysis of emerging threats and a statutory requirement that the Army issue an acquisition strategy to achieve initial operational capability by the end of fiscal year 2023. The program originally planned to transition to a rapid fielding effort but now expects to transition to the major capability acquisition pathway at production. This change was made to allow a longer time frame for fielding than the 5 years described in DOD policy for MTA rapid fielding efforts, according to program officials. The Army approved a new acquisition strategy in the second quarter of fiscal year 2022 with a planned transition date in the first quarter of fiscal year 2024 because delivery delays extended the time needed to complete the MTA effort.

Software Development as of January 2023

Approach: Agile



Program Essentials

Prime contractor: Raytheon

Contract type: FFP (build and test prototypes) (using other transaction authority)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	○	●
Approved middle tier of acquisition strategy	○	●
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	○	○
Formal schedule risk assessment	○	○

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

LTAMDS Program

Updates to Program Performance and Business Case

Delivery and testing challenges delayed LTAMDS's planned transition date, which may cause the program to exceed the 5-year MTA time frame established by DOD policy. In February 2023, program officials discussed transition options with the Army. They told us that they anticipate obtaining a memorandum to authorize remaining MTA program activities leading up to entering production in the major capability acquisition pathway. They expect the transition to occur in the first quarter of fiscal year 2024, one quarter later than planned.

These officials cited prototype delivery delays, which drove flight testing delays, as the cause for completing the MTA effort later than planned. Specifically, program officials delayed the delivery of the second prototype due to integration problems with the first prototype. The later delivery delayed all three flight tests in addition to contractor verification, qualification, and ground testing. The program's testing plan calls for these to be completed prior to the flight tests.

As a result of these delays, program officials postponed the planned operational assessment to the fourth quarter of fiscal year 2023, more than a year later than originally planned. As such, the planned schedule margin between the third flight test and the operational assessment was reduced from more than 4 months to less than one month. During the operational assessment, soldiers are expected to operate the prototype in a realistic environment. Program officials said that they plan to work closely with the Army Test and Evaluation Command throughout contractor verification and ground testing to ensure the Army Test and Evaluation Command can review those test results prior to the operational assessment.

LTAMDS has yet to complete a formal schedule risk assessment and indicated it instead assesses risks through efforts such as ongoing reviews of contractor schedule risk documents. Our prior work found that conducting a formal schedule risk assessment can help leaders make well-informed decisions on whether an MTA effort is likely to meet its objectives within the 5-year time frame laid out in DOD policy. For LTAMDS, conducting such an assessment may have identified schedule challenges earlier in the program, which may have helped the program mitigate delays. LTAMDS plans to complete other key assessments as it nears its transition to the major capability acquisition pathway. For example, independent assessments of the cost estimate and technical risk are scheduled for the fourth quarter of fiscal year 2023.

According to the program, all 10 of LTAMDS's critical technologies are mature. Last year we reported that all but one critical technology was mature. Program officials told us that they now consider this technology mature after having installed it on a prototype and tested it on the test range.

Software and Cybersecurity

LTAMDS completed all 10 planned software deliveries as of July 2022. According to the program, these incremental software deliveries were provided to the Integrated Air and Missile Defense lab for integration testing with the Integrated Air and Missile Defense Battle Command System.

LTAMDS's cybersecurity strategy was approved in 2018 and the program plans to update it before the LTAMDS transitions to the major acquisition capability pathway. In May 2022, LTAMDS completed a cooperative vulnerability identification assessment, and four additional cybersecurity assessments are scheduled in fiscal year 2023.

Key Product Development Principles

LTAMDS reported that it solicited feedback from its end users during the technology development phase and "Sense-Off" demonstration prior to its contract award. We previously found that obtaining feedback from customers for a potential product is an important aspect to attaining a sound business case for leading companies.

The program also collected feedback during subsequent soldier touchpoint events that they conducted approximately on a quarterly basis. The program stated that it has various integrated product teams that consider user feedback when discussing hardware and software improvements. Our prior work showed that leading companies use ongoing engagement with customers to prioritize features and identify product improvements.

We have ongoing work to define metrics associated with our leading principles for product development, which we expect will help refine our evaluation of programs' use of them.

Program Office Comments

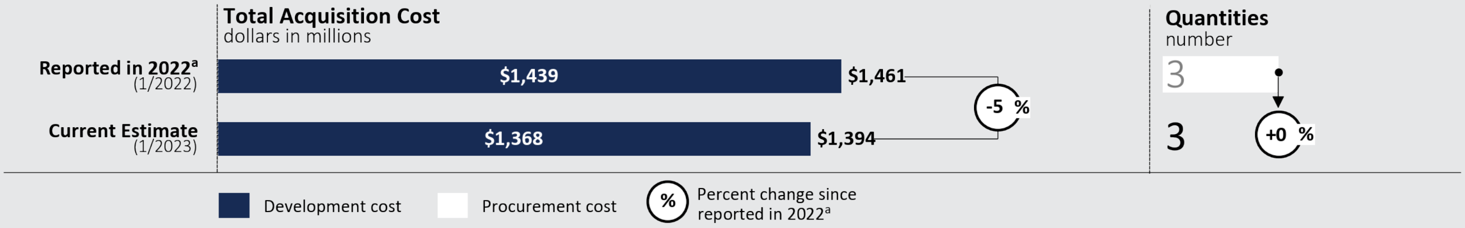
We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated where appropriate. According to the Army, while the program office has not conducted a formal schedule risk assessment, it has implemented a tailored schedule risk management approach. The Army stated that this approach includes reviewing and approving quarterly schedule risk assessments submitted by Raytheon. It also added that the program identifies appropriate mitigation efforts on an as needed basis.

Optionally Manned Fighting Vehicle (OMFV)

The Army's OMFV, an MTA rapid prototyping effort, is the planned solution to maneuver warfighters on the battlefield to advantageous positions for close combat. OMFV is expected to allow for crewed or remote operation. It is intended to replace the existing Bradley Infantry Fighting Vehicle, a legacy vehicle that no longer has the capacity to integrate new technologies. The program is executing a five-phase acquisition approach using the MTA rapid prototyping pathway (phases 1 to 3) and then transitioning to the major capability acquisition pathway (phases 4 and 5).

Source: U. S. Army. | GAO-23-106059

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



Quantities reflects three virtual prototypes. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

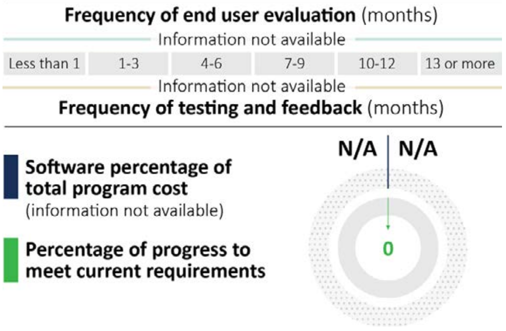
[a] GAO-22-105230

Program Background and Transition Plan

The Army initiated OMFV in 2018 but revised its acquisition plan in 2020, after experiencing difficulties with the desired capabilities and time frames. Under a five-phase plan, the Army completed market research and requirements refinement (phase 1) and the program reported awarding five contracts for concept design (phase 2) in July 2021. The program plans to award up to three contracts in the third quarter of fiscal year 2023 for the combined detailed design phase (phase 3) and prototype build and test phase (phase 4). The Army plans to transition to the major capability acquisition pathway with entry at system development in the fourth quarter of fiscal year 2024.

Software Development as of January 2023

Approach: Information not available



The program reported that software development has not started and the approach and metrics are yet to be determined.

Program Essentials

Prime contractor: TBD

Contract type: FFP (phase 2 - concept design)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	○	●
Approved middle tier of acquisition strategy	○	●
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

OMFV Program

Updates to Program Performance and Business Case

OMFV continued to develop its business case over the past year as it worked to complete its concept design phase (phase 2). Specifically, in July 2022, the Army approved the requirements for the MTA effort in an abbreviated capability development document. The program expects approval of a formal capability development document in the second quarter of fiscal year 2024, before transitioning to the major capability pathway.

The program now has one outstanding element of its business case, a technology risk assessment. The program plans to complete it through an independent technical risk assessment in the fourth quarter of fiscal year 2024. However, according to officials, the program conducted informal technology risk assessments as part of its concept design phase.

As we reported last year, the Army has yet to identify OMFV's critical technologies and will wait until it evaluates the concept designs from phase 2. Program officials stated that the vendors' choice of technologies and subsystems will determine the level of risk for each prototype.

Identifying critical technologies in later stages poses risks that they may not reach maturity before OMFV transitions to the major capability acquisition pathway. Using immature technologies further increases the risk of requiring redesigns. Program officials said that there are a couple of technologies in the phase 2 designs that could become critical if the contractors propose them for the detailed design phase (phase 3). However, they acknowledged that maturity gaps could delay system development start.

Software and Cybersecurity

According to OMFV officials, software development plans and the cybersecurity strategy are contingent upon the design selected at the end of the detailed design phase (phase 3) and subsequent contract award.

Key Product Development Principles

OMFV reported using selected processes that are in line with the key product development principles that our prior work found leading companies employ. For example, the program stated that it received feedback from operational users who worked in 3-D mock-ups of the cockpit and platform prior to the issuance of phase 2 design concepts. The program plans to collect additional feedback during soldier touch points and demonstrations. We previously found that ongoing engagement with customers is an important aspect of iterative development that leading companies use to prioritize features and identify improvements to the product.

The program also stated that it had an established process for prioritizing capabilities in order to meet schedule and cost goals, a practice also used by leading companies. For example, OMFV's requirements document for the current rapid prototyping effort prioritizes requirements by tier. The highest tier, according to the program, includes the most technologically challenging requirements that could be deferred. Our prior work found that leading companies focus on realistic schedules, so they are willing to make difficult decisions to de-scope capabilities.

We have ongoing work to define metrics associated with our leading principles for product development, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

Program officials reported that the contractors for phase 2 are developing digital engineering environments to assist in design. They added that the digital models are expected to assist in future development efforts and planning for maintenance and logistics. Program officials stated that the contractors' final deliverables for phase 2 will be considered in the award selection process for phases 3 and 4.

The program did not report a specific date for a preliminary design review in the detailed design phase (phase 3), but program officials said that the contractors will determine the timing of the preliminary design reviews based on the maturity of their designs. Officials further explained that the intent of this flexibility is to avoid forcing the reviews before a contractor's design is ready.

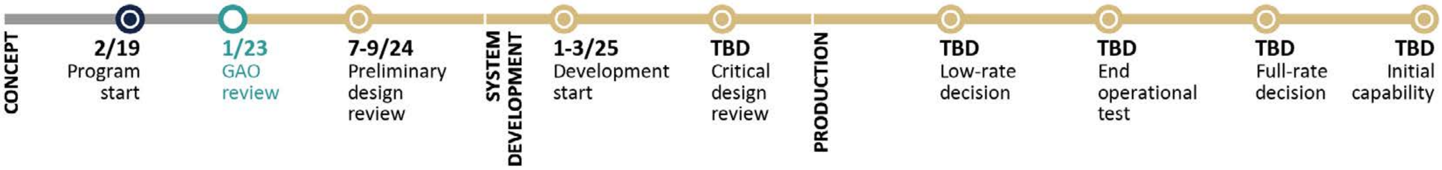
Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated as appropriate. The Army stated that the OMFV program is executing within cost, schedule, and performance parameters. It also noted that the program developed the phase 3 and 4 requirements by using modeling and simulation and that the requirements were informed by the five phase 2 vendors' digital concepts. The Army also stated that the requirements analysis aimed to reduce the technical risk of the program and align with the schedule allocated in phases 3 and 4.

Source: U. S. Army. | GAO-23-106059

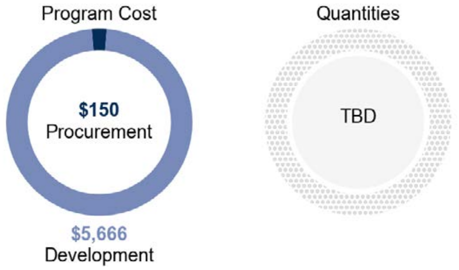
Future Attack Reconnaissance Aircraft Program (FARA)

FARA is part of the Future Vertical Lift portfolio of systems, a top modernization priority for the Army. It is intended to provide enhanced capabilities for reconnaissance, attack, and aerial security. The Army expects FARA to provide these capabilities with increased performance, lethality, range, and sustainability over the current fleet, which is currently using the AH-64 Apache as an interim solution for armed reconnaissance. The Army is pursuing the major capability acquisition pathway and a two-phase competitive prototyping strategy to acquire FARA.



Estimated Cost and Quantities

fiscal year 2023 dollars in millions



Costs represent fiscal years 2020–2028. Total cost is to be determined.

Software Development as of January 2023

Approach: Agile and Waterfall

Frequency of end user evaluation (months)

Information not available

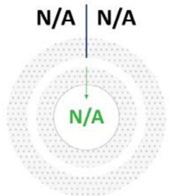
Less than 1	1-3	4-6	7-9	10-12	13 or more

Information not available

Frequency of testing and feedback (months)

Software percentage of total program cost
(information not available)

Percentage of progress to meet current requirements
(information not available)



Program Essentials

Prime contractors: Bell Helicopter Textron, Inc; Sikorsky Aircraft Corporation

Contract type: FFP (prototype design and build) (using other transaction authority)

Current Status

The Army is in the second phase (developing and testing a prototype aircraft) of its two-phased competitive prototyping strategy. According to the program, as of the first quarter of fiscal year 2023, the two vendors the Army selected in March 2020 for this phase were about 90 percent complete with their prototypes. Phase two is scheduled to continue through fiscal year 2024. The Army plans to conduct a flight test evaluation of both prototype vehicles before selecting a vendor to continue to system development. Phase one of the Army's competitive prototyping strategy began in April 2019 with five vendors participating in the initial design phase.

FARA delayed its planned system development start date by one year, in part, due to delays of a critical technology—the Improved Turbine Engine (ITE), developed by a separate program office. We discuss the ITE program in a separate assessment. The FARA program office anticipates the first engine deliveries in the spring of 2023. It would then complete the prototypes, conduct a system-level preliminary design review during the fourth quarter of fiscal year 2024, and start system development in the second quarter of fiscal year 2025.

The program's analysis of alternatives was initially scheduled for completion during the third quarter of fiscal year 2022. However, in April 2022, the Office of Cost Assessment and Program Evaluation approved withdrawal of the analysis of alternatives due to the delays with the ITE. Pending a formal restart of the analysis of alternatives, the completion date and the effects on the program timeline is to be determined.

Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated where appropriate. The Army stated that FARA remains on schedule to start system development and to select a single vendor in fiscal year 2025. It noted that prototype aircraft are more than 90 percent complete, with the intent to fly after receiving the ITE. The Army stated that it intends to reduce program risk through competitive prototyping, requirements refinement, and preliminary design efforts. In March 2023, after our cut-off date for new information, the Army announced that due to parts manufacturing challenges, FARA first engines will be delivered in early fiscal year 2024.

Long Range Hypersonic Weapon System (LRHW)

The Army's LRHW is a ground-launched hypersonic missile designed to engage an adversary's long-range weapons and high-value, time-sensitive targets. LRHW prototype is a research and development effort managed by the Army's Rapid Capabilities and Critical Technologies Office. It is a joint effort with the Navy's Conventional Prompt Strike program, which is developing a ship-fired version of the system. The Army expects to field a system with eight missiles by the end of fiscal year 2023. The program proposed transitioning to the MTA rapid fielding pathway, but as of January 2023, the Army had not finalized that decision.

Source: U. S. Army. | GAO-23-106059

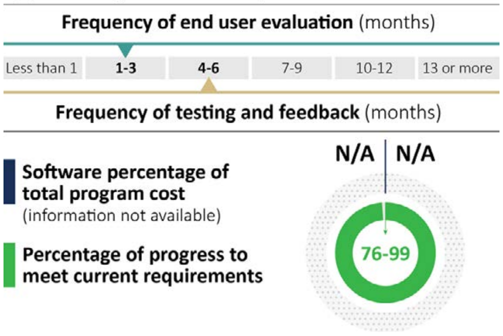
Estimated Cost and Quantities

fiscal year 2023 dollars in millions

Cost and quantity information from fiscal years 2019 to 2023.

Software Development as of January 2023

Approach: Agile and DevSecOps



The program reported that it does not currently track software costs but plans to track them in the future.

Program Essentials

Prime contractors: Lockheed Martin; Dynetics, Inc.; Dynetics Technical Solutions

Contract type: CPIF/CPFF/FFP (includes use of other transaction authority)

Current Status

The Army is on track to field its first LRHW system—including the eight missiles in production—by the end of fiscal year 2023, according to LRHW officials. However, the schedule depends on the success of upcoming tests. The first flight test of a complete missile in 2022 was partially successful. LRHW has two more missile tests scheduled in 2023 before it plans to field the first system. According to LRHW officials, they had to start missile production before the flight tests were complete to meet the tight deadlines that the Army set. This posed a challenge for the program because the design changed based on the outcome of the tests. We found in prior work that starting production before demonstrating a system works as intended increases the risk of discovering deficiencies that require costly rework. The program is managing this risk by continuing to build, but not complete, the missiles until it has more test data.

The Army plans to field two additional LRHW batteries no later than fiscal years 2025 and 2027. In October 2022, the Army announced it may pivot from using an other transaction agreement with the current ground equipment contractor to a Federal Acquisition Regulation-based contract in the future.

Program Office Comments

We provided a draft of this assessment to the Army for review and comment. The Army provided technical comments, which we incorporated where appropriate. The Army stated that it is successfully managing the LRHW program and is on schedule to deliver the nation's first prototype long-range hypersonic weapon. It noted that the program delivered the ground equipment in 2021 and is on track to deliver eight missiles by the fourth quarter of fiscal year 2023. The Army acknowledged that its success is dependent on concurrently designing and building missiles. To do so, the Army stated that the program instituted decision points following each test event, providing an opportunity to pause production and make necessary corrections.

MARINE CORPS

Program Assessments

▲ CH-53K Heavy Replacement Helicopter (CH-53K)

Assessment type	Program name
MDAPs	CH-53K Heavy Replacement Helicopter (CH-53K)

Source (previous page image): U.S. Navy. | GAO-23-106059

MDAP | Lead Component: Marine Corps | **Common Name:** CH-53K

Source: U. S. Navy. | GAO-23-106059

CH-53K Heavy Lift Replacement Helicopter (CH-53K)

The Marine Corps' CH-53K heavy lift helicopter is intended to transport armored vehicles, equipment, and personnel to support operations deep inland from a sea-based center of operations. The CH-53K is replacing the legacy CH-53E helicopter and provides increased range and payload, survivability and force protection, reliability and maintainability, and coordination with other assets, while reducing total ownership costs.

Phase	Date	Event
CONCEPT	11/03	Program start
SYSTEM DEVELOPMENT	12/05	Development start
	7/10	Critical design review
PRODUCTION	4/17	Low-rate decision
	7/21	Start operational test
	2/22	End operational test
	4/22	Initial Capability
	11/22	Full-rate decision
	1/23	GAO review

Program Performance fiscal year 2023 dollars in millions

	Total Acquisition Cost (dollars in millions): Development cost	Procurement cost	Total	Unit Cost (dollars in millions)	Quantities (number)	Cycle time (in months)
First Full Estimate (12/2005)	$5,480	$15,241	$20,720	$133	156	117
Reported in 2022[a] (7/2020)	$9,564	$24,711	$34,289	$171	200	197
Current Estimate (8/2022)	$9,524	$25,197	$34,736	$174	200	196
Percent change since reported in 2022[a]			+1 %	+1 %	+0 %	-1 %

Total quantities comprise four development quantities and 196 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

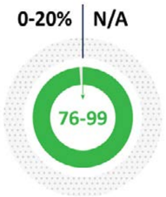
Approach: Waterfall

Frequency of end user evaluation (months)

Frequency of testing and feedback (months)

Software percentage of total program cost (information not available)

Percentage of progress to meet current requirements



The program indicated that software accounts 20 percent or less of program costs, but it did not provide a specific dollar value.

Program Essentials

Prime contractors: Sikorsky Aircraft, General Electric Aviation

Contract type: CPIF (development), FPI/FFP (procurement)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	○	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	○	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	○	○
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	●	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

CH-53K Program

Technology Maturity, Design Stability, and Production Readiness

The CH-53K was approved to enter full-rate production on December 21, 2022. The program also made some progress in the last year addressing technical issues we reported on in our last assessment. Specifically, we previously reported that the program office identified 126 technical issues that needed to be fully addressed before the end of development. According to the program, as of July 2022, 122 of the 126 issues have designs completed for potential solutions, up from 119 in our last assessment. These efforts will be completed through the development contracting efforts.

The program had mixed success in addressing other technical challenges we reported on last year. For example:

- Last year, we reported that the aircraft engine could stall due to sand ingestion. At the time, the program office was trying to find a solution to the issue. In January 2023, the program office reported it implemented procedural controls and engine software updates to reduce risk to aircraft and crew.
- We also reported on shorter than expected life spans of a number of different parts on the aircraft, which places a greater maintenance burden on the warfighter and increases sustainment costs. For example, the program identified a new design for the intermediate gear box that potentially extends the life span to 4500 hours (from its current 1250 hours), but the program will not test the new design until 2024.

The program completed operational testing in April 2022 with a recommendation that there be continued fleet introduction. The Director, Operational Test & Evaluation provided a report to the congressional defense committees in December 2022 on the adequacy of testing and the operational effectiveness, operational suitability, and survivability of the CH-53K in support of the full rate production decision. Follow-on testing for planned configuration upgrades and new capabilities will begin mid-fiscal year 2023.

Some supplier issues we reported on last year improved. For example, the program found a new supplier for the data concentrator units since the supplier told the program office it would no longer be able to support the program. In addition, the program office stated that the fuel cell supplier dramatically improved and it considers the new supplier to be low risk to the program. Finally, the program office noted that the main gear box housing supplier increased its output and, to help further mitigate any issues, Sikorsky is adding additional sources of supply.

Software and Cybersecurity

According to the program office, there are no significant updates to report on cybersecurity and software. The program office reported that an updated Cybersecurity Strategy was approved for the program, which includes additional software and cybersecurity activities.

Other Program Issues

According to program officials, they continue to closely monitor costs. Cost saving initiatives included as part of the program's approved acquisition strategy include the use of multiyear contracting and foreign military sales. The program office's responses this year reflect a change in the way it counts design drawings to improve the accuracy of the count. As a result, the program's current number of releasable drawings is slightly less than the 90 percent that leading practices advocate to help ensure design stability. We updated our Attainment of Product Knowledge accordingly.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, as of December 2022, the program delivered nine CH-53K production aircraft to the fleet and received positive feedback from squadron leadership, operators, and maintainers. Additionally, the program office reported that the recent successful full-rate production decision provided stakeholders with assurances of the program's affordability and ability to consistently produce aircraft. The program office stated that, while challenges remain with suppliers on critical parts, program officials report continued progress on improved planning and anticipate the program will meet production goals in support of the Marine Corps' heavy lift transition plan.

NAVY

Program Assessments

▲ F/A-18E/F Infrared Search and Track (IRST)

Assessment type	Program name
MDAPs	Advanced Anti-Radiation Guided Missile - Extended Range (AARGM-ER)
	Air and Missile Defense Radar (AMDR)
	CVN 78 *Gerald R. Ford* Class Nuclear Aircraft Carrier (CVN 78)
	DDG 1000 *Zumwalt* Class Destroyer (DDG 1000)
	F/A-18E/F Infrared Search and Track (IRST)
	FFG 62 *Constellation* Class Frigate (FFG 62)
	Littoral Combat Ship Mission Modules (LCS Packages)
	MQ-25 Unmanned Aircraft System (MQ-25 Stingray)
	MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)
	Next Generation Jammer Mid-Band (NGJ MB)
	Ship to Shore Connector Amphibious Craft (SSC)
	SSBN 826 *Columbia* Class Ballistic Missile Submarine (SSBN 826)
	T-AO 205 *John Lewis* Class Fleet Replenishment Oiler (T-AO 205)
MDAP Increments	DDG 51 *Arleigh Burke* Class Destroyer, Flight III (DDG 51 Flight III)
	LPD 17 *San Antonio* Class Amphibious Transport Dock, Flight II (LPD 17 Flight II)
	SSN 774 *Virginia* Class Submarine (VCS) Block V
MTA Programs	Conventional Prompt Strike (CPS)
Future Major Weapon Acquisitions	DDG(X) Guided Missile Destroyer (DDG(X))
	Large Unmanned Surface Vehicle (LUSV)
	Light Amphibious Warship (LAW)
	MK 54 MOD 2 Advanced Lightweight Torpedo (ALWT)
	Orca Extra Large Unmanned Undersea Vehicle (XLUUV)

Source (previous page image): U.S. Navy. | GAO-23-106059

Source: Northrop Grumman Innovation Systems (NGIS). | GAO-23-106059

Advanced Anti-Radiation Guided Missile—Extended Range (AARGM-ER)

The Navy's AARGM-ER program is an upgrade to the AGM-88E AARGM. The AARGM-ER is an air-launched missile that is intended to provide increased range, higher speed, and more survivability to counter enemy air defense threats. The AARGM-ER will reuse sections of the AARGM and incorporate a new rocket motor, warhead, and control actuation system, which includes fins that help steer the missile. AARGM-ER will be integrated on the F/A-18E/F and EA-18G aircraft and configured to be carried internally on the F-35 aircraft.

CONCEPT	
7/17	Program start
SYSTEM DEVELOPMENT	
3/19	Development start
2/20	Critical design review
PRODUCTION	
9/21	Low-rate decision
1/23	GAO review
9/23	Initial capability
10/23	Start operational test
9/24	End operational test
12/24	Full-rate decision

Program Performance fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions: Development cost	Procurement cost	Total		Unit Cost dollars in millions		Quantities number		Cycle time in months	
First Full Estimate (12/2018)	$830	$2,987	$3,817		$1.82		2,097		56	
Reported in 2022[a] (9/2021)	$830	$2,941	$3,771	-3 %	$1.80	-3 %	2,097		56	
Current Estimate (8/2022)	$831	$2,826	$3,657		$1.74		2,097	+0 %	56	+0 %

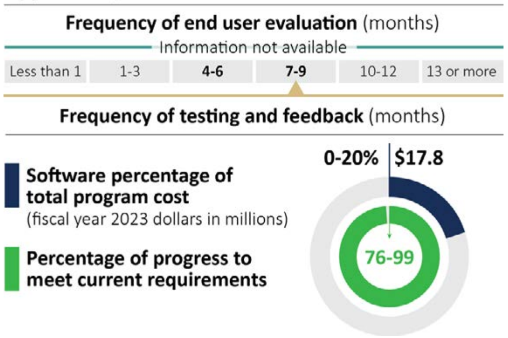
■ Development cost □ Procurement cost (%) Percent change since reported in 2022[a]

Total quantities comprise 17 development quantities and 2,080 procurement quantities.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Spiral



The program reported that end users are not involved in evaluating and providing feedback on the software because the software is for weapon performance, not for a user interface.

Program Essentials

Prime contractor: Alliant Techsystems Operations, LLC

Contract type: CPIF (development), FFP (procurement)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	○	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	○
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	○	○

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

AARGM-ER Program

Technology Maturity, Design Stability, and Production Readiness

As we reported last year, the Navy approved the AARGM-ER program to start production in August 2021, having met some, but not all, leading practices for production readiness. Specifically, the program did not test either a system-level integrated prototype or a production-representative prototype in an operational environment prior to production start. The program has yet to test these prototypes as of December 2022.

The lack of system-level testing continues to be a source of cost, schedule, and technical risk for AARGM-ER. The program completed three additional flight tests since our last assessment, including successful end-to-end tests against a stationary target on land and a moving target at sea. However, the missiles tested to date did not have an upgraded processor or tactical software that will ultimately be included in production missiles. The program does not plan to test a fully-configured, production-representative prototype until the third quarter of fiscal year 2023. This planned date has been delayed by at least 9 months since our last assessment due, in part, to hardware delays stemming from the baseline AGM-88E AARGM program. The test is now scheduled to occur after the Navy plans to award its third low-rate production contract.

We found that starting production before demonstrating a system will work as intended increases the risk of discovering deficiencies that require costly, time-intensive rework. Prior Navy and independent assessments of the AARGM-ER program have highlighted similar risks. In addition, Navy and DOD testers noted that the AARGM-ER tests conducted as of October 2022 were not extensive enough to assess AARGM-ER's operational performance and limitations. Navy test officials told us that they expect that a series of upcoming tests will provide a better basis for assessing the system's performance before the planned start of operational testing in October 2023.

The program demonstrated critical manufacturing processes on a pilot production line at one location, but is in the process of moving to a new production facility. As we reported last year, program officials told us that they expected the new facility to provide a more stable production capacity and have lower labor costs. The program office is tracking this production transition as a schedule risk, but program officials stated that design and construction of the new facility is on schedule.

Software and Cybersecurity

Since our last assessment, software development and integration challenges contributed to an additional 6-month delay in the completion of AARGM-ER developmental testing and the planned start of operational testing. The program released three of its four planned software releases; but the final software release, needed to complete developmental testing on a production-representative missile, was delayed.

Program officials stated that there were two primary reasons for the delay. First, the AARGM-ER program was waiting on upgraded hardware from the baseline AGM-88E AARGM program to complete software testing on the last release. Program officials did not provide an estimate of when the upgraded hardware would be qualified and available to support its software testing. Second, the program continues to experience software staffing issues, which we have reported on in the past. Program officials stated that the contractor has significant staffing challenges, including a 10 percent attrition rate due to more attractive work environments available in commercial industry. These issues and the software schedule pose a program schedule risk and could result in additional delays for the program.

Other Program Issues

The AARGM-ER program is working through a number of issues related to its next set of production contracts, including potential increases in missile costs due to inflation. According to program officials, the contractor's initial proposal for the third production contract was significantly higher than the amount the program budgeted for it. The program office aims to award this contract no later than March 2023.

Program Office Comments

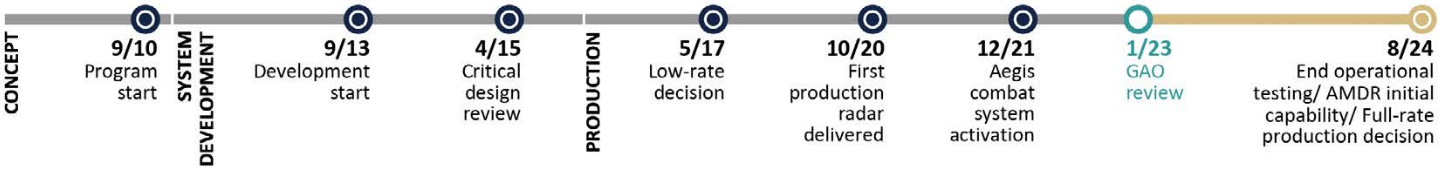
We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. It stated that the re-use of AGM-88E AARGM sensors and electronics, coupled with extensive ground-based testing of the rocket motor and warhead to mitigate risk, aircraft integration testing, and flight testing continue to provide confidence in a stable configuration for production contract awards. It noted that, to date, four developmental test flights were successfully conducted with two remaining; that operational flight testing will begin once developmental testing ends; and that Navy and DOD testers will be able to assess operational performance and limitations.

The program office stated that it follows leading practices for overall production readiness. It noted that it plans to award the third low-rate initial production contract prior to completion of testing due to procurement lead times of materials and to maintain the production line. It added that developmental and operational testing will be completed prior to beginning production of the third missile lot; that the concurrency is necessary to meet warfighter needs in response to the evolving threats; and that it is taking related mitigation steps.

Source: Raytheon Company. | GAO-23-106059

Air and Missile Defense Radar (AMDR)

The Navy's AMDR is a next-generation radar program supporting surface warfare and integrated air and missile defense. The Navy expects AMDR's radar—known as AN/SPY-6(V)1—to provide increased sensitivity for long-range detection to improve ballistic missile defense against advanced threats. The Navy is also developing a radar suite controller to interface with an updated Aegis combat system to provide integrated air and missile defense for DDG 51 Flight III destroyers. In January 2023, the Navy added two Enterprise Air Surveillance Radar (EASR) variants to the program. These variants will provide next generation radars for other ship classes.



Program Performance fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions				Unit Cost dollars in millions		Quantities number		Cycle time in months	
	Development cost	Procurement cost	Total	%		%		%		%
First Full Estimate (10/2013)	$2,269	$4,692	$6,996		$318		22		156	
Reported in 2022[a] (7/2020)	$2,401	$3,901	$6,337		$317		20		167	
Current Estimate (8/2022)	$2,181	$5,158	$7,374	+16%	$284	-10 %	26	+30 %	167	+0 %

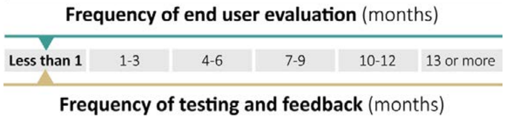
■ Development cost □ Procurement cost (%) Percent change since reported in 2022[a]

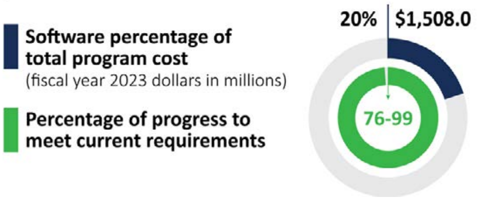
Total quantities comprise zero development quantities and 26 procurement quantities. Program performance data is expected to change due to the addition of EASR variants. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile and Incremental





Program Essentials

Prime contractor: Raytheon

Contract type: FPI (procurement)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	○	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	●	●
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	○	○

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess AMDR's demonstration of critical processes on a pilot production line because the program office stated that this program uses no critical manufacturing processes.

AMDR Program

Technology Maturity, Design Stability, Production Readiness

As we reported last year, AMDR fully matured its critical technologies in December 2021 and its overall design remains stable. The Navy plans to start operational testing of AMDR and Aegis at sea on DDG 125 in November 2023.

Since last year, AMDR's low-rate initial production contract's estimated price increased. According to program officials, this increase was due to earlier optimistic cost estimating by the contractor, supply chain challenges, and issues with the Digital Receiver Exciter (DREX) and Transmit/Receive Integrated Microwave Modules (TRIMM). We previously reported on manufacturing issues with the DREX and TRIMM that required the program to complete some redesign and rework. According to program officials, the contractors addressed these issues and took into account the actual costs from the low-rate initial production contract when preparing to award the follow-on contract, which was awarded in March 2022.

The program continued delivery of radar arrays in 2022. It briefly held up delivery of two arrays after discovering cracking in the material used to fabricate them. Program officials stated that they determined the arrays were within standards but added an inspection step for all future radars to ensure this component continues to meet standards. Program officials told that us they believe this step provides reasonable assurance for future performance.

Program officials also plan to take remedial actions to investigate and address any further issues found with inverter modules after a single module grounded out, causing it to burn during initial testing. According to program officials, these modules are a critical part of the power supply system. Program officials told us that they do not expect this issue to affect deliveries or program costs.

Software and Cybersecurity

AMDR is using a hybrid Agile and incremental software development approach. According to the program office, software is released at various intervals—every 4 weeks for interim releases and builds every year.

The program completed several cybersecurity exercises and, according to officials, plans to include cybersecurity testing during operational testing in 2024. Program officials continue to track a risk from cyber threats related to countermeasures seeking to defeat the radar. They plan to address this risk as part of upcoming cybersecurity testing through 2025.

Other Program Issues

AMDR officials plan to complete operational testing in August 2024, the same month as the planned full-rate production decision. This schedule leaves little time for the program to address any deficiencies discovered during testing. We previously reported that any deficiencies discovered during testing could result in costly and time-intensive revisions for the program. Program officials acknowledge this issue and plan to continue testing radar performance and power requirements in advance of operational testing to mitigate the risk of late discovery of issues in these areas.

AMDR officials stated that the radar performed well as an informal participant in the August 2022 Pacific Dragon exercise, where the radar tracked live missile and aircraft activity. Despite performing well, the program identified some issues during this exercise and plans to run separate high-fidelity performance test scenarios prior to the start of operational testing.

Program officials stated that they made adjustments and conducted additional power system testing with all four arrays in fall 2022. This testing was in response to a risk that prior testing could not adequately model expected operational conditions. We previously reported that the program planned full-array power testing by the end of fiscal year 2022. According to program officials, these interim tests should improve performance during operational testing and reduce risk to meeting power requirements.

The program updated its baseline in January 2023. The update designated two EASR variants as subprograms of the AMDR program. As we previously reported, the Navy plans to install the two EASR variant systems on several classes of Navy ships. The program is tracking related risks, and program officials told us that they plan tests in February and March 2023 to help mitigate these risks.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that it is on track to support DDG 125's schedule and that it successfully completed full-array power testing and supported the ship's December 2022 sea trial. It also stated that integrated live-radar and combat system testing continues to support various classes of Navy ships.

MDAP Lead Component: Navy

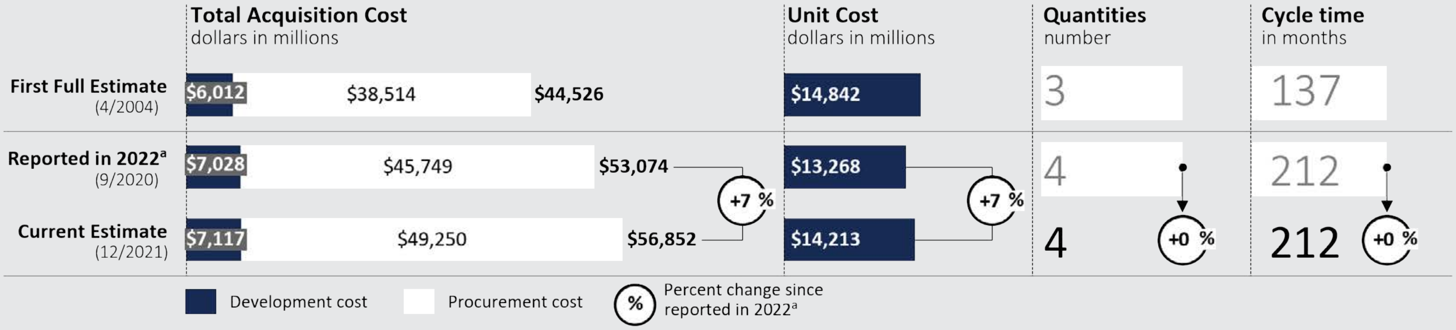
Common Name: CVN 78

Source: U. S Navy. | GAO-23-106059

CVN 78 *Gerald R. Ford* Class Nuclear Aircraft Carrier (CVN 78)

The Navy developed the CVN 78 (or *Ford* class) nuclear-powered aircraft carrier to introduce new propulsion, aircraft launch and recovery, and survivability capabilities to the carrier fleet. The *Ford* class is the successor to the *Nimitz* class aircraft carriers. Its new technologies are intended to create operational efficiencies and increase sustained operational flights, compared with legacy carriers. The Navy also expects the new technologies to enable *Ford* class carriers to operate with a smaller crew than *Nimitz* class ships.

Program Performance fiscal year 2023 dollars in millions

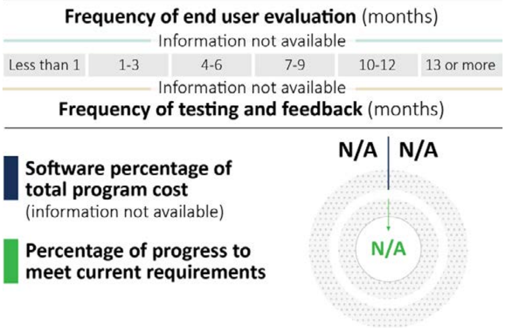


Total quantities comprise zero development quantities and four procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Information not available



The program office reported that it does not separately track software as software is provided by other Navy programs.

Program Essentials

Prime contractors: Huntington Ingalls Industries; Newport News Shipbuilding

Contract type: FPI (detail design and construction)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Construction Preparation Contract Award	Current Status
Demonstrate all critical technologies in a relevant environment	○	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	○	●
Product design is stable	Fabrication Start	
Complete basic and functional design to include 3D product modeling	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We assessed CVN 78 resources and requirements knowledge metrics at the time of the construction preparation contract award, rather than the detail design contract award, because that is the point at which the program began CVN 78 development.

CVN 78 Program

Technology Maturity, Design Stability, and Production Readiness

The Navy continues to face challenges with demonstrating the reliability of key systems, and the CVN 78 program remains about a decade away from demonstrating their reliability. Consequently, the ship may not meet a key performance requirement by the planned end of operational testing in November 2023.

Metrics used to assess system reliability for the electromagnetic aircraft launch system (EMALS) and advanced arresting gear (AAG) are slowly increasing. CVN 78 completed multiple at-sea events, including thousands of aircraft launches and recoveries or landings. These launch and recovery cycles help the program demonstrate system reliability, conduct testing, and certify aircraft on the systems. However, the Director, Operational Test and Evaluation, continues to highlight reliability as a risk to CVN 78's ability to rapidly launch and recover aircraft.

The Navy expects to install the first Enterprise Air Surveillance Radar (EASR) on CVN 79, which it is currently developing for other ship classes. EASR, along with other systems, will replace the program's original Dual Band Radar. The Navy has delivered EASR to the shipyard as it continues testing. However, CVN 79 delivery, planned for late in fiscal year 2024, could be delayed if EASR problems discovered during testing require rework.

The Director, Operational Test and Evaluation, approved the April 2022 CVN 78 Test and Evaluation Master Plan, after the program implemented changes to the test strategy. The Navy subsequently began operational testing in August 2022. Given that operational testing is ongoing, CVN 78 has yet to demonstrate that it is operationally effective and suitable for combat. Any deficiencies discovered during operational testing may lead to a backlog of maintenance issues that the fleet will need to address during future maintenance periods.

Software and Cybersecurity

The CVN 78 program's software and cybersecurity approach has not changed since last year. According to program officials, the program conducted an evaluation of potential cybersecurity vulnerability for EMALS and AAG in June 2022. They stated that other ship systems will undergo cybersecurity assessments in fiscal years 2023 through 2025.

Other Program Issues

Since our report last year, program costs increased by $3.8 billion. Some of the main drivers are CVN 79 contract overruns and EMALS and AAG configuration changes on CVN 80 and CVN 81.

The Navy reported final CVN 78 construction costs of $13.2 billion. Maintenance or other funding categories will cover any additional costs. For example, according to program officials, the Navy is considering replacing the Dual Band Radar with EASR during a maintenance period to ensure a more reliable supply chain for maintenance. The Navy only has one operational Dual Band Radar unit—installed on CVN 78—which makes sourcing and procuring spare parts more expensive, according to program officials.

In August 2021, the Navy increased CVN 79's cost baseline by $1.3 billion to $12.7 billion, primarily due to contract overruns. At over 88 percent complete, CVN 79 is in the complex, final phases of construction when cost growth is most likely. Program officials stated that they do not expect CVN 79 would require additional funding. However, our analysis shows that, based on current performance, the shipbuilder is unlikely to achieve its cost estimate at completion.

The Navy reported saving $4 billion by concurrently awarding contracts for CVN 80 and CVN 81, compared with buying the ships individually. CVN 80 is 25 percent complete, and the Navy requested additional funding to complete the transition from using paper drawings for construction to a digital model. The Navy estimated the new model would reduce production labor hours by 5 to 7 percent. However, program officials indicated that it is too early to determine if the shipbuilder will achieve this target. Additionally, program officials reported that industrial base issues, including supply chain delays and inflation of material costs, could contribute to the unlikelihood of it achieving anticipated savings.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, CVN 78 completed ship construction at a total cost of $13.2 billion. It stated that from October to November 2022, CVN 78 conducted an at-sea deployment and completed more than 1,250 aircraft flights, expended 78 tons of weaponry, and completed 13 resupply efforts at sea. The program office noted that CVN 79 costs increased due to the transition to a new delivery schedule in January 2022 to enable delivery of the ship with its complete warfare systems. It added that costs also increased due to modifications to ensure CVN 79 will be capable of operating and deploying F-35C aircraft upon the completion of the next maintenance period. CVN 80 conducted its keel laying ceremony in August 2022 and the CVN 81 keel laying is scheduled for fiscal year 2026. The program office stated that it expects that the two-ship acquisition strategy for CVN 80 and CVN 81 will deliver significant savings to the government compared with the Navy's cost estimate to procure these ships separately.

MDAP Lead Component: Navy

Common Name: DDG 1000

Source: BAE Systems San Diego. | GAO-23-106059

DDG 1000 *Zumwalt* Class Destroyer (DDG 1000)

The DDG 1000 is a multimission surface ship initially designed to provide advanced capability to support forces on land. DDG 1000 class ships feature a stealth design, an integrated power system, and a total ship computing environment. The Navy adopted a phased acquisition strategy, which separates delivery and acceptance of hull, mechanical, and electrical systems from combat system activation and testing. In addition to the strike mission, the Navy now plans to add hypersonic missiles to the ship.

Phase	Date	Event
CONCEPT	1/98	Program start
SYSTEM DEVELOPMENT	8/06	Development start
PRODUCTION	2/09	Lead-ship (DDG 1000) fabrication start
	4/20	Lead-ship final delivery
	1/23	GAO review
	4/23	Initial capability
	9/23	DDG 1001 final delivery
	12/23	End operational test
	10/24	DDG 1002 final delivery

Program Performance fiscal year 2023 dollars in millions

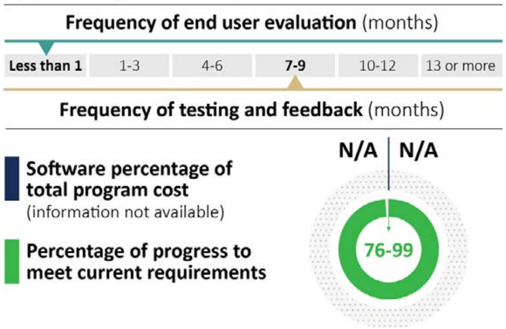
	Total Acquisition Cost (dollars in millions): Development cost	Procurement cost	Total	% change since reported in 2022[a]	Unit Cost (dollars in millions)	% change since reported in 2022[a]	Quantities (number)	% change since reported in 2022[a]	Cycle time (in months)	% change since reported in 2022[a]
First Full Estimate (1/1998)	$2,851	$40,705	$43,557		$1,361		32		128	
Reported in 2022[a] (9/2020)	$13,323	$15,690	$29,013	0 %	$9,671	0 %	3		300	
Current Estimate (10/2022)	$13,222	$15,764	$28,986		$9,662		3	+0 %	304	+1 %

Total quantities comprise zero development quantities and three procurement quantities.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile and DevOps



Software percentage of total program cost (information not available)

Percentage of progress to meet current requirements

The program reported that software cost elements are not tracked.

Program Essentials

Prime contractors: General Dynamics Bath Iron Works; Huntington Ingalls Industries; Raytheon

Contract type: FPI/FFP/CPFF (ship construction); CPFF/CPAF (mission systems equipment)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Detail Design Contract Award	Current Status
Demonstrate all critical technologies in a relevant environment	○	○
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	**Fabrication Start**	
Complete basic and functional design to include 3D product modeling	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

DDG 1000 Program

Technology Maturity, Design Stability, and Production Readiness

The DDG 1000 program has yet to mature a total of four critical technologies despite completing construction of the third and final ship of the class in 2021. Three of these immature technologies, which involve the ships' signature, computing, and radar capabilities, were planned since program start. According to the program, the Navy intends to demonstrate full maturity for these technologies during operational testing.

However, two more recently identified critical technologies—one of which the Navy has yet to mature—face installation delays. As we reported in our last assessment, a communication system and an intelligence system were added to the program in 2020 to enable the new surface strike mission. The program office stated that the Chief of Naval Operations directed a delayed installation of these systems on *Zumwalt* class ships to shift the program's focus to integrating the Navy's new Conventional Prompt Strike (CPS) hypersonic weapon system. We evaluate the CPS program in a separate assessment in this report.

The Navy plans to complete operational testing on DDG 1000 in December 2023—a 12-month delay compared with the schedule during last year's assessment. According to the program office, weather, limited ship availability for testing, and test range and asset limitations contributed to this delay.

Further, the Navy delayed initial operational capability for DDG 1000 an additional 4 months during the past year. Initial operational capability is now planned for April 2023—over 6 years later than the program's approved acquisition program baseline date.

The other two ships continue to face delivery delays. DDG 1001 final delivery was delayed 12 months to September 2023. While the program is working toward the completion of combat systems installation and activation for the DDG 1002, program officials stated that DDG 1002 final delivery moved from fiscal year 2024 to early fiscal year 2025.

Other Program Issues

The Navy requested approximately $160 million in research, development, test and evaluation funds across fiscal years 2022 and 2023 to support the CPS hypersonic weapon system's incorporation into DDG 1000 class ships. According to the program, it continued engineering design planning to support CPS integration initiated last year. This includes plans to replace the ship's advanced gun system with the CPS hypersonic weapon. The Navy plans to install the hypersonic weapon system on the DDG 1000 during a maintenance period in fiscal year 2024. According to the program, the start of the maintenance period and hypersonic weapon system installation on DDG 1000 will not be affected if operational testing—now scheduled to take place immediately prior to the maintenance period—is not completed as planned. The program stated that, in the event that operational testing is delayed until a date during DDG 1000's scheduled maintenance period, the DDG 1001 would be used for the testing instead.

However, the CPS program office noted that significant scope and challenges associated with the first-time integration of CPS may present risks to achieving DDG 1000's installation schedule. In reviewing CPS program office information on critical technologies, we found that significant work remains for the program to demonstrate technology maturity. DDG 1000 program officials stated that they are closely monitoring the delivery of CPS hypersonic weapon missile tubes and both program offices are working to mitigate any risks to ensure the timely integration of CPS into *Zumwalt* class ships. However, if the hypersonic weapon is not ready for integration on the DDG 1000 at the time of the aforementioned maintenance period, the Navy may have to extend the duration of the planned maintenance period or wait for the next scheduled period to incorporate the system on the ship.

Program Office Comments

We provided a draft of this assessment for program office review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that it is making significant progress in construction, testing, activation, and sustainment of the *Zumwalt* class ships. It noted that DDG 1000 completed radar signature and anti-air warfare testing as well as a special trial conducted by the Navy Board of Inspection and Survey. It added that the DDG 1000 participated in operations from August 2022 to November 2022. For DDG 1001, the program office stated that the ship participated in aviation and survivability test events and fleet exercises. Further, the program office noted that DDG 1002 is currently undergoing combat systems installation and activation at Huntington Ingalls Industries' Pascagoula, MS shipyard. According to the program office, the *Zumwalt* class is on track to be the first platform to field a long-range precision hypersonic capability by integrating the CPS weapon system.

MDAP Lead Component: Navy

Common Name: IRST

Source: U. S. Navy. | GAO-23-106059

F/A-18E/F Infrared Search and Track (IRST)

The Navy is integrating new and existing infrared search and track sensors onto the F/A-18E/F fuel tank. The sensors are intended to enable F/A-18s to detect and track objects from a distance and in environments where radar is ineffective. The Navy is acquiring IRST with an evolutionary acquisition approach, including two system configurations (referred to as blocks). Block I integrates an existing IRST system onto the F/A-18 fuel tank. Block II, which we assessed, develops an improved sensor, upgraded processor, and additional software.

CONCEPT
- **10/07** Program start

SYSTEM DEVELOPMENT
- **6/11** Development start
- **9/12** Critical design review

PRODUCTION
- **3/15** Low-rate decision (Block I)
- **8/18** Block II initiation
- **12/18** Low-rate decision (Block II)
- **1/23** GAO review
- **4/24** Start operational test
- **Future event** Initial capability; the Navy deemed the date as not suitable for public release

Program Performance fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions: Development cost	Procurement cost	Total	Unit Cost dollars in millions	Quantities number	Cycle time in months
First Full Estimate (2/2017)	$1,005	$1,513	$2,518	$14.07	179	123
Reported in 2022[a] (9/2020)	$1,052	$1,492	$2,544	$14.71	173	TBD
Current Estimate (12/2021)	$1,086	$1,613	$2,699	$15.60	173	158
Percent change since reported in 2022[a]			+6 %	+6 %	+0 %	N/A %

Total quantities comprise three development quantities and 170 procurement quantities. The program did not report a planned initial capability date last year and, as a result, the cycle time in 2022 could not be calculated.

[a] GAO-22-105230

Software Development as of January 2023

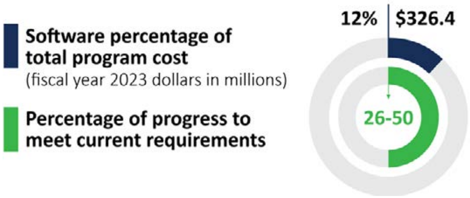
Approach: Agile

Frequency of end user evaluation (months)

Other frequency (see notes)

Less than 1	1-3	**4-6**	7-9	10-12	13 or more

Frequency of testing and feedback (months)



The program reported that aircrews evaluate and provide feedback on software during flight tests. The program plans to conduct seven flight tests from March 2023 to December 2023.

Program Essentials

Prime contractor: Boeing

Contract type: CPIF (development), FPI (procurement)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	○	○
Test a production-representative prototype in its intended environment	○	●

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

IRST Block II did not have a separate development start date from Block I; therefore, we assessed Block II's critical technology based on its technology readiness level at the time Block I development started.

IRST Program

Technology Maturity, Design Stability, and Production Readiness

IRST has yet to mature its manufacturing processes more than 4 years after starting production, consistent with our assessment last year. As a result, production quality issues continue to delay developmental and operational testing as well as full-rate production. The program has, however, matured its one critical technology and has a stable design.

IRST officials said that the program experienced schedule delays in the last year due to production quality issues on parts critical to delivering IRST capability. These officials said that between 20 and 30 percent of the manufactured components failed to meet performance specifications due to microelectronics issues—a problem that has persisted since last year's review. The program continues to work with the subcontractor—such as by holding biweekly update meetings—in an effort to improve manufacturing efficiency to support the planned rate of production.

As a result of these quality issues, the program accepted delivery of the first Block II production representative articles—called infrared optimized configuration (IROC) pods—in January 2023, 10 months later than the program anticipated last year. Program officials stated that the program began developmental testing with IROC pods at that time. IRST officials said that they anticipate sufficient quantities of IROC pods will be delivered in time to complete developmental testing and to enable the start of operational testing in two locations in April 2024, 44 months later than planned under the previous baseline schedule.

The ongoing production quality issues and operational testing delays drove a 33-month delay in the planned full-rate production decision baseline date. In an effort to maintain the production line, IRST officials added a seventh low-rate initial production (LRIP) lot, and preliminary plans for an eighth LRIP lot, increasing the number of Block I and II systems acquired during LRIP to 73—about 43 percent of the total quantity. Our prior work shows that programs increase the risk of costly rework when they proceed with production before maturing manufacturing processes.

Software and Cybersecurity

Program officials reported that less than half of the total software development effort had been completed as of August 2022. The program identified the current pace of software development as a significant risk to its planned start of operational testing. The program delivered the first of six major software releases in October 2022, but significant development and testing of functionality, maintenance, and security features remains to be completed.

Program officials said that staffing challenges and delayed hardware deliveries hampered software development. They added that the program accepted delivery of two lab assets in September 2022, enabling key software development. With the first IROC pods delivered, the program has the hardware to complete developmental testing and mature the software to the level that is needed to start operational testing. The program plans to conduct a system cyber survivability and operational resilience test in October 2023.

Other Program Issues

Last year, we reported that the program breached its baseline schedule and completed a risk assessment to inform a revised schedule. The Navy's senior acquisition executive approved the revised baseline in May 2022. While the program pushed out the start of operational testing by 36 months to August 2023 in this revised baseline, IRST officials currently plan to begin that testing in April 2024. They also told us that they were concerned that future software development and flight test delays could further delay testing.

The program also revised its expected costs. Although development costs remained stable, estimated procurement costs rose about 12 percent. According to the program, inflation and global supply chain disruptions drove the increase. The program also estimated a 44 percent decrease in the planned service life of IRST pods, driven by IRST procurement delays and the expected arrival of an F/A-18E/F replacement aircraft in the 2030s. However, the program estimates this decreased service life will only decrease operation and support costs 33 percent because of upfront costs for support equipment, training aids, and initial spare parts.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated as appropriate. The program office reported that 14 compliant fiber optic gyroscopes were delivered and it improved gyroscope manufacturing efficiency. The program office also stated that the software development contractor addressed its staffing issues. The program office added that it has undertaken initiatives that added 45 days of schedule margin prior to operational testing. It also noted that the program adapted its Agile process to support more tests and feedback by using commercial aircraft—leading to significantly reduced time frames for making necessary fixes identified in testing. Further, according to the program office, by combining IRST component orders with Navy and Air National Guard orders, it achieved a 29 percent reduction in unit cost between the fourth and seventh LRIP lots.

MDAP Lead Component: Navy

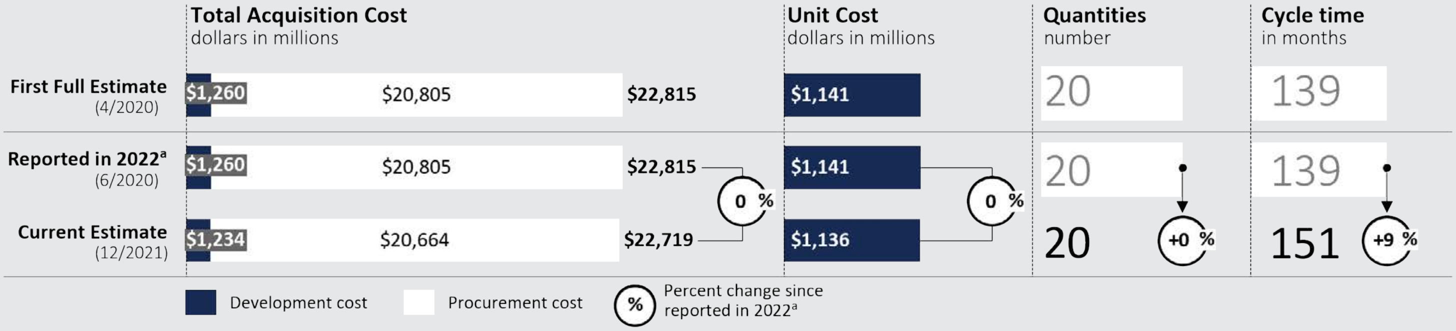
Common Name: FFG 62

FFG 62 *Constellation* Class Frigate (FFG 62)

Source: Fincantieri Marinette Marine. | GAO-23-106059

The Navy's FFG 62 guided missile frigate program is intended to develop and deliver a small surface combatant based on a modified (parent) design of Italian and French Navy frigate variants. The Navy expects the frigates to operate independently or as part of groups to support Navy and joint maritime operations. Planned capabilities include anti-submarine warfare, surface warfare, electronic warfare, and air warfare operations.

Program Performance fiscal year 2023 dollars in millions

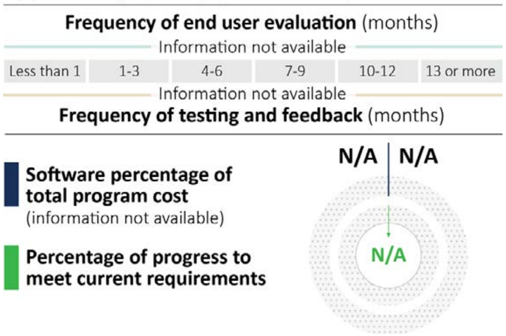


Total quantities comprise zero development quantities and 20 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile, DevOps, and DevSecOps



The program reported end user feedback is planned in the future. According to the program, software costs are not broken out in the cost expenditures, and estimates are provided by the contractor. The program also reported that the contractor will establish a baseline by mid-2023 to better track software development progress.

Program Essentials

Prime contractor: Fincantieri Marinette Marine

Contract type: FPI (detail design and construction)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Detail Design Contract Award	Current Status
Demonstrate all critical technologies in a relevant environment	NA	NA
Demonstrate all critical technologies in a realistic environment	NA	NA
Complete a system-level preliminary design review	●	●
Product design is stable	Fabrication Start	
Complete basic and functional design to include 3D product modeling	○	○

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

We did not assess critical technologies for the FFG 62 because the Navy's technology readiness assessment and independent technical risk assessment for the program found that the ship does not have any.

FFG 62 Program

Technology Maturity, Design Stability, and Production Readiness

The Navy identified no critical technologies for FFG 62. The program uses existing mature systems for its combat and mission systems. However, the Navy expects that integrating its new Enterprise Air Surveillance Radar (EASR) with the latest baseline of the Aegis combat system on FFG 62 may present challenges. To mitigate the risks associated with integration, the Navy procured an EASR emulator to integrate and test with relevant Aegis system equipment in a lab environment. The program office stated it also expects to use lessons learned from planned integration and testing of EASR capabilities on multiple other ship classes—such as the *Ford* class aircraft carriers—before the radar's installation on FFG 62. Once the radar is installed on the lead ship, the program plans to begin testing the radar interfaces and interoperability with other systems in early 2025. Even with these tests, as we previously reported, the program's test plan and 2026 delivery schedule for the lead ship leaves little margin to address any issues identified in onboard integration testing without risk of costly and time-intensive rework.

Since the Navy competitively awarded a detail design and construction contract for the lead ship in April 2020, the FFG 62 program has been working to complete the functional and detail design of the ship. The overall design incorporates significant changes compared with the parent design for FFG 62. As we reported last year, these changes include a lengthened hull, revised bow, and other changes to incorporate combat and mission systems.

Program officials stated that over 90 percent of the FFG 62 functional design and 80 percent of the detail design—which adds 3D modeling to show the configuration of equipment on the ship—were completed when construction began on the lead ship in August 2022. They noted that these results align with the Navy's general expectations for design maturity needed before construction begins. However, beginning construction with an incomplete functional design is inconsistent with leading practices and increases the risk of costly design changes and rework. Such cost risk adds to existing cost growth challenges with the lead ship. Specifically, the program office stated the contract's estimated cost for the lead ship has increased above the contract's ceiling price due to a variety of factors, including defense industrial base issues. March 2023 cost reporting shows the contract's estimated costs for the second and third ships are trending in a similar direction.

Program officials stated that the majority of the remaining functional design work is related to incomplete software. They added that, before the program begins construction for any of the ship's 31 design zones, it will complete the detail design of the zone.

Software and Cybersecurity

Program officials stated that planned approval of the software development plan—which we reported last year was delayed 11 months to February 2022—is now delayed to spring 2023. They noted that a lack of required information on contractor-furnished equipment contributed to this additional delay. They also stated that they are working with the shipbuilder on refining the plan based on Navy feedback.

Program officials said that they plan to inform software development with feedback from formal testing performed by system operators. The program office added that it is using early integration testing efforts and a land-based test site for hull, mechanical, and electrical systems to manage potential software development risks.

The program office stated that it revised FFG 62 test plans to include a combined war game-like exercise in late 2022 that tested cyber capabilities and supported an interoperability assessment for ship systems. The program also scheduled early integration testing events in fiscal years 2024 and 2025 at available land-based test sites. According to the program, these events are intended to assess network cybersecurity controls and reduce shipboard integration risks for government- and contractor-furnished equipment. The program plans to complete a major subsystem cybersecurity assessment in fall 2024 and a full system assessment in 2027 following delivery of the lead ship.

Program Office Comments

We provided a draft of this assessment for program office review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that the critical design review and production readiness review—both conducted in 2022—validated the design and shipyard readiness before moving into the production phase in August 2022 with the start of construction on the first ship. It added that these reviews assessed sufficient design maturity—with an 80 percent overall level of completion—and assessed that the shipyard was ready to begin construction. According to the program office, the second ship of the class will begin construction in mid-2023.

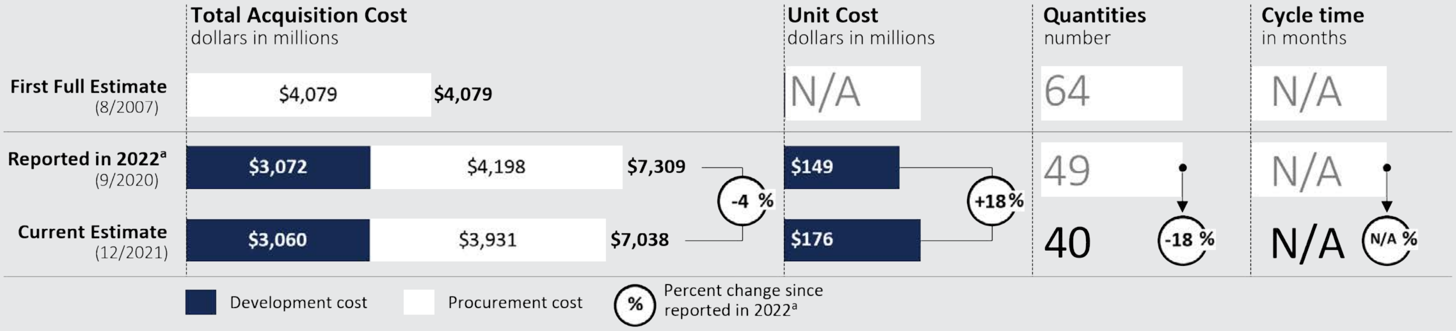
The program office also stated that it is establishing various test sites to demonstrate FFG 62 propulsion systems and to reduce combat system development and schedule risk through systems integration testing. It added that it is implementing a system to enhance ship maintenance and supply planning. The program office also noted its implementation of a collaborative DOD initiative focused on the development and implementation of data analysis and sustainment technology capabilities.

Source: U.S. Navy. | GAO-23-106059

Littoral Combat Ship-Mission Modules (LCS Packages)

The Navy's LCS packages—composed of helicopters and systems such as weapons, boats, sensors, and uncrewed vehicles deployed from LCS—are intended to provide mine countermeasures (MCM), surface warfare (SUW), and antisubmarine warfare (ASW) capabilities. The Navy currently delivers some systems and their support equipment separately when available, with each LCS assigned a semipermanent package. We assessed the status of delivered systems against the threshold requirements for baseline capabilities for the complete package.

Program Performance fiscal year 2023 dollars in millions

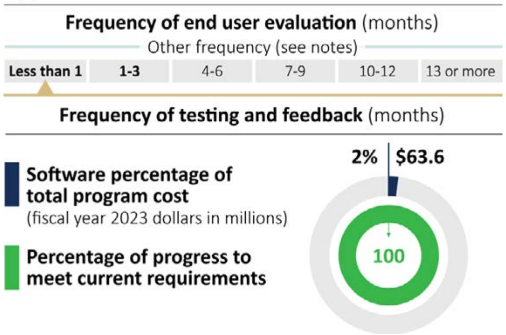


Total quantities comprise five development quantities and 35 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Incremental



The program reported that end users provided feedback during developmental testing and when mission packages were debarked from a ship. Software is in the sustainment phase, with updates every year.

Program Essentials

Prime contractor: Northrop Grumman Systems Corp

Contract type: FFP/CPFF/FPI/CR (procurement)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	○	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	○	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	...	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess LCS package drawings at design review because the program held separate reviews for each LCS package. We also did not assess manufacturing maturity metrics because the program office delivers systems over time and considers a production date as not applicable.

LCS Packages Program

Mine Countermeasures

The Navy completed MCM package initial operational testing in September 2022. The program expects to declare initial operational capability for the MCM package by March 2023, more than 15 years after it took delivery of the first partial MCM package and 11 years later than planned. The Navy plans to conduct MCM cybersecurity testing in fiscal year 2024.

According to the program, the Navy conducted MCM package operational testing before it updated the LCS package test and evaluation master plan. In January 2023, DOD approved an updated master test plan, including changes to the MCM package's requirements. DOD guidance states that the master test plan should capture certain elements to verify technical requirements and to evaluate operational effectiveness, among other things. However, program officials stated that the Navy does not plan to conduct additional MCM package testing. If MCM operational testing did not fully reflect the updated requirements, the package may not perform as expected when fielded.

Recent developmental and operational tests may not have fully demonstrated the MCM package's capabilities. DOD test officials stated that, given the number and complexity of MCM systems operating simultaneously, it is extremely challenging for one LCS crew to continuously conduct MCM operations. Program officials stated that they plan to mitigate this challenge through crew training and additional operational experience. DOD test officials also stated that, given the Navy's compressed test schedule, they could not fully assess developmental test performance of the remote minehunting module (RMH)—which detects mines near or on the seabed—to inform MCM package operational testing. As a result, if the Navy or DOD identify residual performance concerns, the MCM package may enter operations without planned capabilities.

Further, according to the program, 2022 shallow and deep-water testing for the Knifefish Unmanned Undersea Vehicle—an MCM system intended to detect mines at or buried under the ocean floor—did not occur in a suitable environment. Specifically, program officials stated that the seabed in the test area did not meet the test plan's required qualities. An expert group of mine warfare and test officials is working to ensure additional testing occurs where the Knifefish can effectively demonstrate its capabilities. Program officials stated they have yet to confirm a new development schedule and delayed production until at least fiscal year 2024.

Antisubmarine Warfare

In its fiscal year 2023 budget request, the Navy proposed canceling the ASW package. Due to the expected elimination of nine ASW packages, the program's updated cost estimate shows an 18 percent increase in average LCS package unit costs. We previously reported that performance issues with the package's variable depth sonar delayed ASW capability. The program office also stated that it was concerned about LCS's ability to deploy the sonar effectively. The program plans to complete acceptance testing for a previously procured sonar in fiscal year 2023 and then shut down remaining development. Program officials stated that they do not know how the Navy will use the sonar in the future or if it will transition related ASW efforts to another program.

Surface Warfare

Supply chain problems delayed delivery of the SUW's final surface-to-surface mission modules by a year to September 2024. Program officials stated that they successfully completed SUW cybersecurity testing in September 2022, with results expected by February 2023. According to program officials, if they detected a cyber threat, it was not always clear where to improve defenses—whether on the LCS or the SUW package. To help address integration challenges during future software upgrades, the Navy developed teams to conduct limited cyber tests before full operational testing.

Other Program Issues

The Navy plans to retire some LCS and reassign MCM and SUW packages among the remaining LCS in the fleet. Specifically, 24 MCM packages will support 15 MCM-assigned LCS and nine will deploy from shore and other ships. Ten SUW packages will support eight SUW-assigned LCS and two MCM-assigned LCS.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, the SUW package successfully deployed on multiple LCS missions in the past year, including a counter-narcotics mission. It added that it plans to deploy the first production unit of the surface-to-surface missile module in fiscal year 2023.

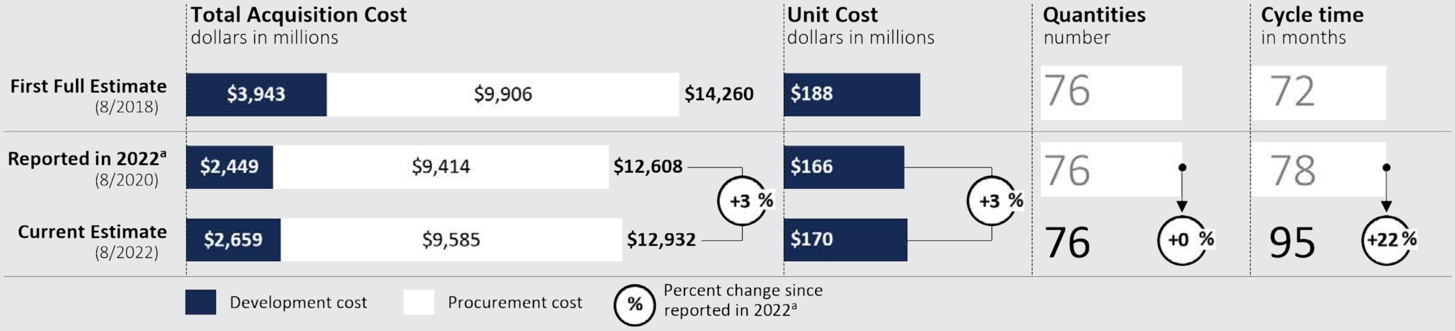
The program stated that the first delivery of the RMH is scheduled in early 2023. According to the program office, as the RMH and other MCM modules complete testing and reach the fleet, the MCM package—which it expects to be the basis of the Navy's MCM capabilities for decades—is expected to enable the Navy to retire its legacy MCM systems by fiscal year 2028. It also noted that it plans to deploy SUW and MCM packages around the world in fiscal year 2023.

Source: U. S. Navy. | GAO-23-106059

MQ-25 Unmanned Aircraft System (MQ-25 Stingray)

The Navy's MQ-25 Stingray is a catapult-launched, uncrewed aircraft system designed to operate from aircraft carriers. The Navy plans for the MQ-25 to provide a refueling capability for the carrier air wing. The MQ-25 is expected to provide the intelligence, surveillance, and reconnaissance capabilities needed to identify and report on surface targets. The system is comprised of an aircraft segment, a control station segment, and a carrier modification segment. We evaluated the aircraft segment and related control station segment.

Program Performance fiscal year 2023 dollars in millions



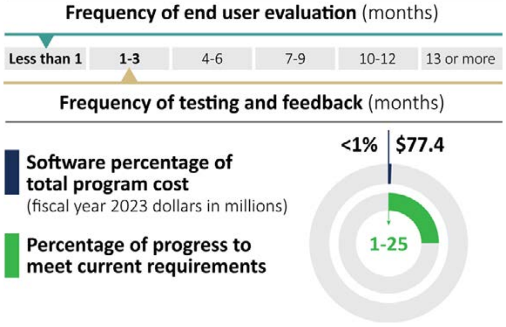
	Total Acquisition Cost (dollars in millions): Development cost	Procurement cost	Total	Unit Cost (dollars in millions)	Quantities (number)	Cycle time (in months)
First Full Estimate (8/2018)	$3,943	$9,906	$14,260	$188	76	72
Reported in 2022[a] (8/2020)	$2,449	$9,414	$12,608	$166	76	78
Current Estimate (8/2022)	$2,659	$9,585	$12,932	$170	76	95
Percent change since reported in 2022[a]			+3 %	+3 %	+0 %	+22 %

Total quantities comprise seven development quantities and 69 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile, Waterfall, and Incremental



Program Essentials

Prime contractor: Boeing

Contract type: FPI (development)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	○	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	●	●
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

While the Navy identified no critical technologies for MQ-25, the program relies on two critical technologies being developed under another program. Our scores for technology maturity reflect these two technologies. We did not assess MQ-25 manufacturing process maturity because the system has yet to reach production.

MQ-25 Stingray Program

Technology Maturity and Design Stability

As we reported last year, MQ-25 Stingray's critical technologies are fully mature, and the program reported its design is stable. However, there is the potential for future design changes based on recent testing. Specifically, the program identified issues during September 2021 system-level integrated prototype flight testing that may require design changes. For example, program officials reported that they are considering several options to address issues with the engine inlet's shape that could lead to engine damage during flight.

Any design changes that would need to be retrofitted into production representative aircraft and low-rate production aircraft could potentially cause delays and cost increases. As part of the fiscal year 2023 Presidential Budget Request, the Navy requested funding for engineering change orders to support potential design changes.

Production Readiness

Since our last assessment, the contractor delayed the delivery of the seven test aircraft, including the first production representative aircraft, from third quarter fiscal year 2022 to first quarter fiscal year 2024. According to program officials, these delays stem from postponed supplier deliveries, as well as quality issues, such as improperly applied coating to parts. According to the program officials, this issue affects entire aircraft sections. Despite these delays, the Navy plans to award the low-rate initial production contract to Boeing on a sole-source basis in February 2023.

As a result of these delays, Boeing will not demonstrate critical manufacturing processes on the production line using a production-representative aircraft prior to production start. According to program officials, to mitigate this risk, the program has contracted with Boeing to obtain manufacturing readiness level data, a risk and readiness assessment, and a risk mitigation plan in January 2023.

To mitigate the risk of further delays in the manufacturing and delivery of aircraft, Boeing increased supplier surveillance, according to the program.

Software and Cybersecurity

The program reported lab resources, key software personnel, and the lack of detailed requirements contributed to software development risk and delivery delays. To date, the program has yet to receive formal software deliveries to support developmental and operational testing. However, Boeing provided engineering releases to support software integration between the aircraft and ground control station and to assess software development maturity.

Despite the delays, program officials reported that they are on track to complete software integration by September 2025, when the program plans to achieve initial operational capability. Program officials stated that they identified a root cause of the software delays and subsequently established rigorous reviews and better defined the technical and software development baselines.

Other Program Issues

The program stated that the test aircraft delivery is critical to achieving initial operational capability, currently planned for September 2025. This date reflects approximately a 7-month delay since our last assessment, due to manufacturing and delivery delays of the test aircraft. The program told us that there is a risk of further delays to initial operational capability and they are working with Boeing to mitigate it. For example, Boeing is increasing manufacturing production staff to three full shifts and has instituted daily build sequencing meetings to prevent further manufacturing delays.

The program also reported seven ground control stations, including embarkable stations that can be transferred from ship to ship, were delivered on time. The delivery of the embarkable station allows the program to ensure it always has at least one station for a carrier available for flight testing requirements, thereby helping to reduce schedule risk.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate.

MDAP Lead Component: Navy

Common Name: MQ-4C Triton

Source: U. S Navy. | GAO-23-106059

MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)

The Navy plans for its MQ-4C uncrewed aircraft system to replace EP-3 aircraft and provide intelligence, surveillance, and reconnaissance as well as data collection and dissemination. Each system includes an air vehicle, communications suites, and mission payload, among other components. The baseline Triton, Integrated Functional Capabilities (IFC)-3, consists of two early operational capability assets. The second version, IFC-4 with signals intelligence, is in development. The Navy plans to develop IFC-4 in progressively capable increments.

CONCEPT

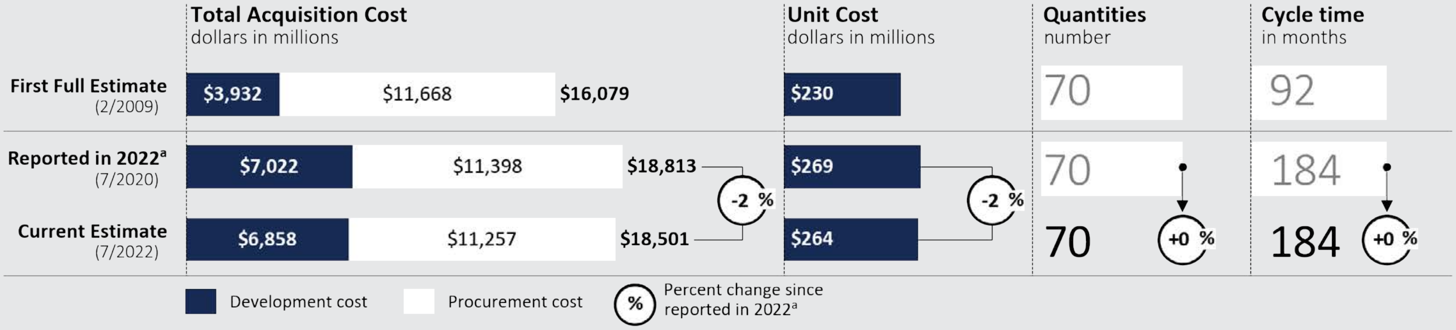
SYSTEM DEVELOPMENT

- **4/08** Program/development start
- **02/11** Critical design review IFC-3

PRODUCTION

- **9/16** Low-rate decision
- **11/17** Critical design review IFC-4
- **1/20** Early capability IFC-3
- **1/23** GAO review/Start operational test
- **4/23** End operational test
- **8/23** Initial capability
- **11/26** Full-rate decision

Program Performance fiscal year 2023 dollars in millions



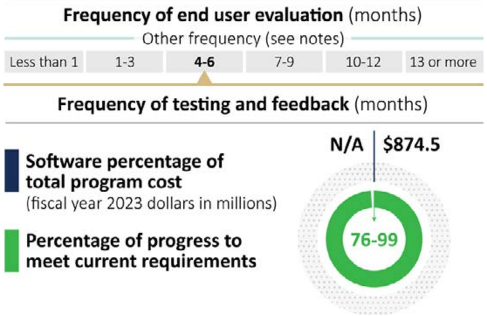
	Total Acquisition Cost dollars in millions				Unit Cost dollars in millions		Quantities number		Cycle time in months	
	Development cost	Procurement cost	Total	Percent change since reported in 2022[a]		Percent change since reported in 2022[a]		Percent change since reported in 2022[a]		Percent change since reported in 2022[a]
First Full Estimate (2/2009)	$3,932	$11,668	$16,079		$230		70		92	
Reported in 2022[a] (7/2020)	$7,022	$11,398	$18,813	-2 %	$269	-2 %	70	+0 %	184	+0 %
Current Estimate (7/2022)	$6,858	$11,257	$18,501		$264		70		184	

Total quantities comprise five development quantities and 65 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile and Incremental



The program reported no formal end user feedback structure is in place, other than defect tracking and change requests as they are discovered. The program stated that software costs were 13 percent of development costs, but did not provide the percentage of total costs.

Program Essentials

Prime contractor: Northrop Grumman

Contract type: Cost-sharing (development), FPI (procurement)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	NA
Demonstrate all critical technologies in a realistic environment	○	NA
Complete a system-level preliminary design review	○	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess MQ-4C critical technologies because the program stated that it no longer has any such technologies. We assessed the design stability and manufacturing maturity of the IFC-4 aircraft because that is the program's current development effort.

MQ-4C Triton Program

Technology Maturity, Design Stability, and Production Readiness

The MQ-4C Triton has no critical technologies. According to the program, the IFC-4 design is stable; however, the Navy continues to rework the MQ-4C cost and schedule baseline due in part to prior development delays. As we reported last year, the program plans to achieve initial operational capability (IOC) in August 2023, with two aircraft versus the previously planned four.

According to the program office, it began IFC-4 initial operational testing and evaluation (IOT&E), using a production representative prototype, in January 2023. However, the program may not be allowing sufficient time to identify design issues ahead of IOC. In a January 2022 annual report, the Director, Operational Test and Evaluation (DOT&E) recommended that the Navy provide more margin in the developmental test schedule to allow for discovery and correction of deficiencies prior to IOT&E.

The program office and DOT&E officials expressed differing views about the extent to which the Navy addressed DOT&E's recommendation. The program said that it extended developmental testing by 3 months to December 2022 to accommodate discovery and correction. DOT&E officials told us that the Navy deferred some integrated testing to maintain schedule. They said that this deferral leaves mission-critical capabilities unevaluated in developmental testing. They noted that the deferred testing will need to be completed during IOT&E—adding time to the test schedule and increasing the risk of discovering significant deficiencies in IOT&E.

DOT&E officials said that they are working with MQ-4C stakeholders to ensure required testing at specific ranges and facilities is completed before Triton's deployment at IOC. Meanwhile, the program continues to track technical risks with potential cost or schedule implications. It stated that it has sufficient time to address issues between the end of IOT&E in April 2023 and the August 2023 IOC. DOT&E officials, in contrast, noted that there is little margin for error or discovery in the test schedule. They said that they do not expect IOT&E to end in April 2023 because of the need to conduct the deferred testing as well as chamber testing, among other reasons.

The program is producing IFC-4 aircraft at the same time it is testing IFC-4. According to the program office, the first IOC aircraft was delivered in October 2022, while the second IOC aircraft is currently on the production line, along with two others. The program expects delivery of these three aircraft during the second and third quarters of fiscal year 2023.

Defense Contract Management Agency officials stated that the first aircraft has been modified to the IOC configuration, including incorporation of software in the version to be delivered to the fleet. They said that the aircraft now in production still require this software modification, which they estimate will take at least a couple of months to complete for each. If system delivery and modification occur as planned, the program would have the second aircraft available by IOC. However, should testing show the need for additional modifications, the concurrency of testing and production carries the possibility of costly rework and schedule delays.

Software and Cybersecurity

Program officials said that they are not tracking software as a program-level risk. The program held cyber risk reduction exercises in 2022 and expects to conduct a major cyber subsystem assessment prior to IOC. It also plans additional vulnerability and penetration, as well as adversarial cyber assessments, within 2 months after IOC.

Other Program Issues

The program office is tracking one major program-level risk for fiscal year 2023—the shortfall of initial spares starting in fiscal year 2024. According to the program, the shortfall will result in reduced readiness for future Triton systems. The Navy reported planning to mitigate the shortfall by reprogramming funding.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office did not have any comments.

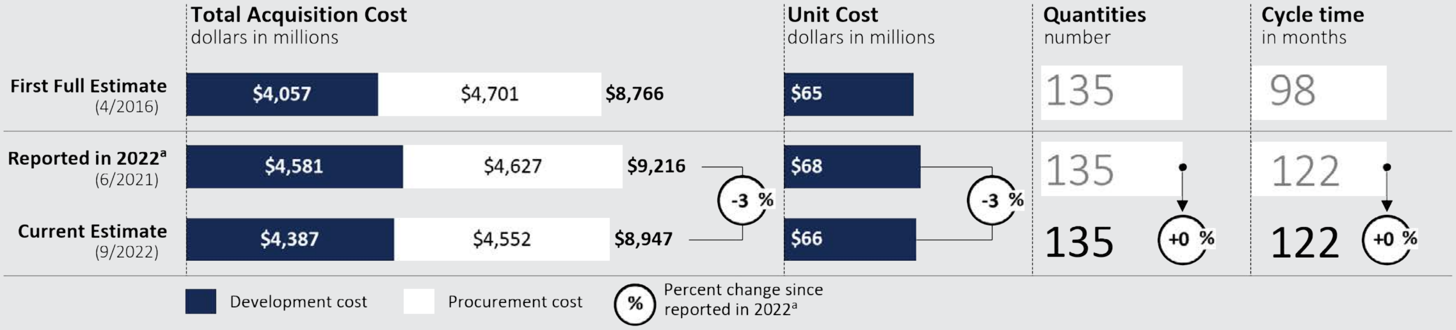
After our cut-off date for new information, the program office stated that it is reducing MQ-4C quantities from 70 to 27 based on direction from the Joint Requirements Oversight Council. It also stated that it is adjusting associated program procurement costs in accordance with the quantity reduction.

Source: U. S. Navy. | GAO-23-106059

Next Generation Jammer Mid-Band (NGJ MB)

The Navy's NGJ MB is an external jamming pod system the Navy plans to integrate on EA-18G Growler aircraft. NGJ MB is expected to augment, then replace, the ALQ-99 jamming system in the mid-band frequency range. The Navy plans for it to provide enhanced airborne electronic attack capabilities to disrupt adversaries' electromagnetic spectrum use for radar detection, among other purposes. The Navy also has a low-band frequency program and will roll out a high-band program at a later date. We assessed the mid-band program.

Program Performance fiscal year 2023 dollars in millions

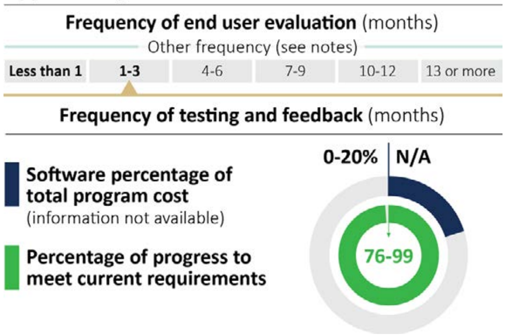


Total quantities comprise six development quantities and 129 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

ªGAO-22-105230

Software Development as of January 2023

Approach: Agile



The program reported that end users provided feedback on software after maintenance and aircrew training. According to the program, software costs were not available because software was not broken out in funding provided to the contractor.

Program Essentials

Prime contractors: Raytheon, Boeing

Contract type: CPIF (development), FPI (low-rate initial production)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

NGJ MB Program

Technology Maturity, Design Stability, and Production Readiness

As we reported last year, the Navy approved the NGJ MB program to start production in June 2021 having met some, but not all, leading practices for production readiness. For example, the Navy did not test a production-representative prototype in an operational environment prior to beginning production, but it has done so in the last year. Design issues, which we previously reported had caused cost increases and delays, have been resolved. But, the program office is still adjusting its test plans to try to minimize any long-term effect. The program also faces ongoing production issues related to low yields, which pose a cost risk for future production contracts and a schedule risk for the program's fielding plans.

The aftereffects of the NGJ MB's design issues continue to be a risk for the program's test plans and its initial fielding goals. The program began flight testing production-representative pods in August 2022—6 months later than the planned date we reported last year. Programs officials stated that several factors caused the delay. They noted that the contractor delivered the test pods later than planned because of COVID-19-related supplier delays and technical challenges associated with redesigning the fan blades in the pod's power generation system. The fan blade redesign, which we covered in our last assessment, delayed the program's ability to demonstrate system performance in the full range of operational flight conditions. This range is referred to as the flight envelope. According to the program office, challenges with expanding the flight envelope to complete necessary tests and the availability of specialized test planes are the biggest risks to fielding an NGJ MB capability by September 2023 as planned.

When the NGJ MB program entered production in June 2021, it had yet to demonstrate production processes were in statistical control—a leading practice. A supplier has since struggled to produce a key component—circuit card assemblies—at the quality and rate needed. Program officials stated that they are implementing measures to improve production process efficiency, such as testing the circuit cards earlier in the process. If the supplier continues to experience low yields, the program's pod deliveries could be delayed and production costs could rise. According to program officials, the first set of production pods are still set to be delivered ahead of schedule in August 2023.

Software and Cybersecurity

The NGJ MB program office continues to identify software development as a risk and is modifying its approach by increasing the frequency and total number of software releases. According to program officials, the NGJ MB prime contractor significantly decreased its number of software engineers to reduce its costs and was only planning on one software release as it moved from development to production. This approach made it difficult for the program to quickly implement software changes to improve system performance and reliability during testing. The program office reported that it plans to direct the prime contractor to increase its staffing levels and the number of software releases in a modification to the NGJ MB development contract, anticipated by spring 2023.

We previously reported that the NGJ MB program office conducted limited cybersecurity testing before production, which increased cost and performance risk. The program office reported it completed additional cybersecurity assessments from March 2022 to July 2022, including tests for identifying vulnerabilities. The program plans to complete other DOD-required cybersecurity tests in April 2023.

Other Program Issues

One of the main cost risks that NGJ MB flight tests identified is the pod's ability to meet reliability requirements. Program officials stated they are taking steps to mitigate this risk, which include increasing the number of flight tests and working with a reliability consultant. If the pods are unable to meet reliability requirements, the Navy may spend more to operate and support the pods than planned.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that the program remains on the schedule approved at the June 2021 production decision. It also identified flight testing and software development as the largest schedule risks to fielding an initial capability on time. According to the program office, the pod hardware design is stable with no major changes anticipated, and production representative pods demonstrated significant performance improvements in flight testing. The program office also stated it was working with circuit card assembly manufacturers to mitigate concerns about quality and low yields.

The program continuously evaluates cybersecurity and does not expect cybersecurity issues to affect the program, according to the program office. The program office also stated that it was on track to correct software deficiencies prior to operational testing, focusing on deficiencies that could improve system reliability.

Finally, the program office noted that training for fleet aircrew and maintenance personnel has started. The program stated that it expects this early fleet involvement will help mitigate risks to operational testing and identify supportability issues.

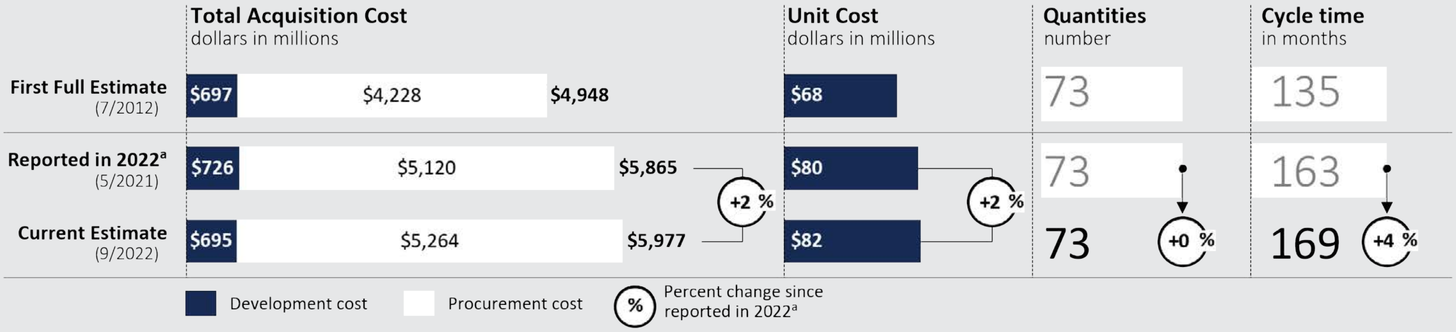
MDAP Lead Component: Navy **Common Name**: SSC

Source: Textron Systems. | GAO-23-106059

Ship to Shore Connector Amphibious Craft (SSC)

The Navy's SSC is an air-cushioned landing craft intended to transport personnel, weapon systems, equipment, and cargo from amphibious vessels to shore. SSC is the replacement for the legacy Landing Craft, Air Cushion (LCAC—a designation that SSCs will share once in service), which is approaching the end of its service life. The SSC is designed to deploy in and from Navy amphibious ships that have well decks, such as the LPD 17 class, and will support operations.

Program Performance fiscal year 2023 dollars in millions

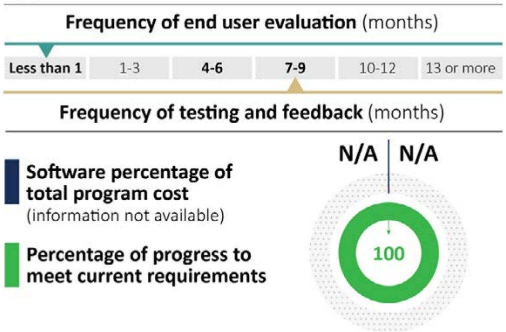


Total quantities comprise one development quantity and 72 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Modified Waterfall



Program officials stated that they do not track software in their cost reporting system. Software development is complete and is currently in the maintenance phase, according to the program.

Program Essentials

Prime contractor: Textron, Inc.

Contract type: FPI (detail design and construction)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	●	●
Complete a system-level preliminary design review	●	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	...	●
Test a production-representative prototype in its intended environment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

Program officials stated that the program demonstrated SSC critical manufacturing processes on a pilot production line but that they did not have information necessary to determine the date the demonstration occurred.

SSC Program

Technology Maturity, Design Stability, and Production Readiness

Since our assessment last year, the program accepted LCAC 104 and continues to plan and conduct testing events to support operational testing and initial operational capability in 2023, according to program officials. LCAC 104 is the program's fourth deployable craft and followed LCACs 101, 102 and 103. In May 2022, the program conducted LCAC 104 acceptance trials. During these trials, the program found three issues that prevented it from immediately accepting the craft:

- a leak in the propeller lubricating oil system,
- abrasions on the craft's bow ramp cables, and
- a failure of the craft's system that de-ices propulsor shrouds, which degrades the craft's mobility capabilities in cold conditions.

These issues were corrected within a few weeks, according to program officials.

Previous LCACs encountered major technical issues, such as propeller blade erosion and air leakage in the craft's cushion vanes. According to program officials, these issues were addressed and did not occur during LCAC 104 acceptance trials.

To date, the program accepted six craft to the fleet, but the craft have yet to be deployed because they are in the final stages of testing. Program officials took delivery of LCAC 106 in November 2022 and LCAC 105 in March 2023. The program expects delivery of additional craft by the end of calendar year 2023.

According to program officials, operational testing and initial operational capability slipped about 6 months since our last assessment. Both are now planned to be completed in calendar year 2023. Program officials noted that craft deliveries slipped, in part, due to effects from the COVID-19 pandemic, which limited the program's ability to conduct post-delivery testing.

According to program officials, prior to initial operational capability, the program plans to conduct further post-delivery testing. Program officials noted that the program also conducted testing of this type with the vehicles they accepted in 2022 during which they loaded an SSC on and off amphibious ships. According to program officials, the program is planning additional testing events for new vehicles in January 2023.

Software and Cybersecurity

There are no particular software risks or challenges to the program at this time, according to the program. Program officials noted that the program is planning to transition its software development approach to an Agile approach by November 2024. Our prior work shows that Agile can help programs mitigate schedule and budget risk.

The program is awaiting the cybersecurity operational test report to determine if it will need funding to address any deficiencies.

Other Program Issues

According to program officials, the program plans to install solutions to the program's top two technical issues—cracking propeller blades and premature gearbox wear—on all new craft during construction. We reported last year that all completed craft were updated with fixes to these issues. Program officials stated that they will continue to monitor the propeller blades and ensure that the program can calculate and validate the service life of the blades.

Program officials also told us that they continue to work with the contractor to identify cost reduction opportunities since our last assessment, but these efforts have yet to yield significant savings.

Program Office Comments

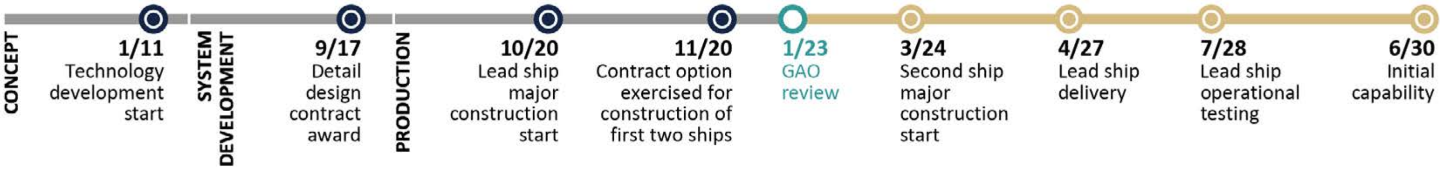
We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, acceptance trials for LCAC 106 resulted in the fewest number of deficiencies to date. The program office also noted that LCACs 107 and 108 have moved into testing. It added that craft under construction show a reduction in overall production labor hours, among other things. In addition, the program office stated that final gearbox design and reinforced blades were installed on all craft and the program is on track to increase delivery to the Navy to four craft per year.

MDAP Lead Component: Navy **Common Name**: SSBN 826

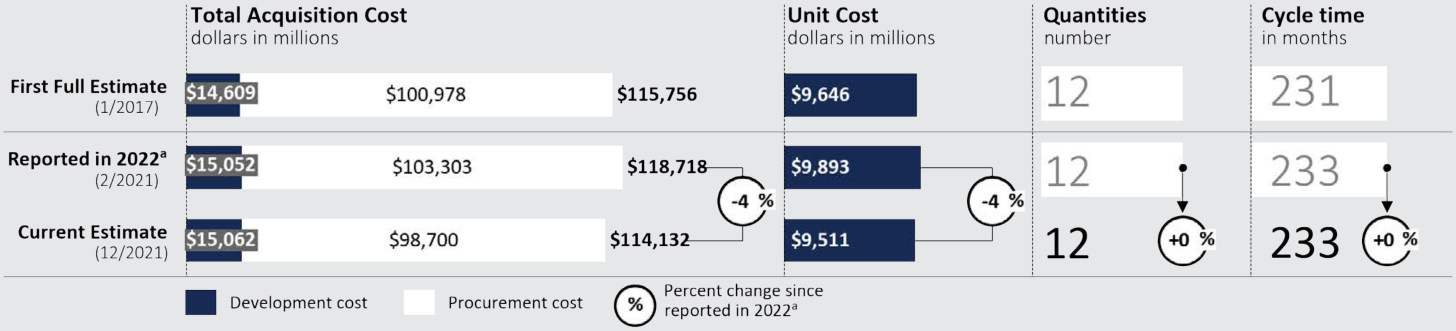
Source: General Dynamics Electric Boat. | GAO-23-106059

SSBN 826 *Columbia* Class Ballistic Missile Submarine (SSBN 826)

The Navy's *Columbia* class (SSBN 826) will replace *Ohio* class ballistic missile submarines, which the Navy plans to retire starting in 2027. The submarine will serve as the sea-based, strategic nuclear deterrent that is expected to remain in service through 2084. General Dynamics Electric Boat is the lead contractor, with Huntington Ingalls Industries Newport News Shipbuilding serving as its major subcontractor. The Navy reported modifying its design contract in December 2022 to include advance construction for follow-on submarines.



Program Performance fiscal year 2023 dollars in millions



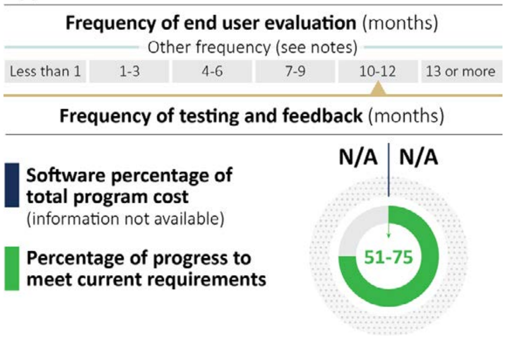
	Development cost	Procurement cost	Total Acquisition Cost dollars in millions	Unit Cost dollars in millions	Quantities number	Cycle time in months
First Full Estimate (1/2017)	$14,609	$100,978	$115,756	$9,646	12	231
Reported in 2022[a] (2/2021)	$15,052	$103,303	$118,718	$9,893	12	233
Current Estimate (12/2021)	$15,062	$98,700	$114,132	$9,511	12	233
Percent change since reported in 2022[a]			-4 %	-4 %	+0 %	+0 %

Total quantities comprise zero development quantities and 12 procurement quantities. The program's procurement cost estimate decreased by 4 percent since last year because the Navy removed supplier development funding from the estimate because related efforts support multiple programs. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Incremental



The program reported that software was developed by the *Virginia* class submarine program. End user feedback is through another Navy program when issues are identified.

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Detail Design Contract Award	Current Status
Demonstrate all critical technologies in a relevant environment	○	●
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	Fabrication Start	
Complete basic and functional design to include 3D product modeling	●	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

The program office completed SSBN 826 *Columbia* class basic and functional design. It is further developing the ship's model, to include detail design and construction planning data.

Program Essentials

Prime contractor: General Dynamics Electric Boat

Contract type: CPIF (development and construction)

SSBN 826 Program

Technology Maturity, Design Stability, and Production Readiness

As we reported last year, the program considers all of SSBN 826's critical technologies mature, though three systems remain below our definition of maturity. We consider technologies mature after successful testing of a prototype near or at the planned operational system configuration in a realistic environment. The program plans to have two of the three remaining technologies reach maturity in fiscal year 2025, but one will remain immature until after lead submarine delivery, planned for April 2027.

The shipbuilder completed basic and functional design before the start of formal construction on the lead ship. However, the program is still at risk of costly and time-consuming design changes if deficiencies emerge during testing or production of its critical technologies. The program also remains behind on producing design products—in particular, work instructions that detail how to build the submarine—because of ongoing challenges using a software-based design tool. These, in turn, contributed to delays in construction of the lead submarine.

As we reported last year, the shipbuilder accelerated its schedule for construction of the lead submarine to reduce the risk of a delivery delay. However, as of September 2022, the shipbuilder was behind this accelerated schedule not only due to design delays, but also because of late delivery of supplier materials and a need for rework due to quality problems.

Program officials stated that the shipbuilder attempted to overcome these delays, in part, by reassigning workers from *Virginia* class submarine construction. This contributed to delays on the *Virginia* class program. Program officials stated that additional workers may need to be reassigned to *Columbia* in the future. The Navy also identified a need for the shipbuilder to improve hiring and training both in the near term and for when the program reaches an annual cadence for follow-on submarine construction. Program officials told us that the shipbuilder plans to continue adding staff to *Columbia* class lead ship construction until it overcomes delays. In September 2022, we reported that the Navy cannot rely on the shipbuilder's schedule for the lead submarine to plan for on-time delivery because it did not substantially meet all of our leading practices for program schedules. Meeting these leading practices would enable the program to determine how schedule risks affect the program's ability to meet key dates, such as delivery.

Software and Cybersecurity

The program office reported no significant updates related to software development or cybersecurity.

Other Program Issues

The program's estimated procurement cost decreased by roughly 4 percent since our last assessment. However, this decrease occurred because of an update to the calculation used for inflation and because the Navy no longer includes supplier development funding in its estimate. The supplier base is among the program's top risks because the program will need quality and timely materials to produce submarines on time. The Navy removed supplier development funding from the cost estimate because it considers these as costs shared with, for example, the *Virginia* class program.

Per the program's updated acquisition strategy, the Navy plans to begin early procurement and construction on one submarine per year from fiscal year 2023 through 2032. The Navy plans for each follow-on submarine to have a progressively shorter construction schedule, based in part on early construction efforts. In order to achieve this schedule goal, the shipbuilder would need to overcome staffing issues and build the submarines in a shorter amount of time than it achieved on any of its recent submarines.

Program Office Comments

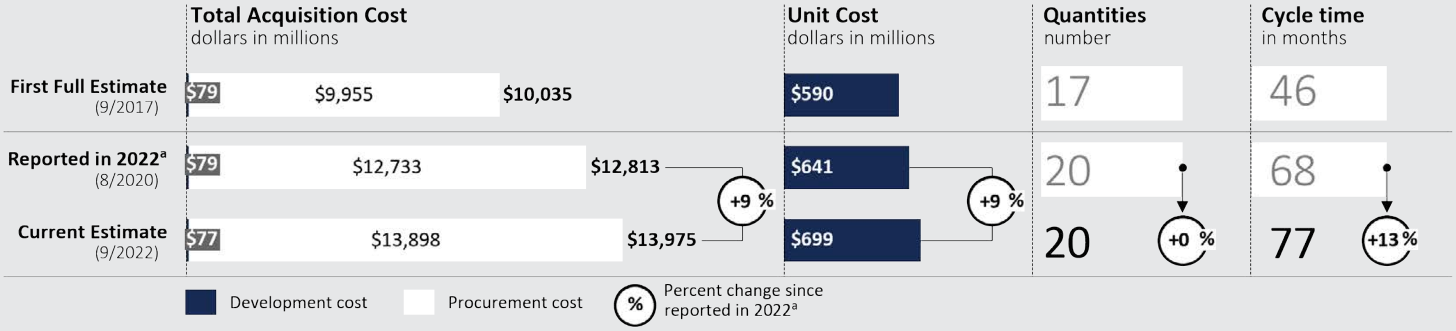
We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that it is positioned to deliver the capabilities needed to meet strategic deterrent requirements on cost and schedule. It also stated that it took actions to reduce risks, such as ensuring stable requirements, executing manufacturing readiness and supplier base efforts, and pursuing cost reduction actions. It added that the program exceeded 83 percent overall design maturity by the start of lead ship construction–higher than achieved for other submarine classes—and it worked through initial design tool issues that delayed design products. Further, it noted that the Navy took actions to address construction performance challenges in 2022. The program office stated that the Navy conducts schedule reviews for this program similar to those conducted for previous submarine classes. It noted that the program continues to comply with all Navy, DOD, and statutory requirements associated with managing critical technologies and engineering integration efforts.

T-AO 205 *John Lewis* Class Fleet Replenishment Oiler (T-AO 205)

Source: General Dynamics NASSCO. | GAO-23-106059

T-AO 205 will replace the Navy's 15 existing *Henry J. Kaiser* Class Fleet Oilers (T-AO 187), which are nearing the end of their service lives. The primary mission of the oiler is to replenish bulk petroleum products, dry stores and packaged cargo, fleet freight, mail, and personnel to other vessels at sea. The Navy is in the process of determining how many ships it plans to buy per year to reach the total inventory objective.

Program Performance fiscal year 2023 dollars in millions



	Total Acquisition Cost dollars in millions				Unit Cost dollars in millions		Quantities number		Cycle time in months	
First Full Estimate (9/2017)	$79	$9,955	$10,035		$590		17		46	
Reported in 2022[a] (8/2020)	$79	$12,733	$12,813		$641		20		68	
Current Estimate (9/2022)	$77	$13,898	$13,975	+9 %	$699	+9 %	20	+0 %	77	+13 %

Total quantities comprise zero development quantities and 20 procurement quantities.
[a] GAO-22-105230

Software Development as of January 2023

Approach: Information not available

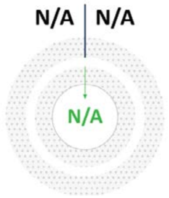
Frequency of end user evaluation (months)

Information not available

Less than 1	1-3	4-6	7-9	10-12	13 or more

Information not available

Frequency of testing and feedback (months)



Software percentage of total program cost (information not available)

Percentage of progress to meet current requirements (information not available)

The program reported it is using off-the-shelf software systems and does not collect information on software delivery time frames or cost.

Program Essentials

Prime contractor: General Dynamics National Steel and Shipbuilding Company

Contract type: FPI (detail design and construction)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Detail Design Contract Award	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	●	●
Complete a system-level preliminary design review	○	●
Product design is stable	Fabrication Start	
Complete basic and functional design to include 3D product modeling	●	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

T-AO 205 Program

Technology Maturity, Design Stability, and Production Readiness

The Navy accepted delivery of the lead ship in July 2022. The shipbuilder originally planned to deliver the lead ship in November 2020 but experienced testing and fabrication challenges that delayed the ship by 20 months. The lead ship also reached its contract ceiling price of $715.8 million—$119.3 million over the contract target cost.

Planned delivery dates for the next five ships are also delayed between 22 and 29 months. Shipyard workforce issues are at the center of these delays. According to the program office, the shipyard reported recruitment and retention challenges, exacerbated by an increase in retirements. The program office stated that this resulted in a less-experienced labor pool that reduced the anticipated efficiencies for the program.

The shipyard workforce shortages exacerbated the Navy's ability to manage supply challenges. For example, Navy officials stated that the program had delays with the ship's main reduction gear—a critical propulsion component comprised of gears that harness the power generated by the engines to move the shaft and propeller. Main reduction gears are so critical to shipbuilding that shipbuilders often request receipt of these components by a specific date before proceeding with the next stage of production.

According to the Navy and a subcontractor, the manufacturer of the ships' main reduction gear moved aspects of its operations from Europe to the United States to meet growing requirements for U.S.-made content for Navy ships. As a result, the delivery of the main reduction gears was delayed. Program officials stated that to accommodate the delays for the fourth ship, T-AO 208, the shipyard adjusted the order in which it built the ship to prevent the shipyard from having to cut into the side of the hull to install the main reduction gear. However, the main reduction gears for T-AO 208 were damaged during production, according to program officials. The officials said that the gears' delivery is expected to be consequently delayed by 12 months, and the shipyard will have to cut into the hull to install them.

Software and Cybersecurity

Program officials stated that the Navy modified the T-AO contract in August 2022 to include new cybersecurity clauses prescribed by DOD regulations last year.

Other Program Issues

For the first four ships, the costs for which the Navy is responsible increased, thus far, by a total of $273.8 million. DOD reported that approximately $164.5 million is the government's share of contract overruns and approximately $78.2 million is a result of material inflation. The remaining $31.1 million is due to other reasons, including increases to the purchase price of government-owned equipment.

As we reported last year, the program was working on reducing costs through a working group. To date, the program has identified $73 million in cost avoidance for the first through sixth ships and more than $23 million for each subsequent ship. As an example, the group identified that the size of the ship's deckhouse could be reduced, thereby reducing the cost of each ship by $7.2 million starting with the fourth ship.

In August 2022, the Navy issued a sole source contract modification for ships 7 and 8. The target price totaled $1.37 billion ($680 million for ship 7 and $690 million for ship 8), about $40 million more than initially planned for each ship. The contract includes an option for the ninth ship in 2023 with a target price of $715 million. Program officials told us that inflation mainly drove these cost increases. In addition, officials stated that they are still developing the acquisition strategy for the follow-on contract for the final 11 ships, which the Navy plans to award in 2024.

Since our last review, the Navy delayed several key program events by 4 to 7 months. According to program officials, these delays were caused by the lead ship delay. As a result, the planned date for the start of operational testing was delayed from October 2022 to February 2023. The planned dates for initial operational capability and full-rate production were also delayed.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program stated that the lead ship of the class, T-AO 205, is undergoing post-delivery testing and trials with several successful demonstrations to date. It also stated that, for follow-on ships, it continues to utilize shipbuilding best practices and leverage commercial vessel design practices to minimize risks, reduce ship costs, and drive affordability into the design. According to the program office, beyond cost reductions identified to date, the Navy and the shipbuilder continue to seek out opportunities to reduce costs, while balancing life-cycle costs and fleet requirements. In addition, the program noted that, to improve schedules, the Navy is working with the shipbuilder to better understand and address post-pandemic related effects on the shipbuilder's workforce and supply chain, including material and labor related inflation costs.

Source: Huntington Ingalls Industries. | GAO-23-106059

DDG 51 *Arleigh Burke* Class Destroyer, Flight III

The Navy's DDG 51 Flight III destroyer is planned to be a multimission ship designed to operate against air, surface, and underwater threats. Compared with existing Flight IIA ships of the same class, the Navy expects new Flight III ships to provide the fleet with increased ballistic missile and air defense capabilities. Flight III's changes include replacing the current SPY-1D(V) radar with the Air and Missile Defense Radar program's AN/SPY-6(V)1 radar and upgrading the destroyer's Aegis combat system.

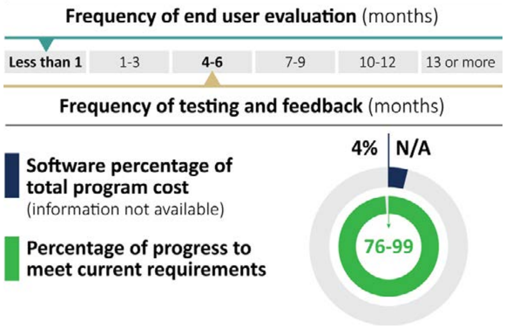
Estimated Cost and Quantities

fiscal year 2023 dollars in millions

Cost reflects the 24 Flight III ships bought and planned from fisca years 2017–2027. The Navy plans to procure additional ships during this period and is authorized to enter into one or more multiyear contracts to procure up to 15 additional ships starting in fiscal year 2023.

Software Development as of January 2023

Approach: Agile, Incremental, and DevSecOps



Program Essentials

Prime contractors: General Dynamics-Bath Iron Works; Huntington Ingalls Industries

Contract type: FPI (construction)

Current Status

The program reported that the first eight DDG 51 Flight III ships are under construction, with an additional six under contract, and the Navy plans to deliver the lead ship—DDG 125—in June 2023. Program officials noted that there is a risk to the delivery schedule due to first-time integration of the new electrical power system and combat system. They said that they plan to use recently completed sea trials and further testing to mitigate these risks.

The program pushed back the planned start of sea trials from September 2022 to December 2022 due to these first-time integration challenges and continues to assess cost and schedule effects, according to program officials. We previously reported on risks to program cost and schedule due to power system updates after tests on Flight IIA ships showed the initial system did not meet requirements. The program mitigated this risk with a replacement power system on Flight IIA ships, according to program officials.

The program experienced additional cost growth for the first two Flight III ships over the past year and reported receiving $168 million in fiscal year 2023 to cover the government's portion of cost overruns for certain contracts. Program officials told us that the cost growth is primarily due to first time build challenges and is capped by the price ceiling on the contract.

The Navy purchased a total of 14 Flight III ships thus far and received authority to enter into one or more multiyear contracts to procure up to 15 ships starting in fiscal year 2023, according to program officials. Competition for these procurement contracts is ongoing. This plan aligns with the Navy's current long-range planning for force structure requirements.

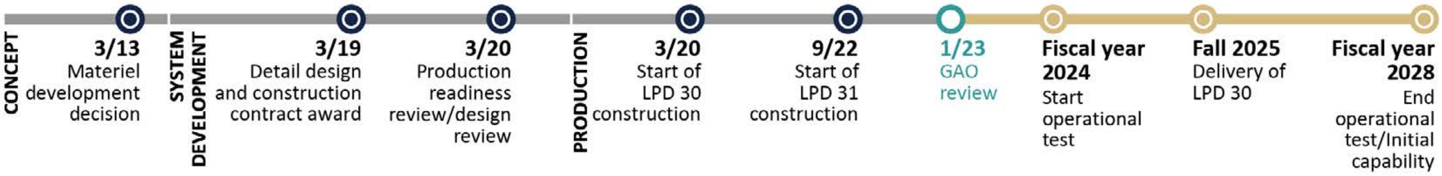
Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program, the *Arleigh Burke* class destroyer is one of the Navy's longest-running production lines, which delivered 72 ships. Production continues with a number of ships under contract, in various stages of production, and in preconstruction activities, according to the program. It added that, in addition to ongoing progress to deliver the final few Flight IIA destroyers, the program continues toward Flight III delivery, test and evaluation, and deployment.

Source: Huntington Ingalls, Ingalls Shipbuilding. | GAO-23-106059

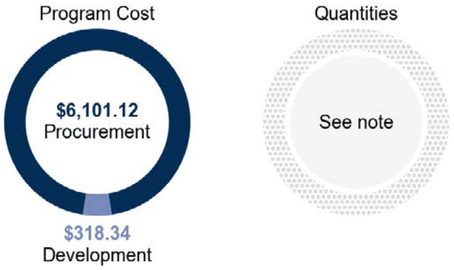
LPD 17 *San Antonio* Class Amphibious Transport Dock, Flight II (LPD 17 Flight II)

The Navy's LPD 17 Flight II will replace retiring transport dock ships. The Navy intends to use LPD 17 Flight II ships to transport Marines and equipment to support expeditionary operations ashore as well as noncombat operations for storage and transfer of people and supplies. The Flight II ships include a larger hull than the ships they replace, and the Navy expects them to provide additional capabilities. The Navy plans to acquire 13 Flight II ships, beginning with LPD 30.



Estimated Cost and Quantities

fiscal year 2023 dollars in millions



Costs represent fiscal years 2010–2027 and funding for 3 ships, while the program plans to procure 13 Flight II ships.

Software Development as of January 2023

Approach: Information not available

Frequency of end user evaluation (months)

Information not available

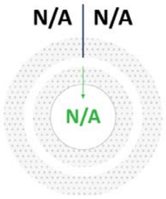
Less than 1	1-3	4-6	7-9	10-12	13 or more

Information not available

Frequency of testing and feedback (months)

Software percentage of total program cost (information not available)

Percentage of progress to meet current requirements (information not available)



The program reported that it does not track these metrics because software is not a significant work element.

Program Essentials

Prime contractor: Huntington Ingalls Industries

Contract type: FPI (detail design and construction)

Current Status

Construction of LPD 17 Flight II ships is underway. The first ship in Flight II, LPD 30, is nearly 30 percent complete. The Navy now expects delivery of LPD 30 in the fall of 2025, a delay of approximately 6 months from our last assessment. In addition, the Navy began construction of LPD 31 in September 2022—a delay of 5 months.

The program continues to experience schedule delays due to labor shortages resulting from COVID-19. For example, the shipbuilder reassigned workers from LPD 30 to mitigate ongoing labor shortages on Flight I ships. As of September 2022, the LPD 30 workforce was at approximately 80 percent of planned levels. Program officials said that they expect to see workers reassigned to LPD 30 and 31 as work on the final Flight I ship, LPD 29, is completed. The Navy has yet to realize any cost increases from the delays.

As we reported last year, testing plans for Flight II are under revision, with a final test and evaluation master plan expected in early 2023. The Navy and the test authority agreed on a testing approach but still need to develop a full test strategy. Specific areas under discussion include the need for a Full Ship Shock Trial and testing the new mast and radar—introduced on the final Flight I ships and to be included in Flight II ships.

The program office and test authority characterized the design changes between Flight I and Flight II—including the new mast and radar—as iterative technology enhancements, not an introduction of new critical technologies. While they may not consider these systems new critical technologies, there is risk with this first time integration of these systems on LPD 17 class ships.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, they are in the process of testing and delivering LPD 17 class ships. The program also stated that it laid the keel for LPD 30, started fabrication of LPD 31, and placed LPD 32 under contract to procure long lead time materials.

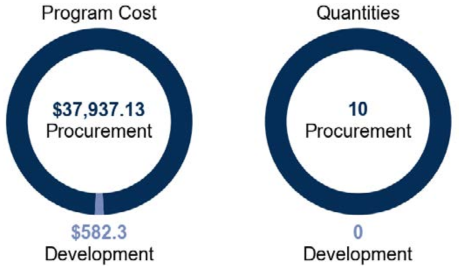
SSN 774 *Virginia* Class Submarine (VCS) Block V

The Navy's VCS is a class of nuclear-powered, attack submarines capable of performing multiple missions. The most recent version, called Block V, includes enhanced undersea acoustic improvements for all 10 submarines. The Navy also plans for the last nine submarines to increase capacity for Tomahawk cruise missiles by inserting the Virginia Payload Module, a new midbody section that makes them 30 percent larger.


Source: U.S. Navy photo courtesy of Huntington Ingalls Industries. | GAO-23-106059

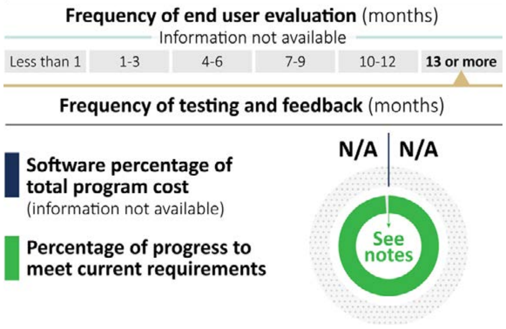
Estimated Cost and Quantities

fiscal year 2023 dollars in millions



Software Development as of January 2023

Approach: Waterfall



The program reported that all software has been developed and tested, and costs are not tracked separately. According to the program, software is modified as necessary to accommodate additional payload and revised ship characteristics.

Program Essentials

Prime contractor: General Dynamics Electric Boat

Contract type: FPI (procurement)

Current Status

Performance on VCS construction continues to degrade. The program now estimates construction of each Block V submarine will take an average of over 2 years longer than reported last year. The delays are due to problems meeting original staffing and work efficiency estimates.

Due to delays, program officials are developing a new, more realistic schedule for Block V. They said that they expect to complete this process in early 2023. Program officials stated that the shipbuilders do not have sufficient workforce to complete VCS while also constructing the *Columbia* class submarines and overhauling several *Los Angeles* class submarines. They noted VCS construction is about 25 percent below staffing needs as of September 2022.

In an effort to improve VCS construction, shipbuilders are outsourcing certain work that they would have otherwise completed in their shipyards, noted program officials. The officials told us that the shipbuilders implemented these changes due to shipbuilders' workforce constraints and the limited physical capacity of some facilities.

The same factors that delayed the schedule also contributed to cost increases. While the fixed price incentive contract set target and ceiling prices for each submarine, program officials reported that the VCS shipbuilders have not met the work efficiency and material cost estimates that informed the target pricing. Consequently, the Navy plans to request more funds to complete Block V, as its prior budget requests covered the target prices, but not up to the ceiling prices.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, it remains challenged to meet a two ship per year construction rate. It also stated that the Navy is working with shipbuilders and investing in the submarine industrial base to address challenges, such as supply chain issues and workforce skills gaps, and to improve production capacity through strategic outsourcing

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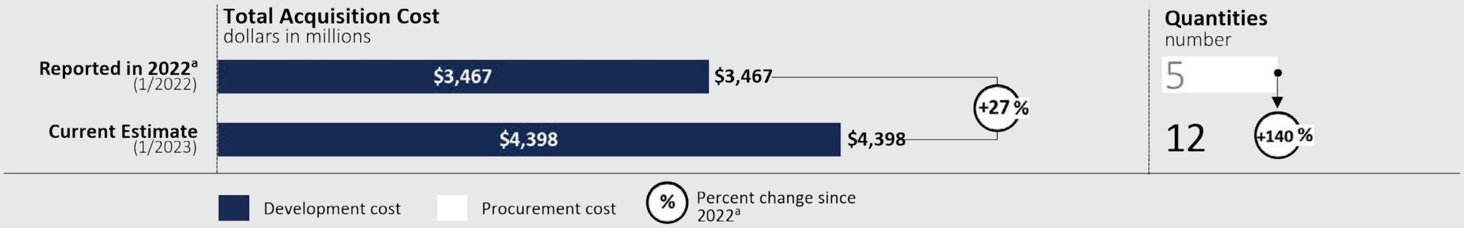
Source: U. S. Navy. | GAO-23-106059

Conventional Prompt Strike (CPS)

The Navy's CPS program aims to develop an intermediate-range, hypersonic missile in phases. We assessed phase one—an MTA rapid prototyping effort. That effort plans to conduct a cold-gas launch—in which the booster ignites after the missile ejects—by 2024. The second phase—a planned MTA rapid fielding effort—aims to field the missile on a surface ship by 2025. The third phase—a planned major defense acquisition program—aims to field the missile on *Virginia* class submarines by 2030. CPS partners with the Army's Long Range Hypersonic Weapon program.

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



The CPS program is acquiring 12 test assets to support the rapid prototyping phase. Four are complete missiles to support flight tests. The remaining eight include other types of test vehicles or missile simulators.

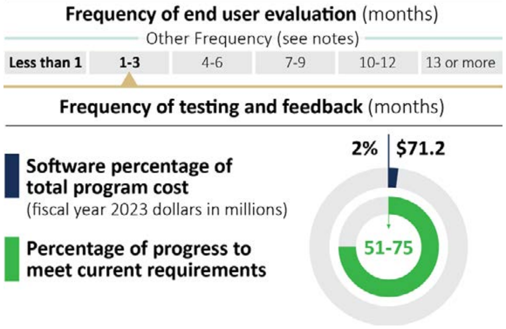
ªGAO-22-105230

Program Background and Transition Plan

The Navy initiated the CPS MTA rapid prototyping effort in 2019, based on a 2009 technology development effort. Since our last assessment, CPS extended the end of its rapid prototyping effort by 6 months to include an additional test that was originally planned for the follow-on rapid fielding effort. CPS plans to complete its rapid prototyping effort within the 5-year MTA time frame established in DOD policy in 2024 by conducting a cold-launch test of a representative missile. The Navy then plans to transition to a rapid fielding effort for the second phase.

Software Development as of January 2023

Approach: Agile, Waterfall, Incremental, and DevSecOps



The program reported end user feedback occurs once or twice per year through operational exercises.

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	○	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	○

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

Program Essentials

Prime contractor: Lockheed Martin

Contract type: CPIF

CPS Program

Updates to Program Performance and Business Case

Since our last assessment, the Navy revised multiple elements of the CPS business case to reflect a restructuring that occurred after the program received less funding than requested in fiscal year 2021. In July 2022, CPS updated its requirements document to add *Zumwalt* class destroyers as ships that would fire the missile and remove nuclear-powered *Ohio* class guided missile submarines, among other changes. CPS also extended its rapid prototyping effort by 6 months to include an additional test originally planned for the rapid fielding effort. According to the program, the test will include a missile that is more representative of the ones the Navy plans to field. The program was also updating its acquisition strategy and cost estimate as of December 2022.

One of the primary ongoing schedule risks for the rapid prototyping effort is the concurrency between designing, building, and testing the system, according to program officials. For example, as the program discovered issues in testing last year, it made design changes that delayed subsequent tests. In June 2022, the program conducted a partially successful flight test of a complete missile. The two-stage booster worked as expected, but the glide body did not separate. Program officials said that separation events—a clean separation of the glide body from the second stage booster and having the glide body continue on its flight—as the main technical risk identified in testing. The program implemented a design change to address the issue and plans to conduct its next flight test of the complete missile by the second quarter of fiscal year 2023–3 to 5 months later than planned.

The CPS program's estimated costs increased by approximately 27 percent since last year. The program attributed the cost increase, in part, to the addition of seven test assets and a test event to the rapid prototyping effort. Program officials also stated that building the missile for the June 2022 test cost more and took the contractor longer than anticipated. According to program officials, contract costs for the rapid prototyping effort continued to grow, albeit slower than in the past.

The CPS program also reported that industrial base issues, such as gaps in the supply chain, continued to affect its cost and schedule. Officials stated that these supply chain risks include having a single source for rocket motors and missile guidance components and material shortages. To address these risks, the program identified the need to make targeted investments to improve the supplier base in fiscal year 2023.

Software and Cybersecurity

According to program officials, the concurrency between the development and production of prototype missiles is also a large contributor to CPS software development risk. Hardware design changes led to additional software development and made software validation more challenging. The program also continued to report difficulty hiring and retaining sufficient staff. Program officials stated that they were able to mitigate staffing-related schedule risks, in part, by leveraging a U.S. government lab.

Key Product Development Principles

The CPS program employs an iterative development process, which it refers to as technology insertion, an approach in line with aspects of our leading principles for product development. CPS established its process to strategically prioritize capabilities. Program officials stated that technology insertions are intended to incorporate new capabilities every 2 years and are informed by factors such as technology maturity and affordability.

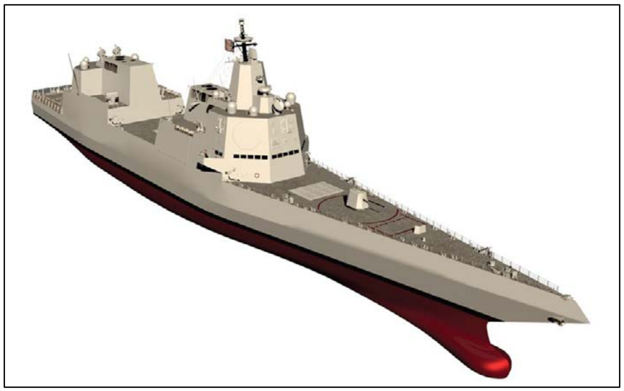
We have ongoing work to define metrics associated with these leading principles, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

Several issues could affect the planned fielding dates in phases two and three of the CPS program. According to program officials, the amount of design and launch system installation work needed to field CPS on the *Zumwalt* class destroyers is a schedule risk for phase two. In addition, as a result of delivery delays for the newest Block V *Virginia* class submarines, CPS will not be fielded on the submarine in phase three until 2030—2 years later than planned—unless another submarine option is identified.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the CPS program, it remains on track to meet the fielding requirements set by the military services. To support these fielding timelines, CPS and the Army's Long Range Hypersonic Weapon program plan to continue to jointly conduct hypersonic flight tests of the common hypersonic missile, focusing on range, environmental extremes, use of multiple launch platforms, and operational considerations. The program also stated that it will continue efforts to improve affordability of the weapon system through initiatives to reduce material costs, among other measures. The program added that it will continue to coordinate with the *Zumwalt* class and *Virginia* class programs to support design, development, and testing in preparation for the eventual sea-based fielding of the weapon system.



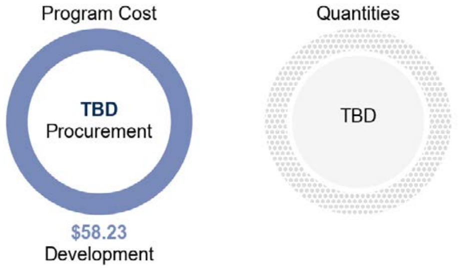
Source: U. S. Navy. | GAO-23-106059

DDG(X) Guided Missile Destroyer

The DDG(X) program is developing a new integrated air and missile defense large surface combatant to follow the DDG 51 class destroyers, which the Navy plans to be more fuel efficient and to accommodate future capability growth. The Navy expects DDG(X) to incorporate existing weapons, such as the Aegis combat system and SPY-6 radar, onto a new hull with a new integrated power system. The Navy intends for the design of the DDG(X) to provide sufficient size and power margins to enable greater flexibility to incorporate new systems as they become available.

Estimated Cost and Quantities

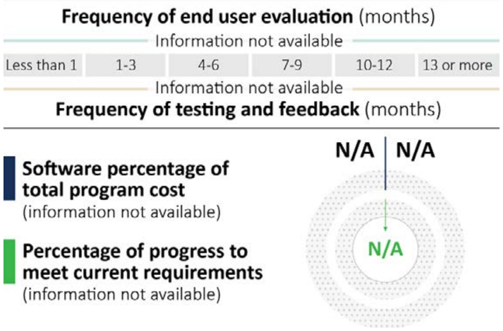
fiscal year 2023 dollars in millions



Costs represents the program's development efforts in 2022 and 2023 in preparation for development start.

Software Development as of January 2023

Approach: Information not available



Program officials stated that it is too early in the program to know the need for or extent of software development.

Program Essentials

Contractors: General Dynamics Bath Iron Works; Huntington Ingalls Industries

Contract type: CPAF (design)

Current Status

The Navy's DDG(X) program, in its concept design phase, continues to develop documents required for its planned fiscal year 2028 development start milestone review. Since last year, the program delayed this review by 2 years, due to lower-than-expected funding. According to the program, it plans to use this time to refine its requirements, begin ship design, and mature its technologies.

The program is using a Navy-industry collaborative approach for its design phases. According to the program, this approach helps inform requirements and identify opportunities for cost savings. In July 2022, the Navy awarded two shipbuilder design contracts that describe a framework for the ship design process.

The Navy has yet to determine estimated costs because requirements and planned ship quantities are still under consideration. However, a Congressional Budget Office cost estimate indicates that the average cost of the ships will be about 14 percent more expensive than the current DDG 51 class.

The Navy identified two critical technologies, the hull-form and the integrated power system (IPS). The program plans to conduct scale-model testing of the hull form and IPS critical systems testing at a land-based test site through 2027. According to the program office, it plans to meet certain statutory requirements related to these critical technologies prior to development start. Doing so would also be consistent with our leading practices for shipbuilding programs. Maturing technologies early is a key step in reducing the risk of program cost growth and schedule delay.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program provided technical comments, which we incorporated as appropriate. The program office stated that the DDG(X) will utilize non-developmental ship systems along with land-based testing to reduce risks prior to detail design. The program also stated that it will leverage DDG 51 systems while allowing for future warfighting improvements.

Source: U. S. Navy. | GAO-23-106059

Large Unmanned Surface Vessel (LUSV)

The Navy's LUSV is a planned, long-endurance, uncrewed ship intended to conduct warfare operations with varying levels of autonomy and in conjunction with crewed ships. The Navy also expects the LUSVs to be low-cost, reconfigurable ships with capacity for carrying various modular payloads. LUSV is a research and development effort that builds upon earlier prototyping efforts funded by the Office of Naval Research and the Office of the Secretary of Defense (OSD) Strategic Capabilities Office. LUSV started concept development in September 2020.

CONCEPT

9/20 Conceptual design contract award

1/23 GAO review

SYSTEM DEVELOPMENT

4-6/24 Request for proposal release

7-9/25 Detail design and construction contract award

TBD Critical design review

PRODUCTION

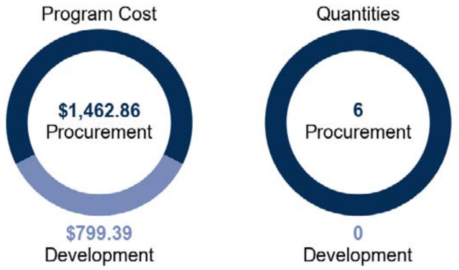
TBD Start of lead ship fabrication

TBD Start operational test

TBD Initial capability

Estimated Cost and Quantities

fiscal year 2023 dollars in millions



Cost and quantity represent fiscal years 2021–2027.

Software Development as of January 2023

Approach: Information not available

Frequency of end user evaluation (months)

Information not available

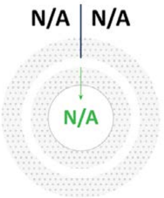
Less than 1	1-3	4-6	7-9	10-12	13 or more

Information not available

Frequency of testing and feedback (months)

Software percentage of total program cost
(information not available)

Percentage of progress to meet current requirements
(information not available)



Program officials stated that it is too early in the program to know details about the software development.

Program Essentials

Prime contractor: TBD

Contract type: CPFF (current studies)

Current Status

In May 2022, the Navy completed its Offensive Surface Fires Analysis of Alternatives, which LUSV is using to inform its requirements, according to program officials. These officials added that the Navy is making trade-offs between the capabilities the service needs and the capabilities uncrewed surface vehicles can provide in the near future. The Program Executive Office for Unmanned and Small Combatants is currently determining its acquisition strategy.

While determining its requirements and acquisition strategy, the program office plans to receive seven prototypes. To date, the program has received five—two from the Office of Naval Research, two from OSD, and one from the Navy. The Navy plans to deliver the remaining two prototypes in 2023 and 2024.

The Navy is experimenting with these prototypes to understand their capabilities, familiarize sailors with operating them, and determine if LUSV will have any potential critical technologies. The Navy completed over 100,000 nautical miles in autonomous driving with these prototypes. But the prototypes require constant monitoring offshore and hands-on crewing by humans when operating close to shore.

The Navy is working toward a milestone review in 2025, when it plans to transition LUSV to an acquisition program using the major capability acquisition pathway to begin design and development. Subsequently, the Navy plans to begin construction of the first of six production LUSVs in 2027.

In June 2022, we reported that the Navy had yet to develop schedules that would align its uncrewed maritime vehicle prototypes, including LUSV, with key investment decisions. Without a schedule to align these prototype efforts, DOD may make investment decisions for LUSV before attaining adequate knowledge.

Program Office Comment

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, it took several steps to increase technical maturity, such as demonstrating technologies in an operationally relevant environment, to reduce risk prior to transitioning to an acquisition program.

Light Amphibious Warship (LAW)

Source: U. S. Navy| GAO-23-106059

The Navy's LAW program is developing a medium-sized landing ship in an effort to fill a gap in capability between the Navy's large, multipurpose amphibious warfare ships and its smaller landing craft. The Navy plans for LAW to be capable of transporting 50 to 75 Marines and their supplies from shore to shore in contested operational environments. The Navy expects LAW to provide distributed maneuverability, mobility, and logistics in support of near-shore expeditionary operations, such as operations by the new Marine Littoral Regiments.

Estimated Cost and Quantities

fiscal year 2023 dollars in millions

Cost and quantity represent fiscal years 2021–2027. Total cost and quantity are to be determined.

Software Development as of January 2023

Approach: Information not available

Frequency of end user evaluation (months)

Information not available

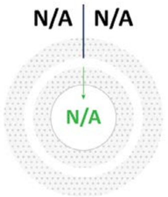
Less than 1	1-3	4-6	7-9	10-12	13 or more

Information not available

Frequency of testing and feedback (months)

Software percentage of total program cost (information not available)

Percentage of progress to meet current requirements (information not available)



The program reported that software development has yet to start.

Program Essentials

Prime contractor: TBD

Contract type: TBD

Current Status

Since our last review, the Navy delayed the detail design and construction contract award for LAW from fiscal year 2023 to fiscal year 2025. According to Navy officials, this change was due to ongoing efforts to engage with industry and refine program requirements, as well as delays in gaining approval of the program's analysis of alternatives (AOA)—a key document to help DOD and the Navy decide if a new ship class is needed. As of January 2023, the Office of the Secretary of Defense had yet to approve the AOA, which is at least a 19-month delay in the planned approval since our last review.

Although an approved AOA has yet to confirm the need for LAW, the program continues to work toward a detail design and construction contract award and is looking for opportunities to shorten LAW's development time. For example, the program plans to modify an existing parent ship design, instead of creating a new one, and has been assessing potential designs with five companies since 2021. The program also plans to seek approval to streamline its schedule by eliminating certain early acquisition oversight reviews. We previously found that eliminating such reviews can increase the risk that senior acquisition and warfighting leaders lack information needed for sound investment decisions.

Currently, several key program elements remain undefined. In particular, the Navy is still determining LAW's requirements. In alignment with leading principles for iterative development, the Navy is making changes to draft requirements based on industry feedback and ongoing AOA efforts. DOD has also yet to determine LAW's total procurement quantities. The Marine Corps suggested 35 ships, but the Navy proposed acquiring only 18. The Navy cannot estimate LAW's costs until it defines requirements and quantities.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. It stated that the Navy is following a deliberate requirements process to determine its needs for the LAW program. It noted that the Navy endorsed the AOA in March 2022 and is awaiting the sufficiency review by the Office of the Secretary of Defense. It added that it is incorporating the analysis results and feedback from the five industry preliminary designs into the upcoming Capabilities Development Document.

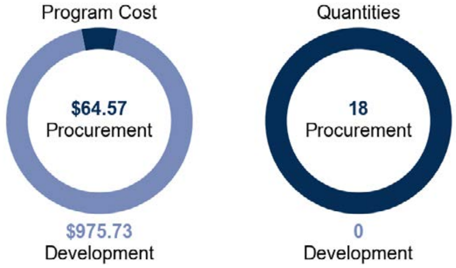
Source: Alion Science and Technology. | GAO-23-106059

MK 54 MOD 2 Advanced Lightweight Torpedo (ALWT)

The Navy's MK 54 MOD 2 program is developing an advanced lightweight torpedo for use by U.S. surface ships, fixed-wing aircraft, and helicopters in anti-submarine warfare. The Navy plans to upgrade the MK-54 MOD 1 torpedo's guidance and control, propulsion system, and warhead to achieve higher speeds and maneuverability, greater depths, and increased lethality. The program is currently conducting early system development activities and plans to formally enter system development as a major defense acquisition program in 2023.

Estimated Cost and Quantities

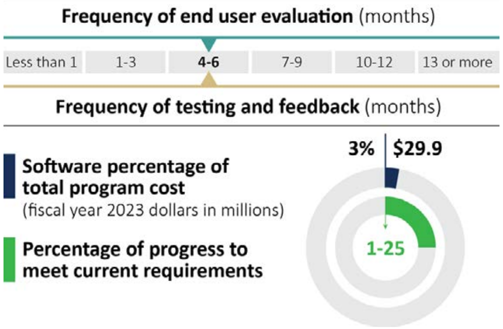
fiscal year 2023 dollars in millions



Cost and quantity represent fiscal years 2019–2028.

Software Development as of January 2023

Approach: Agile and Iterative (other than Agile)



Program Essentials

Prime contractors: Progeny Systems Corporation, Northrup Grumman Corporation, Aerojet Rocketdyne, Raytheon Technologies

Contract type: CPFF (using other transaction authority)

Current Status

The Navy is using a tailored version of the major capability acquisition pathway to try to accelerate delivery of the MK 54 MOD 2 torpedo. In an effort to shorten development, the MK 54 MOD 2 program collaborated with industry early on the system's requirements and preliminary design and took advantage of the flexibility offered by other transaction authority (OTA) agreements. The Navy reported that using an existing OTA with Advanced Technology International, it selected four companies to develop improved guidance and control, warhead, propulsion systems, and a prototype torpedo. The program does not expect to hold a decision review to formally enter system development until 2023, due to challenges associated with creating an independent cost estimate for a fully upgraded torpedo.

The Navy's acquisition strategy has significant risks. The program started system development before technology maturation was complete. Our prior work shows that programs increase the risk of costly rework when they proceed with system development without fully mature technologies. The Navy also completed an independent assessment in June 2022 that noted the program's planned schedule was shorter than prior torpedo upgrades, which were more limited in scope. A compressed schedule makes addressing technical risks more challenging and delays in delivering capability more likely.

Nevertheless, the program incorporated several leading industry practices for iterative product development. For example, according to program officials, the program deferred the high-altitude and vertical launch capabilities for the MK 54 MOD 2 until after initial operating capability to deliver a minimally viable product faster, and plans to begin work on this requirement in fiscal year 2024.

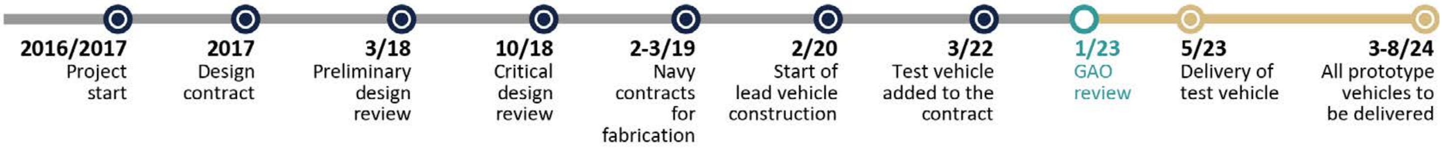
Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, the MK 54 Mod 2 is intended to address a capability gap in countering adversary submarine targets and near-peer threats. The program office stated that it is executing a compressed development schedule to meet operational needs while maintaining focus on fielding capabilities on time and within cost targets.

Source: U. S. Navy. | GAO-23-106059

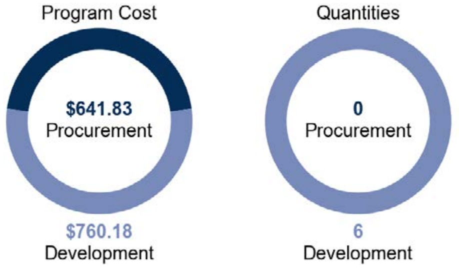
Orca Extra Large Unmanned Undersea Vehicle (XLUUV)

The Navy's XLUUV is an uncrewed undersea vehicle that is expected to meet various undersea missions by leveraging a modular payload bay that can carry and deploy various payload types. The Navy began developing XLUUV in fiscal year 2017 in response to a critical and time-sensitive need to lay undersea mines. Navy strategic plans state that it will likely serve a key role in the future fleet by removing sailors from performing dangerous missions. XLUUV is currently a research and development effort.



Estimated Cost and Quantities

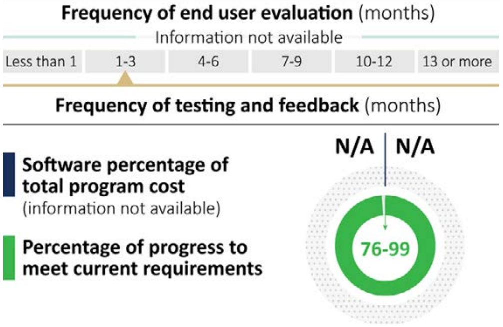
fiscal year 2023 dollars in millions



Estimated procurement cost and quantities reflect potential costs in the event the Navy proceeds with the purchase of additional XLUUVs.

Software Development as of January 2023

Approach: Agile and Incremental



The program reported that the frequency of end user evaluation is yet to be determined. According to the program, software costs are not known because it is developed through the contractor's own research and development funding.

Program Essentials

Prime contractor: Boeing

Contract type: FPIF

Current Status

The XLUUV is $242 million, or 64 percent, over its original 2016 cost estimate, although the program reported that the contractor has reached the ceiling price for the fabrication work.

Even though the Navy began the XLUUV project in 2017 to meet an urgent need, the system is on track to be over 3 years late. Navy officials said that the contractor originally planned to deliver one prototype vehicle in December 2020 and five prototype vehicles by the end of 2022. But the contractor now plans to deliver them between March 2024 and August 2024. Changes to the XLUUV to meet Navy requirements combined with challenges stemming from the COVID-19 pandemic account for some of the delays. According to Navy officials, the contractor changed the originally planned battery to meet endurance requirements. As of March 2023, the new battery has yet to be completed. In addition, the Navy has yet to identify XLUUV critical technologies.

To reduce the effect of delays and gain a better understanding of the system, the Navy contracted for an unplanned sixth vehicle for $73 million, which contributed to the program's cost growth. The Navy plans to use this vehicle to test the system while it awaits the delivery of the five originally planned vehicles. However, this prototype vehicle does not have the planned battery or payload module, which is used to carry critical systems or weapons.

The Navy plans to use the major capability acquisition pathway with the intention to purchase more XLUUVs at some point in the next several years. In September 2022, we recommended that the program conduct production readiness reviews prior to additional purchases beyond the six planned XLUUVs; the Navy agreed with our recommendation.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that it is developing the first-ever autonomous uncrewed diesel-electric submarine. It noted that while the program experienced delays, it is moving faster than a traditional development effort. The program office also acknowledged the need to enhance the supplier base and stated that it is assessing potential critical technologies to inform future procurements.

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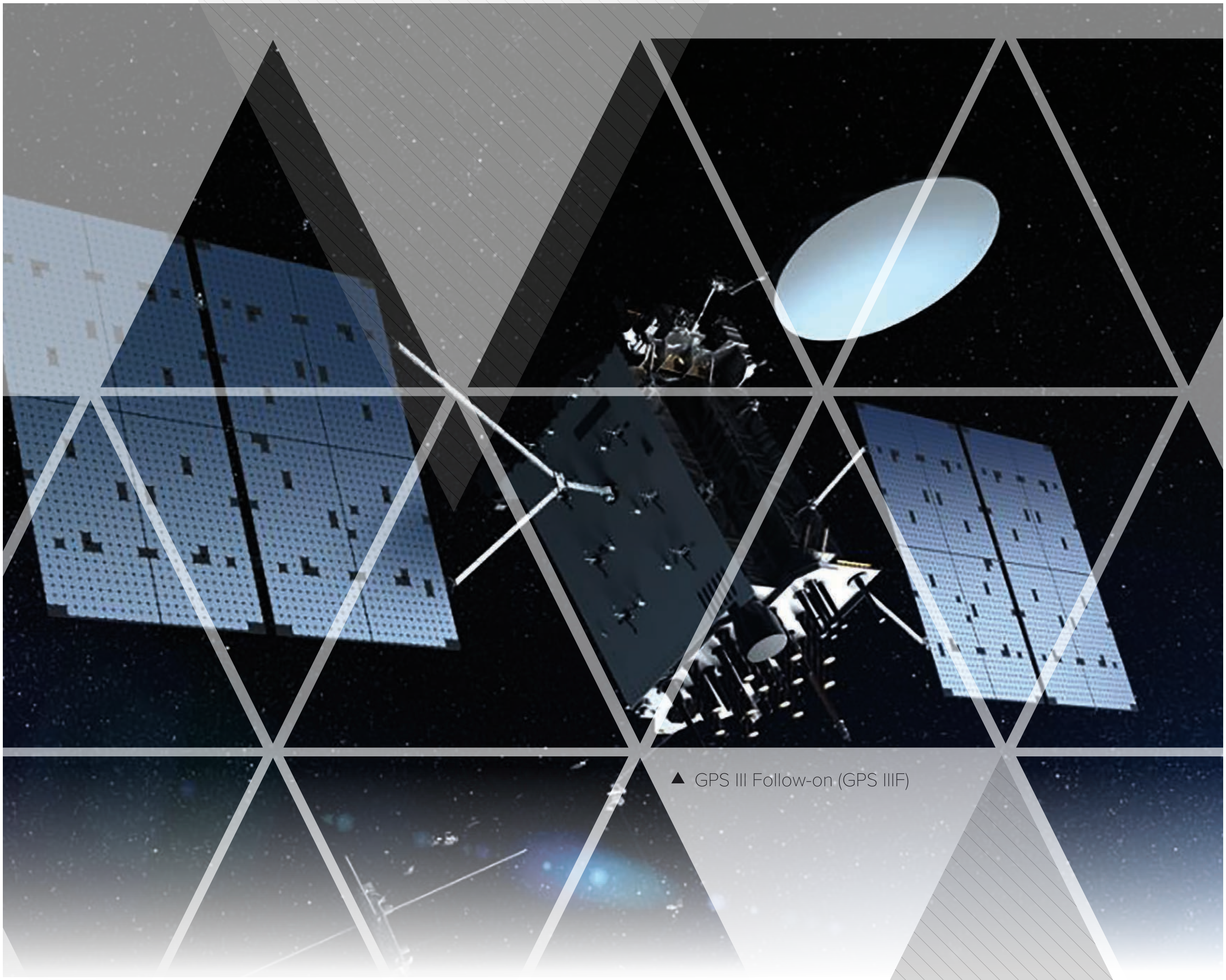
SPACE FORCE

Program Assessments



▲ GPS III Follow-on (GPS IIIF)

Assessment type	Program name
MDAPs	GPS III Follow-on (GPS IIIF)
	Military GPS User Equipment Increment 1 (MGUE Increment 1)
	Next Generation Operational Control System (OCX)
	Weather System Follow-On (WSF)
MDAP Increments	National Security Space Launch (NSSL)
MTA Programs	Deep Space Advanced Radar Capability (DARC)
	Evolved Strategic SATCOM (ESS)
	Future Operationally Resilient Ground Evolution (FORGE)
	Military GPS User Equipment Increment 2 (MGUE Increment 2)
	Next Generation Overhead Persistent Infrared Block 0-Geosynchronous Earth Orbit Satellites (Next Gen OPIR Block 0-GEO)
	Protected Tactical Enterprise Service (PTES)
	Protected Tactical SATCOM (PTS)
	Tranche 1 Tracking Layer (T1 TRK)
	Tranche 1 Transport Layer (T1TL)

Source (previous page image): Lockheed Martin Corporation. | GAO-23-106059

MDAP Lead Component: Space Force

Common Name: GPS IIIF

Source: Lockheed Martin Corporation. | GAO-23-106059

GPS III Follow-On (GPS IIIF)

The Space Force's GPS IIIF program is intended to build upon the efforts of the GPS III program to develop and field next-generation satellites to modernize and replenish the GPS satellite constellation. In addition to the capabilities built into the original GPS III design, GPS IIIF is expected to provide new capabilities. These capabilities include a steerable, high-power military code (M-code) signal—known as Regional Military Protection—to provide warfighters with greater jamming resistance in contested environments.

Program Performance fiscal year 2023 dollars in millions

	Total Acquisition Cost dollars in millions: Development cost	Procurement cost	Total	Percent change	Unit Cost dollars in millions	Percent change	Quantities number	Percent change	Cycle time in months	Percent change
First Full Estimate (9/2018)	$3,572	$6,908	$10,480		$476		22		N/A	
Reported in 2022[a] (9/2020)	$3,378	$7,071	$10,448	+5 %	$475	+5 %	22	+0 %	N/A	N/A %
Current Estimate (8/2022)	$3,628	$7,295	$10,923		$497		22		N/A	

■ Development cost ☐ Procurement cost (%) Percent change since reported in 2022[a]

Total quantities comprise two development quantities and 20 procurement quantities. We could not calculate cycle time because the initial capability depends on the availability of complementary systems.

[a]GAO-22-105230

Software Development as of January 2023

Approach: Waterfall and Incremental

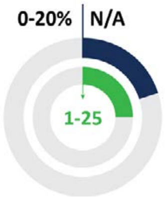
Frequency of end user evaluation (months)

Less than 1	1-3	**4-6**	7-9	**10-12**	13 or more

Frequency of testing and feedback (months)

Software percentage of total program cost (Information not available)

Percentage of progress to meet current requirements



The program indicated that software accounts for 20 percent or less of program costs but did not provide a specific dollar value. The program expects to begin tracking software costs in May 2023.

Program Essentials

Prime contractor: Lockheed Martin

Contract type: FPI (development); FPAF (procurement)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	NA	NA
Complete a system-level preliminary design review	○	○
Product design is stable	Design Review	
Release at least 90 percent of design drawings	●	●
Test a system-level integrated prototype	○	○
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess either GPS IIIF critical technologies in a realistic environment or testing of a production representative prototype in its intended environment due to the difficulty of conducting tests in a realistic or intended environment—space. Also, the Air Force waived the requirement for conducting a preliminary design review prior to development start.

GPS IIIF Program

Technology Maturity, Design Stability, and Production Readiness

As previously reported, the GPS IIIF program demonstrated two critical technologies—a linearized traveling wave tube amplifier (LTWTA) and a digital waveform generator—in a relevant environment. According to our leading practices, this maturity level is sufficient to begin satellite system development.

Over the past 2 years, however, the program experienced delays in developing the LTWTA. The program selected the LTWTA due to the power requirements of the satellite's Regional Military Protection capability. The program also plans for these amplifiers to power other GPS signals.

Technical and manufacturing challenges, such as a surface coating change, as well as the need for additional technical staff drove LTWTA delays. In April 2020, following the program's critical design review, the contractor projected early 2022 deliveries of five developmental LTWTAs for testing purposes. As of March 2023, one was delivered, while the remaining four are late to the program's stated need. Delivery projections shifted to May 2023. During the same period, the program shifted planned delivery of one LTWTA intended for design qualification from September 2022 to April 2024 and canceled a second qualification LTWTA.

To mitigate the effects of the late qualification LTWTA, the contractor built two additional developmental LTWTAs, which were delivered in mid-2022. According to the Defense Contract Management Agency, in the summer of 2022 the contractor implemented a mitigation plan. The plan includes schedule changes and the subcontracting of LTWTA manufacture for the fifth GPS IIIF satellite onward.

Additionally, the program experienced delivery delays of the mission data unit (MDU)—the brain of the satellite's navigation mission—beyond what we reported last year. Continued challenges building developmental units drove these delays. In 2022, the program faced delays due to an anomaly related to the frequency synthesizer. As of October 2022, one of the developmental MDUs was delivered, a second had completed acceptance review, and a third was awaiting completion of its acceptance review. The remaining three were projected for delivery between January 2023 and June 2023. According to the program, the contractor restructured the planned uses of some developmental MDUs to mitigate the delays.

As we reported last year, the program plans to complete testing of a non-flight, system-level, integrated testbed in November 2023. The program plans to include all key subsystems and components in the prototype-like testbed but with less redundancy than a final configuration GPS IIIF satellite. Program officials stated that Lockheed Martin took delivery of various testbed components and began assembly in September 2022. The program expects the building of and demonstrations with this testbed to inform integration and testing of the first GPS IIIF satellite, currently planned to begin in mid-2024.

However, program officials expressed concern about delays to the testbed's developmental LTWTAs, four of which have yet to be delivered. The program office indicated that it adjusted the testbed assembly schedule to accommodate the expected late delivery of the LTWTAs.

Since the Air Force approved production for the program in July 2020, the Space Force exercised options to procure eight additional satellites beyond the initial two under contract prior to the production decision. The most recent exercise of options was in October 2022 for the procurement of three satellites.

Software and Cybersecurity

A significant amount of software development remains for the GPS IIIF program. The program estimated that, as of August 2022, it completed less than 25 percent of the software necessary to meet system requirements. The program plans to conduct qualification testing of the satellite software on a satellite simulator in mid-2023 to permit the software's integration and testing on flight hardware for the first GPS IIIF satellite in summer 2023.

Other Program Issues

Launch and operation of GPS IIIF satellites depends upon the delivery of Next Generation Operational Control System (OCX) Block 3F, which formally started development in May 2022. The Defense Contract Management Agency reported that the OCX Block 3F program experienced cost increases and schedule changes due to the diversion of personnel and resources to the OCX Block 1/2 program, which we assess separately in this report. Persistence of these diversions to Block 1/2 could affect the timeliness of the OCX Block 3F delivery, with potential corresponding effects to the GPS IIIF program.

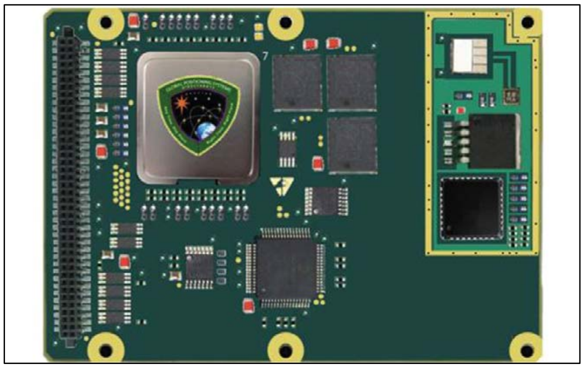
Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, it is encountering technical delays but is working closely with the contractor to address these issues. The program office stated that appropriate and stable funding would enable the program to mitigate current and future challenges.

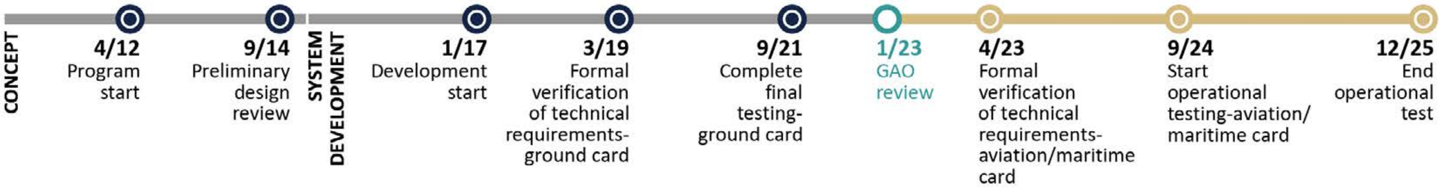
MDAP Lead Component: Space Force **Common Name:** MGUE Increment 1

Military GPS User Equipment (MGUE) Increment 1

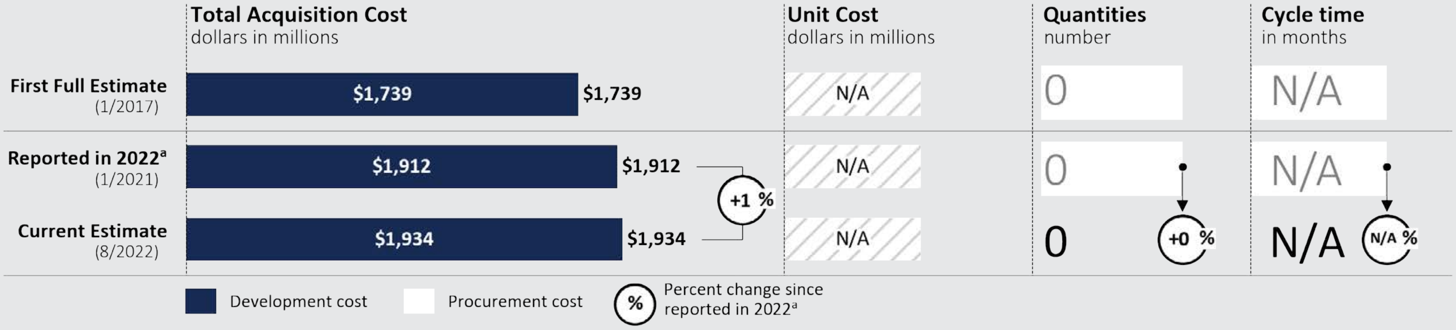
The Space Force's MGUE Increment 1 program develops GPS cards capable of receiving a modernized GPS signal known as military code (M-code). The receiver cards are expected to provide the military departments with more robust position, navigation, and timing capabilities for resistance to threats. The program is developing one card for aviation and maritime applications and one for ground applications. The military departments will make procurement decisions.



Source: U. S. Air Force. | GAO-23-106059



Program Performance fiscal year 2023 dollars in millions

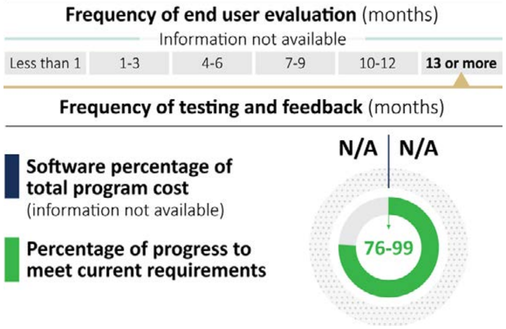


We did not assess unit cost because the program does not intend to procure cards beyond test articles, which are not reported as development or procurement quantities. We did not assess cycle time because the program will end with operational testing.

ªGAO-22-105230

Software Development as of January 2023

Approach: Agile, DevOps, and Incremental



The program reported that end users have not evaluated and provided feedback on the software. It reported that, instead, the services acquiring the product have this responsibility. The program does not track software costs.

Program Essentials

Prime contractors: L3Harris: Raytheon Technologies; BAE Systems

Contract type: CPIF/CPFF/FFP (development)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	NA	NA
Test a system-level integrated prototype	NA	NA
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess MGUE design stability or manufacturing maturity metrics because the program is only developing production-representative test items that the military departments may decide to procure.

MGUE Increment 1 Program

Technology Maturity

As we reported last year, four of five critical technologies are mature, with the remaining one nearing maturity. The program anticipates the last critical technology—the anti-spoof software—will reach maturity once testing is complete in the first quarter of fiscal year 2025.

Development on the ground card is now complete. The program encountered difficulties with flawed test procedures during a September 2021 test of the ground card on the lead platform, but officials said that they determined a retest was not needed. Specifically, the operators used an expired encryption key, which meant that the card never connected to an M-code signal. According to program officials, operators were unaware of this issue during testing because the receiver did not indicate which GPS signal it was operating with. Program officials stated that, even though software was not exclusively at fault, the contractor developed a software update that could prevent this error from happening again. Program officials also stated that, while a full retest of the card on the lead platform would not be necessary, additional testing on the software update confirmed its effectiveness in preventing the error from recurring.

The aviation/maritime card is approaching its technical requirements verification milestone, which certifies that the card can meet specific requirements. As of January 2023, the program successfully verified 963 out of 980 technical requirements. The program office expects to achieve this milestone by April 2023.

Operational testing for MGUE Increment 1 continued to slip since our previous report. The MGUE Increment 1 program now plans to begin combined developmental and operational testing on the Air Force's B-2 Spirit bomber platform in the fourth quarter of fiscal year 2024 and will end approximately one year later. Operational testing on the Navy's DDG platform (also known as the *Arleigh Burke* class of destroyers) is planned to begin in the first quarter of fiscal year 2025 and is planned to end in December 2025. Program officials said that the later date for DDG testing is driven by funding and test scheduling considerations that are outside MGUE's control. As we previously reported, delays in the development of the aviation/maritime card led to delays in some receivers for this card.

Design Stability

As we reported last year, the hardware design of both cards is largely stable. According to program officials, the work that remains is almost entirely confined to software issues and related testing. Further, they stated that any remaining hardware issues will be resolved with software updates and modifications to the receivers into which the military departments will integrate the cards.

Production Readiness

The contractors demonstrated all critical manufacturing processes on a pilot production line for both cards in June 2021. The program will not, however, request a low-rate or full-rate production decision. Instead, the military departments and their respective programs will make procurement decisions when integrating the cards into their platforms.

Software and Cybersecurity

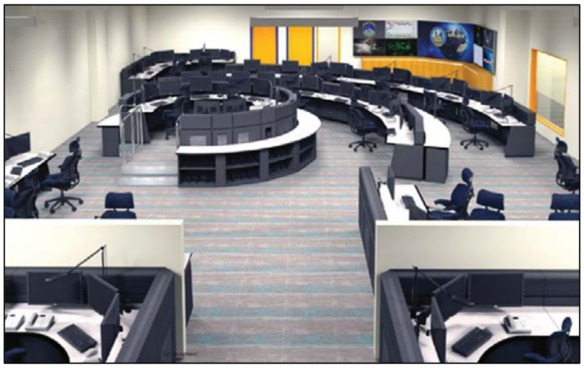
Program officials stated that the contractor completed software development for the ground card, with the delivery of the final software version in November 2021.

In September 2022, the contractor delivered software version 6.3 for the aviation/maritime card, which will support final integration and platform testing. Program officials expect this version to address the remaining deficiencies and outstanding requirements.

The program stated that MGUE contractors had some difficulty finding software development staff and that changes to cybersecurity requirements resulted in additional software development efforts. They also noted that there are no known outstanding cybersecurity risks within the program. However, according to the program, some cybersecurity requirements are the responsibility of the programs that seek to integrate MGUE cards.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, MGUE Increment 1 made significant progress in fiscal year 2022, including the delivery, security certification, and approval of the ground card's final software build. The program stated that, with these steps, MGUE Increment 1 ground card development is complete and the card is available to the military departments for procurement. The program delivered the aviation/ maritime card's software build 6.3 to the Air Force and Navy receiver programs in early fiscal year 2023. The program also stated that the aviation/maritime card continues to make progress towards meeting its technical requirements verification date in April 2023.

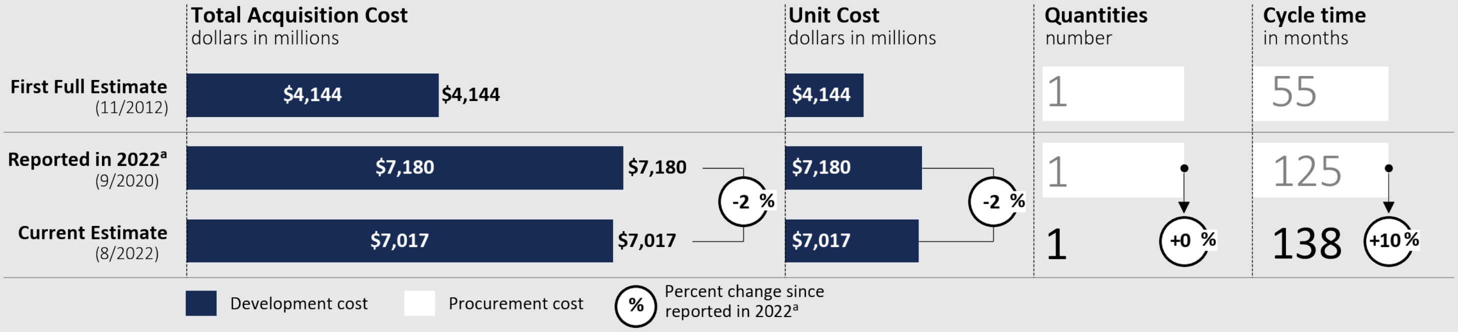


Source: U. S. Air Force. | GAO-23-106059

Next Generation Operational Control System (OCX)

The Space Force's OCX program is developing new hardware and software to replace the existing GPS ground control system. The Space Force intends for OCX to ensure reliable, secure delivery of position, navigation, and timing information. The Space Force is developing OCX in a series of blocks. The first, called Block 0, is for launch and limited testing of GPS III satellites. The second, called Blocks 1 and 2, includes satellite control, among other functions. OCX Block 3F is a separate follow-on program for the GPS IIIF satellites. We assessed Blocks 0, 1, and 2.

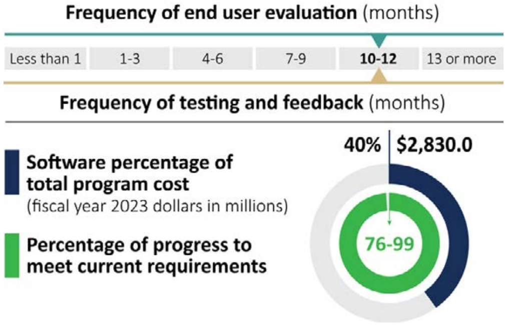
Program Performance fiscal year 2023 dollars in millions



Total quantities comprise one development quantity and zero procurement quantities.
[a]GAO-22-105230

Software Development as of January 2023

Approach: DevSecOps and Waterfall



Program Essentials

Prime contractor: Raytheon

Contract type: CPIF/CPAF (development)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	NA	NA
Test a system-level integrated prototype	NA	NA
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess OCX design stability or manufacturing maturity because OCX is primarily a software program and therefore does not track the metrics we use to assess this knowledge.

OCX Program

Technology Maturity and Design Stability

The program continues to report its five critical technologies as mature, which is consistent with our last assessment. As OCX is primarily a software development effort, the program does not track the metrics we use to measure design stability, such as the number of releasable design drawings.

Over the past year, the OCX program continued its software qualification testing on the new Hewlett Packard hardware that replaced the program's original IBM hardware. As we reported last year, the program completed software certification on the old hardware. However, in 2020, the OCX program reported that it could no longer use that hardware after the sale of IBM's product line intended to support OCX to a foreign entity presented a cybersecurity risk.

The program delayed planned completion of the testing on the new hardware by an estimated 11 months to March 2023. Program officials stated that the delay was partly due to challenges with software segment integration. As a result, the program also delayed pre-delivery, system-level demonstration by an estimated 1 year to May 2023.

Software and Cybersecurity

The number of deficiencies remaining continues to be a risk to the program. According to program officials, as of December 2022, OCX had 308 discrepancies of higher severity, which are critical deficiencies, affecting 234 contractual requirements and ranging from documentation errors to software problems requiring fixes.

These deficiencies contributed to a delivery delay. The contractor discovered additional deficiencies during software testing that required more time to address before delivery.

Other Program Issues

Over the past year, the program delayed estimated delivery by approximately 1 year to the end of 2023 due to challenges presented by overlapping efforts to integrate the software, test the navigation algorithm using live satellites, test the hardware and software at their final location, and develop training materials. Specifically, a technical issue with the GPS System Simulator affected the testing schedule. Program officials said that delivery may be delayed further due to funding challenges.

Because of the risk that not all requirements would be complete by delivery, the program modified the schedule to allow more time for software testing and addressing deficiencies, as well as developing technical manuals and training operators. As OCX nears delivery, the program reported that it plans to award a contract modification to Raytheon to perform support tasks between delivery and operations, to include addressing some deficiencies.

Block 1 and 2 delivery delays have, in turn, delayed the program's initial capability date by an estimated 1 year to spring of 2024. The program stated that it is mitigating schedule risk by conducting early software testing and focusing on critical software deficiencies.

Space Force officials told us that they are concerned about the demands on the operators between delivery and initial capability. During this time, the operators need to complete training and assist with transition activities, while controlling the GPS constellation using the existing system. Space Force officials stated that they are training operators on the current system and are working with the OCX program office to schedule events. But, they told us that they remain concerned about the ability of trained operators to support the OCX events as scheduled.

Space Force plans to transition from the current control system to OCX in 2024 and expects the transfer to take up to 3 weeks, followed by operational testing. Space Force officials stated that they anticipate a low risk of encountering issues during this process, as they plan to do extensive testing prior to the transition.

While schedule margin exists for the Block 3F program, the continuing delays to Blocks 1 and 2 pose a risk because of high demand for shared resources, including development and testing environments and personnel. Program officials stated that the Block 3F program will not have full access to the shared environment and simulator until Blocks 1 and 2 complete development and testing.

Program Office Comments

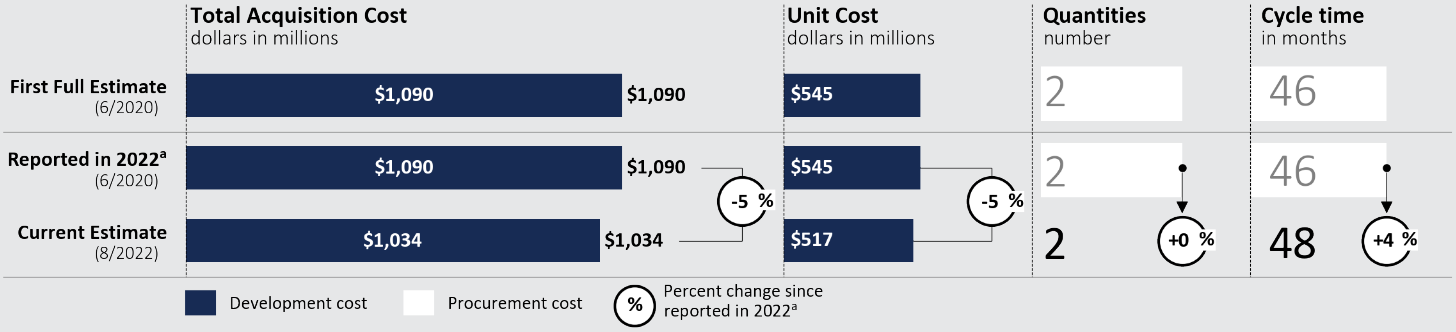
We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that the GPS Launch and Checkout System, also known as OCX Block 0, is prepared to support the launch of the sixth GPS III satellite. The program office also stated that, for OCX Blocks 1 and 2, the program continues to focus on finishing formal segment testing, integrating with external networks, and training initial operations cadre. The program added that it will also be ramping up the Interim Contractor Support effort in order to conduct initial integration with the space and user segments in 2023.

Source: © 2020 by Ball Aerospace & Technologies Corp. All rights reserved. | GAO-23-106059

Weather System Follow-On (WSF)

The Space Force's polar-orbiting WSF satellite is intended to contribute to a family of space-based environmental monitoring (SBEM) systems by providing three of 11 mission critical capabilities in support of military operations. WSF aims to conduct remote sensing of weather conditions, such as wind speed and direction at the ocean's surface, and to provide real-time data for use in weapon system planning and weather forecasting models. The family of SBEM systems replaces the Defense Meteorological Satellite Program.

Program Performance fiscal year 2023 dollars in millions



	Total Acquisition Cost dollars in millions	Unit Cost dollars in millions	Quantities number	Cycle time in months
First Full Estimate (6/2020)	$1,090	$545	2	46
Reported in 2022[a] (6/2020)	$1,090	$545	2	46
Current Estimate (8/2022)	$1,034	$517	2	48
	-5 %	-5 %	+0 %	+4 %

Total quantities comprise two development quantities and zero procurement quantities.

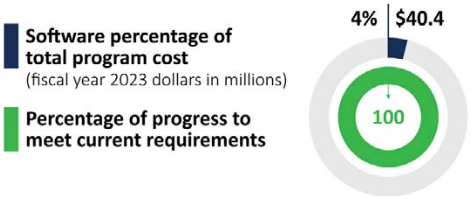
[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile, Waterfall, and Incremental

Frequency of end user evaluation (months)

Frequency of testing and feedback (months)



The program reported that software development was completed in April 2021.

Program Essentials

Prime contractor: Ball Aerospace and Technologies Corporation

Contract type: FFP (development)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	NA	NA
Complete a system-level preliminary design review	●	●
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	NA	NA
Test a system-level integrated prototype	NA	NA
Manufacturing processes are mature	**Production Start**	
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

We did not assess whether WSF demonstrated critical technologies in a realistic environment because satellite technologies demonstrated in a relevant environment are assessed as fully mature. We also did not assess design stability because the program told us the metrics were not applicable and did not assess manufacturing metrics because the program does not have a production milestone.

WSF Program

Technology Maturity and Design Stability

WSF's critical technologies are mature and the program considers the design complete, as we previously reported. Over the past year, the program continued developmental testing and resolved two moderate technical risks identified in its August 2020 critical design review.

- It addressed a risk that the satellite's Reflector Deployment Assembly hardware could fail to deploy, resulting in mission loss. In our last assessment, we reported that the program delivered redesigned hardware to the contractor for integration onto the microwave sensor subsystem. The program conducted a successful test readiness review of the microwave sensor in April 2022 and delivered the sensor for satellite integration in October 2022.
- It resolved a potential requirement mismatch between the satellite's legacy hardware and the vehicle selected for launch. Specifically, during critical design review, the program noted that, if the Space Systems Command's Launch Enterprise selected a different launch vehicle than the program used for testing to date, the program would have to redesign and retest its legacy hardware based on the new launch vehicle's requirements. However, in January 2022, the Launch Enterprise selected Space Exploration Technologies' (SpaceX) Falcon 9R—one of the program's test vehicles—preventing related costs and schedule delays.

According to the program office, the prime contractor identified a risk to WSF's launch segment, one of three segments that comprise the WSF system. Specifically, Ball Aerospace's evaluation of SpaceX's early analysis predicted that Blaze—a mount for six other Space Force or external program satellites on the Falcon 9R—amplified the vibration transmitted to the WSF satellite, significantly exceeding the current load design limits of WSF subsystems. Originally, according to the program office, WSF was intended to fly as a standalone satellite. The Blaze model was modified after SpaceX's initial analysis. However, program officials told us that in December 2022, the prime contractor found that the modifications made some improvements but did not resolve the issue.

If load predictions for the WSF satellite and Blaze continue to exceed WSF subsystem limits, then the WSF program may have to delay launch to address the issue. The program office told us that the prime contractor is working with SpaceX and the Aerospace Corp Structural Dynamics Department to begin mitigation efforts between February 2023 and April 2023. The program office expects to conduct a final analysis on these issues between April 2023 and July 2023 and to have the first WSF satellite available for launch by October 2023.

The program plans to begin mission-level testing for the WSF system in April 2023 to be completed by August 2023, according to program officials. In February 2023, the program completed the last planned integration and testing event for the ground segment. For the space segment, the program successfully completed a spacecraft manufacturing readiness review and integration readiness review in April 2022. The program delivered the spacecraft to the contractor for integration and testing in October 2022.

In November 2022, the program exercised a contract option to purchase a second WSF satellite. The program plans for the second satellite to be available for launch in July 2027.

Software and Cybersecurity

The program reported that it completed all software development efforts to support its core capabilities, but additional work remains to fully test cybersecurity. It plans to complete four additional cybersecurity tests in 2023, some of which were delayed. For example, the second cooperative vulnerability assessment, delayed 14 months from December 2021, was completed in February 2023. Our past work showed that delaying cybersecurity testing increases the risk that vulnerabilities will be identified later in development and may require costly, time-intensive rework.

Other Program Issues

In May 2019, an independent technical risk assessment deemed mission capability a high risk since the Space Force's Satellite Control Network (SCN)—managed as a separate program—might not have the capacity to support the WSF satellites' data needs. Telemetry, tracking, and commanding data are transmitted to and received from the WSF satellite through SCN to WSF's primary satellite operations center. However, SCN is working to expand its capacity. In April 2021, WSF signed a program support plan with SCN that includes two SCN supports per orbit, which the WSF program expects to meet its requirements.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program provided technical comments, which we incorporated where appropriate.

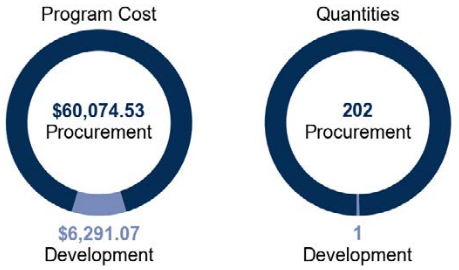
National Security Space Launch (NSSL)

Source: SpaceX and United Launch Alliance. | GAO-23-106059

The Space Force's NSSL provides space lift support for national security and other government missions. Currently, NSSL procures launch services from United Launch Alliance (ULA) and Space Exploration Technologies Corporation (SpaceX). These procurements are intended to support U.S. policy, as stated in law, to undertake actions appropriate to ensure, to the maximum extent practicable, the U.S. has the capabilities necessary to launch and insert national security payloads into space when needed. We focused our review on NSSL's investment in new launch systems from U.S. providers.

Estimated Cost and Quantities

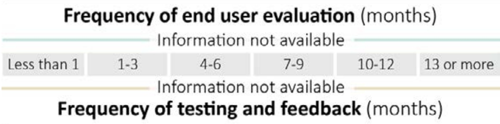
fiscal year 2023 dollars in millions



The cost figure represents costs for the total program. Quantities represent launch services.

Software Development as of January 2023

Approach: Information not available



According to the program office, this information is not available because software is procured from launch service contractors.

Program Essentials

Prime contractors: Space Exploration Technologies Corporation; United Launch Alliance

Contract type: Other Transaction (engines and launch vehicle prototypes); FFP (launch services)

Current Status

NSSL continues to order launch services from ULA and SpaceX as the program plans for approximately 40 national security launches—known as Phase 2—between fiscal years 2022 through 2028. The first Phase 2 mission was successfully launched in January 2023 using SpaceX's Falcon Heavy rocket.

ULA's efforts to develop its new Vulcan launch system to meet Phase 2 needs continued to encounter delays. These delays resulted from technical challenges with the booster engines. The Vulcan's BE-4 booster engine development is complete. However, NSSL program officials stated that ULA delayed planned acceptance testing 3 months to October 2022. They also said that ULA delayed the first certification flight of the Vulcan launch system to May 2023 to accommodate challenges with the BE-4 engine and a delayed commercial payload, nearly 2 years later than originally planned. In the event that Vulcan is unavailable for future missions, program officials stated that the Phase 2 contract allows for the ability to reassign missions to the other provider.

According to program officials, the program is in the midst of finalizing its acquisition strategy for Phase 3 launch services with procurements starting in fiscal year 2025. It is considering what the Space Force refers to as a block buy approach where it would commit to awarding a certain number of launch services to providers able to meet the most demanding requirements. NSSL would compete other, less demanding launches to encourage competition and potentially on-ramp new launch providers.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program provided technical comments, which we incorporated where appropriate. The program office stated that NSSL strives to maximize delivery of capability on orbit, which includes countering threats and maintaining the U.S.'s advantage in space. According to the program, NSSL's 97 consecutive launches relied on industry partnerships to ensure mission success. It noted that the Phase 3 strategy builds on previous successes using a dual lane approach: Lane 1 for less complex missions allowing on-ramping as providers are ready and Lane 2 for more complex missions.

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MTA Lead Component: Space Force

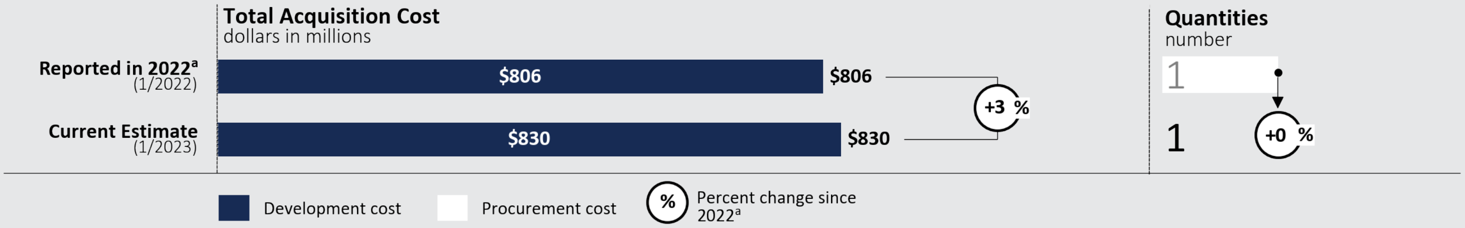
Common Name: DARC

Source: JHU/APL. | GAO-23-106059

Deep Space Advanced Radar Capability (DARC)

The Space Force's DARC, an MTA rapid prototyping effort, seeks to develop a ground-based radar site. DARC plans to leverage defense science and technology efforts to mature radar concepts and technologies that can demonstrate increased sensitivity, capacity, search rates, and scalability to detect and track objects in deep space orbit. The DARC system will rely on three ground-based radar sites in order to track objects in the entire geosynchronous satellite belt. We assessed the first site, which is being developed through the rapid prototyping effort.

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



According to the program, the higher cost reported this year is due to the addition of software maintenance costs that it did not include in last year's estimate.

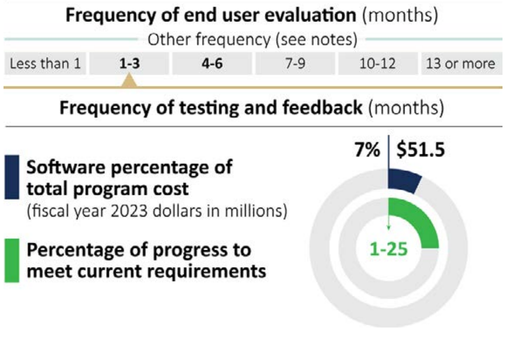
[a] GAO-22-105230

Program Background and Transition Plan

The Air Force initiated the DARC MTA effort in 2021 to develop an initial site (site 1) and a command and control center. The Johns Hopkins University Applied Physics Laboratory completed a technology demonstration the same year, which the Space Force reported successfully tested the radar's technology. Site 1 is expected to transition to operations and sustainment at the end of the current effort. The program is seeking approval to pursue sites 2 and 3 as MTA rapid fielding efforts in fiscal year 2023.

Software Development as of January 2023

Approach: Agile and DevSecOps



The program reported that end users evaluate and provide feedback on software every quarter or as needed when software is available. The program provided an updated software cost percentage this year based on current cost estimates.

Program Essentials

Prime contractor: Northrop Grumman Systems Corporation

Contract type: CPIF (using other transaction authority)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

DARC Program

Updates to Program Performance and Business Case

Since our last assessment, the program reported awarding an other transaction agreement to Northrop Grumman for system integration in February 2022. The program also completed its system requirements review and preliminary design review in May 2022 and August 2022, respectively.

During the past year, the Air Force Cost Analysis Agency performed a formal schedule assessment for DARC. The assessment estimated the program will finish 1 year after the 5-year time frame for MTA efforts called for in DOD policy. However, program officials told us that they disagreed with the assessment because it did not account for learning from the program's 22-month technology demonstration, which it started before the MTA effort and completed in August 2021. Specifically, they said that their ability to leverage information learned from this demonstration will allow them to finish sooner than predicted by the schedule assessment.

The program's delay in conducting a schedule risk assessment, which our prior work recommends completing prior to program initiation, limited the amount of information available to decision makers about the program's likelihood of demonstrating a prototype in an operational environment within 5 years.

Further, the program continues to report no plans to conduct a formal assessment of technology risk. As we noted last year, given that none of the program's four critical technologies are fully mature, the lack of such an assessment increases the risk of costly, time-intensive rework later in the program.

Software and Cybersecurity

The program assessed software development as high risk due to factors such as the estimated amount of effort needed for software development, which poses a schedule risk. The program's acquisition strategy includes objectives to improve delivery speed and reduce costs. These objectives include the use of a government-owned DevSecOps development environment, use of an open system architecture based on an existing standard for radar systems, and seeking data rights for software developed by the program.

The program documented its cybersecurity requirements and reported that it has set aside funding for cybersecurity testing and correcting of deficiencies. The program is planning to conduct two key cybersecurity assessments in 2025.

Key Product Development Principles

DARC reported that employing some practices aligned with principles for product development used by leading companies. For example, it coordinated with end users for feedback through regular briefings and working groups prior to development. DARC reported that using this feedback to develop key performance parameters and site selection criteria, among other things. We previously found that leading companies solicit early feedback from customers to help understand whether the product's business case is sound.

Additionally, the program reported that it is willing to off-ramp requirements, as needed, to meet its planned schedule. Program officials stated that they have yet to conduct a formal prioritization of capabilities but plan to do so as needed. Our prior work found that leading companies make an intentional decision to off-ramp capabilities that present a risk to delivering, on schedule, the capability prioritized by customers.

We have ongoing work to define metrics associated with our leading principles for product development, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

The program plans to start construction of sites 2 and 3 prior to operational demonstration of site 1. As we noted last year, this concurrency increases the risk for cost and schedule challenges on later sites. Program officials acknowledged that their schedule is aggressive.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that it leveraged the technology demonstration to successfully complete the system requirements review, preliminary design review, and critical design review within a year of awarding the other transaction agreement to Northrup Grumman. According to the program office, negotiations with international partners are in the final stages and the memorandum of understanding with these partners is expected to be in place by June 2023.

The program office stated that the second year of the contract will focus on finalizing the factory acceptance testing of key hardware components, aggressively continuing software development, and beginning site 1 construction after the memorandum of understanding is finalized. The program office added that cost and schedule parameters from the prime contractor have aligned with the program office estimates thus far.

MTA Lead Component: Space Force

Common Name: ESS

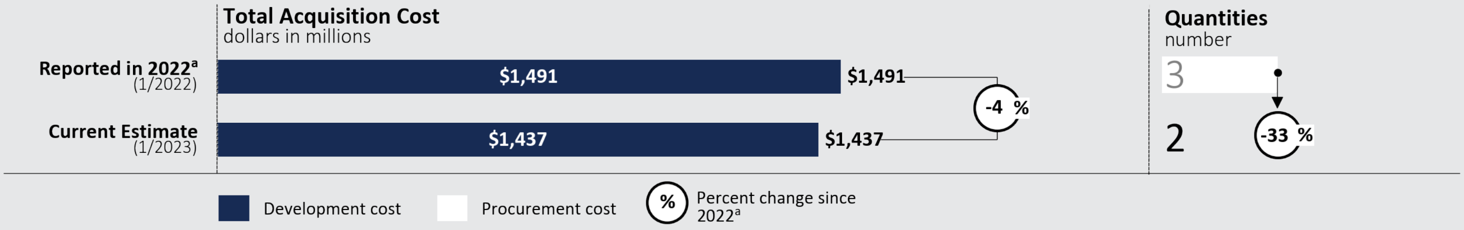
Evolved Strategic SATCOM (ESS)

The Space Force's ESS, a program using the MTA pathway, is developing space-based capabilities expected to provide worldwide DOD users with strategic and secure communications to support DOD's nuclear command, control, and communications mission. ESS expects to develop an advanced satellite communications payload during the rapid prototyping effort. The Space Force aims to incorporate the payload onto an eventual ESS satellite in the future using a rapid fielding effort or major capability acquisition pathway.

Source: U.S. Space Force. | GAO-23-106059

8/19	MTA initiation
9/20	MTA funds obligated
9-11/20	Contract award
10/21	Program review
12/21	First demonstration
1/23	GAO review
9/25	Operational demonstration/ 5 years since MTA funds obligated/ Expected MTA completion

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



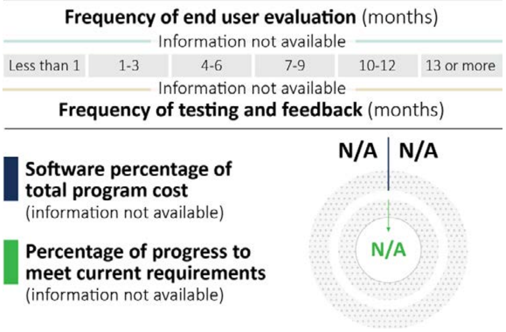
[a]GAO-22-105230

Program Background and Transition Plan

The Air Force initiated ESS as an MTA rapid prototyping effort in August 2019. From September 2020 through November 2020, the program awarded contracts to three contractors, each to develop an advanced satellite communications payload prototype. In October 2022, the program elected to discontinue working with one contractor and continue technology development with the remaining two. By the end of the MTA effort, planned for September 2025, the program expects to test and demonstrate critical payload capabilities for each contractor's payload.

Software Development as of January 2023

Approach: Agile and DevSecOps



The program reported that software deliveries have yet to be made and end users will evaluate and provide feedback on the software in the future. The program reported that it does not know software costs and progress at this time.

Program Essentials

Prime Contractors: Boeing; Northrop Grumman

Contract type: FFP (development)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	○	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	○	●
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

ESS Program

Updates to Program Performance and Business Case

The program continues to report that its schedule is on track, and it plans to accelerate its schedule for the next phase. Last year, program officials told us that they planned to perform prototype demonstrations in December 2022. This year, program officials clarified that the demonstrations it is conducting consist of prototype subcomponents and that those demonstrations began in December 2021 and continued through 2022. Multiple demonstrations on various subcomponents are planned for 2023.

As of October 2022, ESS determined it would continue work with only two of the three original contractors. The program decided not to continue development with one contractor and reprioritized associated resources to reduce development risk for the other two contractors.

Software and Cybersecurity

According to program officials, ESS has a contractor-led software approach and each contractor is responsible for its associated satellite and payload software development. Each contractor is executing Agile software development, with a different cadence of software deliveries.

To assess cybersecurity, the program plans to conduct an exercise in 2024. However, the program does not have plans for any other cybersecurity assessments during the MTA effort, such as an adversarial assessment, which gauges the ability of a system to support its mission while withstanding cyber threat activity. Program officials said that a majority of traditional cybersecurity assessments will be deferred to the follow-on contract at the conclusion of the MTA effort.

Including needed cybersecurity requirements in the contract helps to reduce the risk of the need for design changes and any associated costs to meet those requirements later. The program reported that while the contract includes cybersecurity testing, it does not include specific requirements for embedded testing tools because they are working at a different pace from a typical MTA effort and those testing tools are not yet required.

Key Product Development Principles

ESS is implementing practices associated with a number of key principles used by leading companies to develop innovative products. For example, the program established parameters for cost, schedule, and performance, which it evaluates on a regular basis. Continual evaluation of these types of parameters can increase confidence that a program will meet established targets and take corrective action as needed.

Further, the program identified its end users, including deployed units and satellite operators, and reports that it routinely solicits feedback from them. The program collects feedback through quarterly forums and uses it to inform design, such as ensuring user end terminals are compatible with the space segment. We previously found that ongoing engagement with customers is an important aspect of iterative development that leading companies use to prioritize features and identify improvements to the product.

We have ongoing work to define metrics associated with these principles, which we expect will help refine our evaluation of programs’ use of them.

Other Program Issues

The program continues to report that four of its eight critical technologies are mature, and one technology is approaching maturity. Assigning a singular maturity level to the remaining three technologies is difficult, according to the program, because of varied contractor approaches to development. Specifically, program officials stated that the three critical technologies—microelectronics, advanced antenna technology and electrically scanned arrays—have different maturation levels depending on the payload design. In addition to these eight critical technologies, program officials said that contractors identified other critical technologies they are incorporating to improve resiliency and respond to emerging threats.

The program office reported it is encouraging the utilization of modular open systems architecture as it continues to develop prototypes into fully operational satellites. Program officials stated that this approach may benefit later integration of payload prototypes into host satellites. While the program has yet to fully determine the roles contractors and the government will play in integration, program officials said that it may pursue a hybrid approach with government involvement.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program stated that it is maturing designs, burning down risks, and building in resiliency to future threats and is on track to meet program cost, schedule, and performance goals. According to the program office, each contractor completed multiple design reviews and demonstrations in the second year of the MTA rapid prototyping effort. The program office stated that the program is now shifting focus to two contractors and accelerating development of the most promising contractor approaches to address emerging operational threats. It stated that each of the two remaining contractors is maturing critical elements by conducting integrated tests based on system level performance requirements.

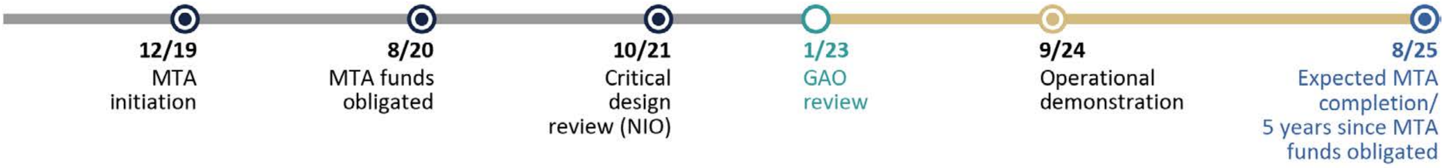
MTA Lead Component: Space Force

Common Name: FORGE

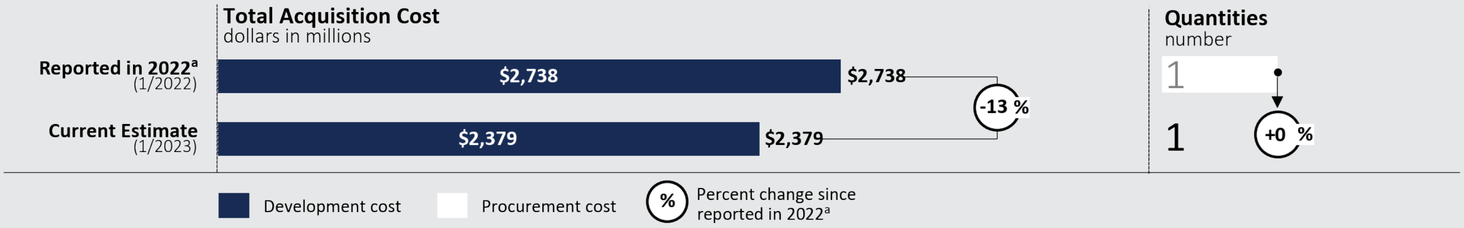
Source: SAIC. |GAO-23-106059

Future Operationally Resilient Ground Evolution (FORGE)

The Space Force's FORGE is using the MTA rapid prototyping pathway to develop a follow-on capability to the Space Based Infrared System (SBIRS) ground processing system. FORGE is designed to process data from both SBIRS and Next Generation Overhead Persistent Infrared (Next Gen OPIR) missile warning satellites and is developing capabilities in three areas: satellite command and control, mission data processing, and communication relay stations. The program is also developing an interim command and control solution called Next Gen Interim Operations (NIO).



Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



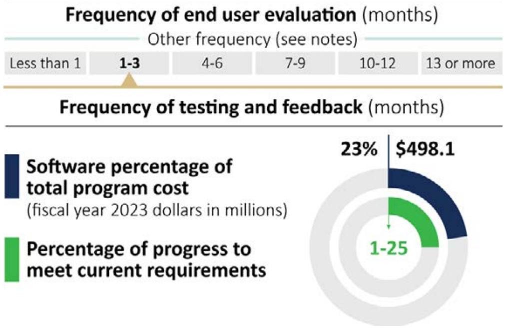
ªGAO-22-105230

Program Background and Transition Plan

The Air Force initiated FORGE as a rapid prototyping effort in December 2019. FORGE is intended to support legacy satellites and provide enhanced ground processing capabilities for Next Gen OPIR satellites. The program's interim solution, NIO, is intended to modify the current SBIRS ground processing system to provide satellite command and control capabilities for at least the earliest planned Next Gen OPIR satellite, scheduled to launch in 2025. The program office expects to transition remaining development efforts to the software acquisition pathway at the end of the MTA effort.

Software Development as of January 2023

Approach: Agile and DevSecOps



The program reported that timing of end user engagement varies depending on stakeholder needs.

Program Essentials

Prime Contractors: Raytheon (for MDPAF); SciTec (for MDPAP)

Contract type: Cost reimbursement with various fee structures (using other transaction authority)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	○	●
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	●	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

Previously, the program office stated that it had an approved acquisition strategy in place as of December 2019. This year, it said that this date was an error in reporting by the program and that the correct date was May 2020. We have updated our table accordingly this year.

FORGE Program

Updates to Program Performance and Business Case

In August 2022, after reviewing prototype efforts from three contractors, the program awarded a contract to SciTec to act as the program's Mission Data Processing Application Provider (MDPAP), according to program officials. SciTec will develop applications that process and disseminate data from legacy and Next Gen OPIR satellites. The program's Mission Data Processing Applications Framework (MDPAF), developed under a separate contract, will host the applications.

The NIO effort was assessed by the Office of the Deputy Assistant Secretary of the Air Force (Science, Technology, and Engineering) as part of a broader June 2022 assessment of technology risk for the Next Gen OPIR effort. The assessment focused on risks that affect mission capabilities and Space Force's ability to achieve initial launch capability in fiscal year 2025. The report identified capability and schedule risks related to NIO. The report also concluded that the FORGE system was not sufficiently mature to support a proper risk assessment at that time.

The program does not expect FORGE to be fully complete in time to support the first Next Gen OPIR satellite launch. In August 2022, the Air Force Acquisition Executive for Space determined that NIO would be designated as the baseline ground system to provide command and control capabilities for launch, early on-orbit testing, and initial operations of the Next Gen OPIR satellites. NIO was previously designated as only a risk reduction effort in case FORGE was not ready to command and control the planned first satellite launch in 2025. Program officials stated that they plan to conduct a schedule risk assessment by the spring or summer of 2023 to assess the likelihood that NIO will be operational in time to support that launch. Even for the first Next Gen OPIR satellite, FORGE will be needed to provide mission data processing capabilities. The program estimates that it will fully complete FORGE, including command and control capabilities to replace NIO, by March 2026.

The Space Force completed an updated cost assessment in August 2022. This new estimate shows a cost decrease for the MTA efforts. Program officials said that the decrease for the MTA efforts resulted from a better understanding of costs that fall outside of the MTA time frame.

The program is reevaluating its approach for delivering some key capabilities. It planned to use satellite command and control capabilities from the Air Force's Enterprise Ground Services (EGS)—a separate acquisition effort intended to automate command and control functions for a range of satellite constellations. Program officials stated that a February 2022 review of EGS determined that it would not fully support FORGE and that they are working with industry to evaluate what capabilities they will need to develop.

Software and Cybersecurity

Program officials reported that contractors have been providing major software deliveries three times per year utilizing Agile and DevSecOps principles. Other software development contractors will follow a similar cadence as they begin executing. To assess cybersecurity, a system survivability and operational resilience test is planned for September 2024, according to program officials.

Key Product Development Principles

FORGE reported taking certain actions that align with principles for product development used by leading companies. For example, FORGE defined schedule parameters at initiation, which we found that leading companies use to guide how long an effort should take. However, the program's planned approach to measuring progress for delivering command and control capabilities is no longer achievable due to the problems identified with the EGS program.

We have ongoing work to define metrics associated with our leading principles, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

As we previously reported, the government faces significant management challenges serving as the lead system integrator for Next Gen OPIR and FORGE, which includes responsibility for ensuring hardware and software components from different contractors form a functioning system. In addition, program officials said that the planned award of a key support contract was delayed. Program officials said that the delay resulted in removing some planned trade studies and analysis to inform integration efforts.

The Space Force, in coordination with the Missile Defense Agency and other partners, has acquisition efforts underway to prototype missile warning, missile tracking, and missile defense capabilities in low earth orbit and medium earth orbit. According to program officials, the FORGE program office is coordinating with these other programs to determine the extent to which it will leverage components of the FORGE architecture.

Program Office Comments

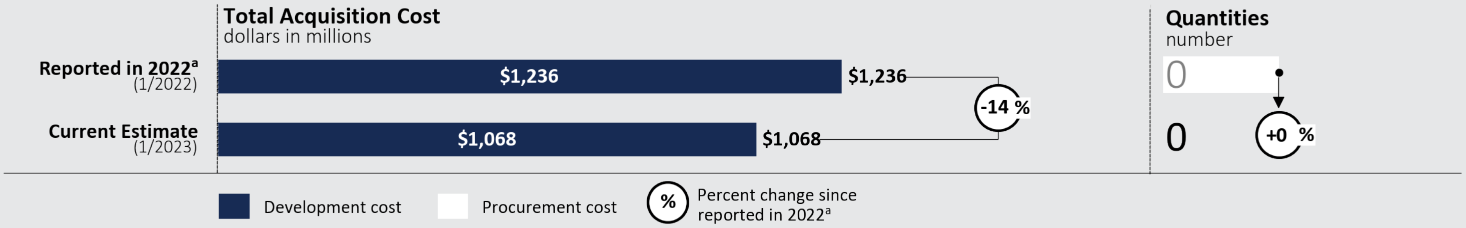
We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate.

Military GPS User Equipment (MGUE) Increment 2

The Space Force's MGUE programs are developing GPS receivers compatible with the military code (M-code) signal. MGUE Increment 2 is an MTA rapid prototyping effort intended to mature a miniature serial interface (MSI) card for use in receiving GPS signals with handheld devices and munitions. A future MTA effort will develop the handheld receiver device for use across the military departments. We assessed the current effort to mature the MSI receiver cards.

Source: U. S. Air Force. | GAO-23-106059

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



The program office updated its reported costs this year to more closely align with the Increment 2 program. For example, this year, the program office removed costs related to the handheld receivers (a future increment), which it previously reported to us as part of Increment 2.

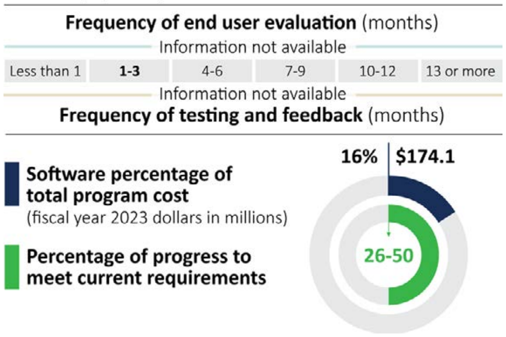
[a] GAO-22-105230

Program Background and Transition Plan

The Air Force first obligated funds for MGUE Increment 2 in November 2020, awarding contracts to three vendors to develop the next-generation, application-specific integrated circuit (ASIC) and MSI. The next-generation ASIC is a key component of the MSI on which the vendors will encode M-code receiver functions. The program completed preliminary design reviews for the ASIC in mid-2021 and conducted these reviews for each MSI concept in November 2022. The program plans to transition production-ready receiver card capability for the departments to procure through separate efforts in the first quarter of fiscal year 2026.

Software Development as of January 2023

Approach: Agile, Waterfall, Incremental, DevOps, DevSecOps, and Spiral



The program reported that end users do not evaluate and provide feedback because the software does not have a direct user interface. Delivery of software for testing has yet to occur.

Program Essentials

Prime contractors: BAE; Raytheon; Interstate Electronics

Contract type: CPIF/CPAF, CPFF, FFP

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

MGUE Increment 2 Program

Updates to Program Performance and Business Case

The program office continues to track schedule as a moderate risk. Program officials stated that they assess schedule risks about every 6 months to capture any changes to the program. For example, they plan to include updates to address new Army requirements for alternative navigation capabilities in the next risk assessment, planned for January 2023.

MGUE Increment 2 requirements and contract deliverables continue to evolve, contributing to cost and schedule uncertainty. Program officials said that each of the three vendors continues to have challenges related to cost, schedule, or technical performance consistent with our assessment last year in which we identified vendor challenges meeting power and thermal requirements. To address some of these challenges, program officials told us that they requested a reduction in key requirements from the Joint Requirements Oversight Council (JROC). Two vendors indicated that, if these are not reduced, it could result in approximately $300 million in additional costs and a four-year delay. Program officials expect the JROC's decision by June 2023 prior to critical design review.

In addition, program officials stated that the program is considering the third vendor's request to change aspects of its verification process intended to help avoid further schedule delays without affecting performance. They said that the program office must accept or reject the vendor's requested changes prior to critical design review in the last quarter of fiscal year 2023. Critical design review is a key point at which the program's decision authority determines whether the program can meet its requirements within the planned 5-year schedule and if changes are needed to the program.

Further, the program expects to attain less knowledge about the performance of the card before the end of the MTA effort than it originally planned. Previously, the program planned to conduct an operational demonstration event by the end of fiscal year 2025. However, the program office is now planning for the event to be held in the first quarter of fiscal year 2026, which coincides with the expiration of the 5-year MTA period. Until the program conducts this demonstration, it will lack key information about MSI readiness for transition to the military departments for integration with weapon systems.

Software and Cybersecurity

Program officials said that vendors continue to experience challenges in hiring on-site software development staff. This has resulted in additional combined cost growth across the vendors of nearly $1 million with additional cost growth likely. Program officials still expect to complete software development for the receiver card by November 2025.

Program officials currently plan to complete a cybersecurity assessment during developmental testing and also plan to test cybersecurity objectives during the operational demonstration. The program has yet to determine the specific dates for these assessments.

Key Product Development Principles

The program reported some activities in line with leading principles for product development that we identified in past work. For example, MGUE Increment 2 had cost and schedule parameters defined at the start of the MTA effort. Our prior work found that leading companies use these parameters to guide how much an effort should cost and how long it should take. The program has a guardrail for developmental cost growth of more than 10 percent above the military department cost position. For schedule, the guardrail requires a critical design review for all awarded vendors by the end of fiscal year 2023.

Program officials said that representatives of the Army and Navy are staffed to the program office and they regularly engage with the services to understand their needs. However, MGUE does not solicit feedback directly from the warfighter, which it defined as the end user, in the design and development of the receiver cards. Our prior work found soliciting this user feedback is an important aspect to attaining a sound business case. We have ongoing work to define metrics associated with these leading principles, which we expect will help refine our evaluation of programs' use of them.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that the program made significant progress in 2022 toward delivering a critical warfighting capability. It noted that the program office successfully completed the MSI preliminary design reviews with each of its three contractors, and it is addressing various obstacles and uncertainties to mitigate schedule delays. The program office stated that, despite challenging requirements and a limited timeline, it is on track to meet the warfighter's need and complete the MSI critical design review by the end of fiscal year 2023 as planned. In addition, it noted that the team for the future handheld receiver completed multiple capability demonstrations with the vendors that show significant potential.

MTA Lead Component: Space Force

Common Name: Next Gen OPIR Block 0-GEO

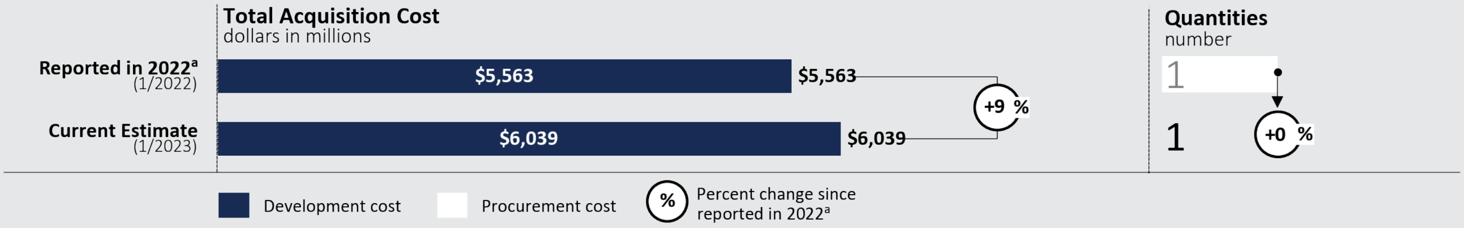
Next Generation Overhead Persistent Infrared Block 0-Geosynchronous Earth Orbit Satellites (Next Gen OPIR Block 0-GEO)

Source: U.S. Space Force. | GAO-23-106059

The Space Force's Next Gen OPIR Block 0-GEO, a follow-on to the Space Based Infrared System with a primary mission of missile warning, will consist of three geosynchronous earth orbit (GEO) satellites. The Block 0 GEO MTA rapid prototyping effort, which we assess here, will deliver the main mission payload—an infrared sensor. Two additional, ongoing MTA efforts are expected to deliver two Block 0 polar coverage satellites and modernize the ground segment.

6/18 MTA initiation	**10/18** Funds obligated	**9/19** Preliminary design review	**10/21** Critical design review	**1/23** GAO review	**10/23** 5 years since MTA funds obligated/Expected MTA completion	**9/25** First GEO satellite launch

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



[a] GAO-22-105230

Program Background and Transition Plan

The Air Force initiated Next Gen OPIR Block 0-GEO in June 2018 as an MTA rapid prototyping effort. The Space Force plans to complete rapid prototyping in 2023, when the payload is delivered. The program plans to transition to the major capability acquisition pathway in system development when prototyping is complete, at which point it will integrate the main mission payload on the first GEO satellites. The first Next Gen OPIR Block 0-GEO satellite is scheduled to launch in 2025.

Software Development as of January 2023

Approach: Agile

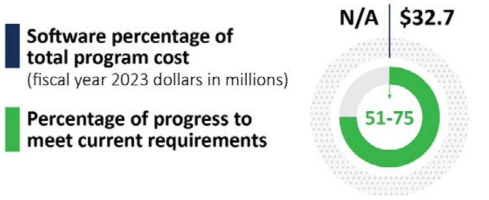
Frequency of end user evaluation (months)

Other frequency (see notes)

Less than 1	1-3	4-6	7-9	10-12	13 or more

Information not available

Frequency of testing and feedback (months)



The program reported that end users are involved in various activities, such as verifying requirements and assessing test results. The program also reported that software deliveries vary by component and the cost estimate is partial.

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	●	●
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

We assessed the GEO portion of the Next Generation OPIR Block 0 program, which contains the MTA deliverable.

Program Essentials

Prime contractor: Lockheed Martin

Contract type: CPIF (development)

Next Gen OPIR Block 0-GEO Program

Updates to Program Performance and Business Case

The Next Gen OPIR Block 0-GEO program must overcome numerous challenges before its first planned launch in 2025. As we reported last year, the GEO satellite's competing payload developers—Raytheon Technologies and a team of Northrop Grumman and Ball Aerospace—achieved a major milestone when they completed critical design reviews of their respective infrared payloads. Program officials announced that Raytheon would provide the main mission payload for two of the three Next Gen GEO satellites and Northrop Grumman/Ball Aerospace would provide the payload for one. The payload developers will fly their respective payload on one of the first two GEO satellites. Program officials have yet to determine which payload will integrate on the first GEO satellite. They also noted that the program will integrate whichever payload's delivery time frame best aligns with the spacecraft delivery schedule.

Offices within the Deputy Assistant Secretary of the Air Force and Space Systems Command jointly conducted an independent technical risk assessment in 2022. The Office of the Deputy Under Secretary of Defense for Research and Engineering approved the assessment and concurred with the identified risks. The assessment outlined several high-risk areas to achieving the scheduled 2025 launch. Program officials confirmed that the delivery of the main mission payload is the primary driver of schedule and technical risk to the program. Delays in delivery of the payload prototype increase the risk that the integration activities planned for the first GEO will not complete in time for the scheduled first launch in 2025.

Our review of this program indicates that delivery of both payloads and the first launch are likely to be delayed. According to program officials, each payload developer is working to overcome supply chain issues that could delay payload deliveries. Additionally, the complex integration of a novel payload and a modified spacecraft continue to present significant risk to the launch schedule.

Software and Cybersecurity

The program reported difficulty in hiring and retaining qualified engineering personnel due to a limited labor market. They indicated that additional personnel with specialty expertise would be helpful but noted that they are making tradeoffs within the program with current personnel to ensure the program's success is not hindered.

Key Product Development Principles

The program reported taking certain actions aligned with principles for product development used by leading companies. For example, it leverages risk and opportunity boards to assess the potential effects of deferring capabilities to achieve its cost and schedule goals. According to the program, these boards evaluate the estimated cost and schedule benefits of capabilities, the relevance of the capabilities or features in achieving key performance parameters, and utility to the end user. The program cited routing and processing electronics for communications, among the capabilities that have been deferred to date. Our prior work found that leading companies make an intentional decision to off-ramp capabilities that present a risk to delivering, on schedule, the capability prioritized by customers.

We have ongoing work to define metrics associated with these leading principles, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

Following an increase in technology readiness levels of three of the program's critical technologies, the program reported it achieved maturity in all 18 critical technologies this year.

In August 2022, Space Systems Command, the Space Development Agency, and the Missile Defense Agency finalized a memorandum of agreement to establish a combined program office. The office is expected to deliver integrated sensor-to-shooter capabilities that meet requirements in strategic missile warning, missile tracking, and missile defense.

It is too early to determine whether the combined program office will be effective in developing and integrating a system of systems strategy. Our ongoing work in this area suggests that coordination among all three agencies is occurring, but that integration plans and enterprise-wide risk assessment are still in the preliminary stages of development. We are following this and other related issues in our ongoing work.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program provided technical comments, which we incorporated where appropriate.

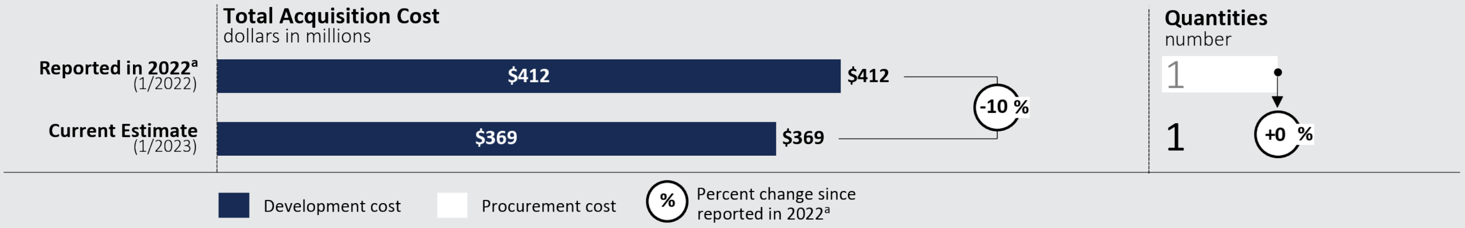
MTA Lead Component: Space Force Common Name: PTES

Source: LinQuest. | GAO-23-106059

Protected Tactical Enterprise Service (PTES)

The Space Force's PTES MTA rapid prototyping effort plans to develop and field the ground system for enabling initial capabilities of adaptive, anti-jam, wideband satellite communications under the Space Force's broader Protected Anti-Jam Tactical Satellite communications effort. We evaluated the planning and execution of the MTA rapid prototyping effort that the Space Force expects will demonstrate initial operational readiness for anti-jam tactical communications in the Pacific theater.

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



The reported cost decrease is due to a change in how the program is allocating costs to the MTA effort and does not reflect a cost savings, according to program officials.

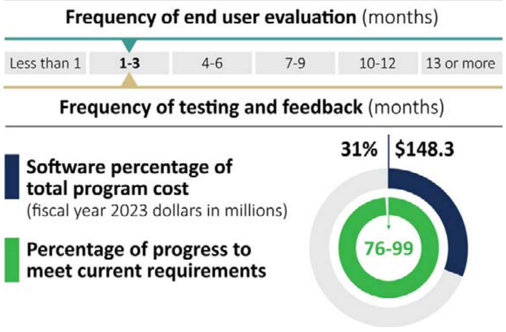
[a] GAO-22-105230

Program Background and Transition Plan

The Air Force initiated PTES as a rapid prototyping effort in June 2018. Program officials stated that the program began producing and testing prototype units in April and May of 2020, respectively, and completed an operational demonstration in January 2023 for the rapid prototyping effort. The program plans to transition to the software acquisition pathway in March 2023 and deliver initial capabilities to the Pacific theater by December 2023.

Software Development as of January 2023

Approach: Agile and DevSecOps



Program Essentials

Prime contractor: Boeing

Contract type: CPIF (development)

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	○	●
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

PTES Program

Updates to Program Performance and Business Case

Program officials reported holding a successful operational demonstration in January 2023. This demonstration had been delayed from June 2022. This delay was in addition to a 6-month delay we reported on last year. Program officials stated that this shift was due to a delay in the availability of user terminals—the devices that connect to the protected tactical satellite communications capability. These officials noted that they were following the development of three different user terminals by different programs across the services and conducted the operational demonstration with the first one available. Program officials stated that, while they could have conducted the demonstration earlier with a simulated terminal, they wanted the demonstration to be as realistic as possible. This delay is not expected to affect delivery of initial capabilities.

Critical technologies for the program are now all mature. However, according to program officials, the program continues to face challenges getting its crypto solution—which enables secure transmission of data—certified by the National Security Agency (NSA). Program officials stated that the challenges are due to high demand on NSA resources but that the program is continually working with the NSA to reduce risks of programmatic effects.

Software and Cybersecurity

According to program officials, they accelerated the cadence of delivering software demonstration builds and are delivering these builds quarterly. They also stated that these builds are the basis for the program to work cooperatively with users and test organizations to ensure the software meets desired outcomes.

The program plans to deliver its minimum viable product by December 2023 to support initial operational capability and incrementally add features as needed to meet future requirements. Program officials cited the availability of software development staff and personnel with other related skills to be a risk as development continues.

The program completed multiple cybersecurity-related activities during 2022, including a cooperative vulnerability identification, risk identification exercise, and major subsystem assessment. Program officials stated that the program plans to continue cybersecurity assessments throughout development.

Key Product Development Principles

The PTES program reported using certain approaches consistent with our leading principles for product development. For example, the program:

- established cost and performance parameters at initiation, which we found leading companies use as guideposts for their project teams; and
- reported having a process for prioritizing or deferring capability to meet schedule or cost goals. Program officials said that the program deferred some automation capabilities and prioritized other needs for near-term deployment.

While the program has yet to utilize modern digital engineering design tools, officials told us that they plan to use them in the future. They also said that, if these tools had been available for use before program start, risks to the program would have been reduced and prioritization decisions better informed.

We have ongoing work to define metrics associated with these leading principles, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

PTES plans to transition to the software acquisition pathway in March 2023, pending senior leadership approval. The program office made this decision since our assessment last year, when program officials stated that they were still determining the transition pathway. These officials stated the software pathway will best support the plan to continue incrementally adding features to PTES through software to support deployment to additional theatres.

This year, PTES reported costs for its MTA effort show a reduction. Program officials stated that this reduction is due to a change in how they are allocating costs to the MTA effort and does not reflect a cost savings.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that the program made progress in demonstrating system maturity. It also noted that PTES will continue to hold demonstrations as it incorporates additional software functionality. According to the program office, now that the program completed a successful operational demonstration, the program will transition to the software acquisition pathway. The program office added that it will continue to focus on the U.S. Indo-Pacific Command region as it works toward major test events and achieving initial operational capability.

Protected Tactical SATCOM (PTS)

Source: U. S. Air Force. | GAO-23-106059

The Space Force's PTS, an MTA rapid prototyping effort, is a space-based system that will transmit a protected, antijamming waveform to users in contested environments. The PTS MTA effort is intended to prototype modular, scalable, hostable payloads. PTS is part of the Space Force's broader Protected Anti-Jam Tactical SATCOM (satellite communications) mission area, which also includes the Protected Tactical Enterprise Service, another MTA effort assessed separately in this report.

11/18 MTA initiation

6/19 MTA funds obligated

10-12/21 Critical design review

1/23 GAO review

8/23 Transition to follow-on pathway

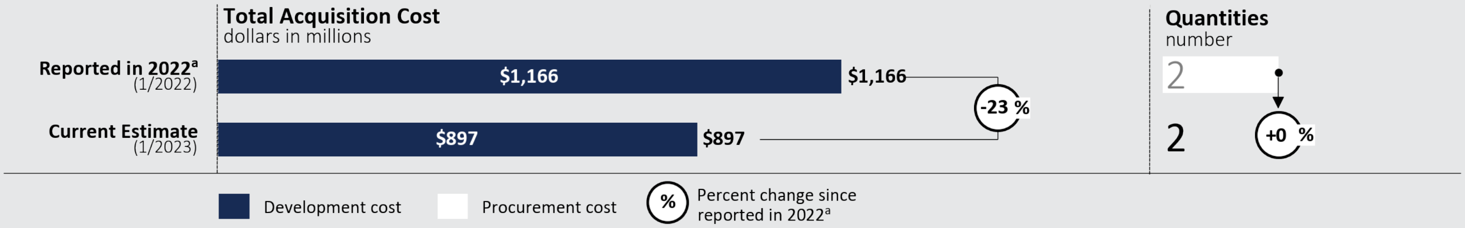
5/24 Expected MTA completion/ prototypes delivered

6/24 5 years since MTA funds obligated

7/24 First flight test

7/25 On-orbit testing and demonstration

Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



PTS revised its cost reporting approach this year to exclude Launch On-Orbit Operations and Residual Operations because those efforts are beyond the current MTA effort. The program included these costs in its reported estimate for our prior report.

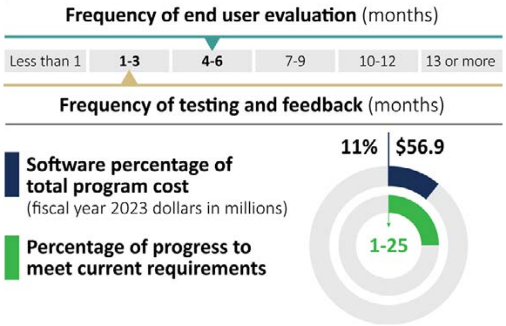
[a]GAO-22-105230

Program Background and Transition Plan

The Air Force initiated PTS using the MTA pathway in 2018. The program awarded three contracts in 2020 for different vendors to design payload prototypes, per program officials. Following preliminary design reviews, the program reported selecting two contractors in 2021 to continue building payloads. The program plans to transition to a follow-on effort in August 2023—prior to the planned May 2024 prototype payload deliveries. Program officials said that the previous plan to transition to the major capability acquisition pathway is in flux due to ongoing Department of the Air Force operational priority assessments.

Software Development as of January 2023

Approach: Agile and DevSecOps



Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	○	●
Approved middle tier of acquisition strategy	○	●
Formal technology risk assessment	●	●
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	○

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

Program Essentials

Prime contractors: Boeing; Northrop Grumman

Contract type: FFP (development)

PTS Program

Updates to Program Performance and Business Case

Obtaining approval and documentation from the National Security Agency (NSA) for one of its critical technologies continues to be PTS's biggest challenge, according to the program. While PTS officials reported that they made progress on this issue since last year's report, the program further delayed planned test events for the cryptographic unit. According to program officials, they now plan to hold the test readiness review in March 2023 and the security verification testing in April 2023. The program office previously reported it planned for these events to occur between December 2022 and early January 2023.

To help mitigate integration risks during the heart of the prototype payloads' building and testing phase in 2023, program officials told us that they delivered test cryptographic units to the vendors for early integration.

Certification delay of the cryptographic unit continues to drive schedule uncertainty. After the unit's security verification testing is complete, the program plans to conduct a formal schedule risk assessment in May 2023—more than 4 years after initiation. Our prior work shows that completing a schedule risk assessment at initiation can help decision makers assess whether an MTA rapid prototyping effort can meet the 5 year time frame for delivering residual operational capability, as called for by DOD policy.

The program experienced several new industrial base challenges in 2022 that led to schedule issues. Program officials said that pandemic-driven supply chain and staffing issues created shortages in contractors' and subcontractors' supplies, materials, and staff. Despite mitigation steps that contractors and the program took to address these issues, contractors and subcontractors depleted their schedule margin. The program expects contractors to resolve schedule issues associated with industrial base challenges in 2023. The program reported that it uses fixed price contracts and, therefore, schedule issues did not result in added costs for the government.

Software and Cybersecurity

PTS is experiencing challenges with both government and contractor software development staffing, which increases schedule risk. Program officials said that hiring staff with the appropriate certifications, expertise, and clearance is difficult due to the pandemic and the competitive labor market in Los Angeles.

According to program officials, they completed the first cybersecurity assessment for PTS in January 2023. According to program officials, the dates for several cybersecurity assessments were delayed to better align with the maturity of the software development effort. They told us that they do not anticipate that this delay will affect the prototype available-for-launch dates.

Key Product Development Principles

PTS reported undertaking certain efforts in line with leading principles for product development. For example, the program stated that it coordinated with its end users prior to beginning development and continues to solicit user feedback to inform design decisions. We previously found that involving end users helps leading companies attain a sound business case. The program also stated that its payload contractors are using modern design tools, such as digital engineering and modeling. Our prior work found these tools help leading companies iterate on design. We have ongoing work to define metrics associated with these leading principles, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

PTS's five critical technologies remain immature. These immature technologies may pose future challenges, since our prior work shows that entering system development with immature technologies creates risk for cost increases and schedule delays.

We previously reported that the program planned to transition to the major capability acquisition pathway at system development. However, this year program officials told us that plan is being reconsidered as part of a broader Department of the Air Force assessment of operational priorities. Program officials said that they expect the fiscal year 2024 budget request will provide additional information about the plans for the program's transition.

Program Office Comments

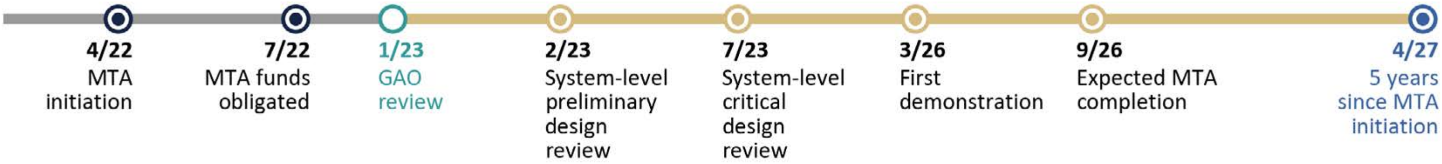
We provided a draft of this assessment to the program office for review and comment. The program provided technical comments, which we incorporated where appropriate. The program office stated that it made progress in the payload build phase of the program. It noted that the payload contractors completed 17 demonstrations, which showcased payload capability, matured critical technology, and mitigated risks. The program office also stated that it completed installation of equipment for development and test use.

Further, the program office stated it completed critical design review for the cryptographic unit, which it considered a significant milestone. The program office added that, while delays to NSA certification continue, it is mitigating these delays and still plans for payload delivery in fiscal year 2024.

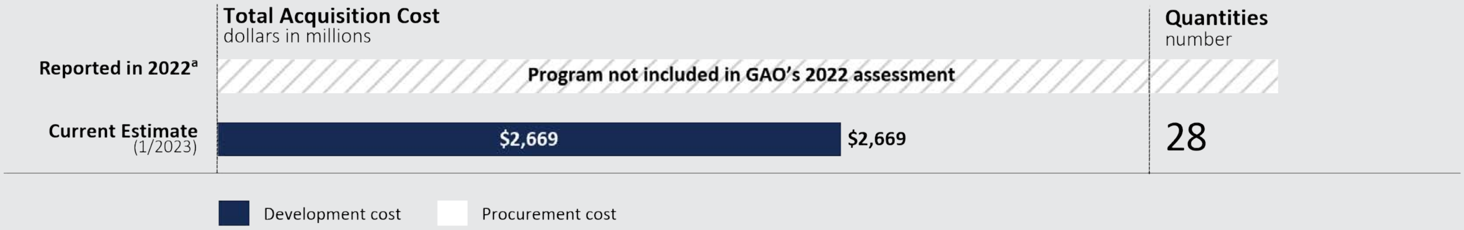
Source: Avantus/Qinteq on contract to Space Development Agency. | GAO-23-106059

Tranche 1 Tracking Layer (T1 TRK)

T1 TRK is a new MTA rapid prototyping effort by the Space Force's Space Development Agency (SDA). The Tracking Layer is one of several layers in SDA's planned Proliferated Warfighter Space Architecture (PWSA),to include data communications, missile warning, and other satellites. T1 TRK is the first tranche of space vehicles and consists of low Earth orbit space vehicles equipped with infrared sensors to provide initial missile warning and missile tracking capabilities. T1 TRK will interoperate with SDA's data communications T1 Transport Layer (T1TL), which we assessed separately.



Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



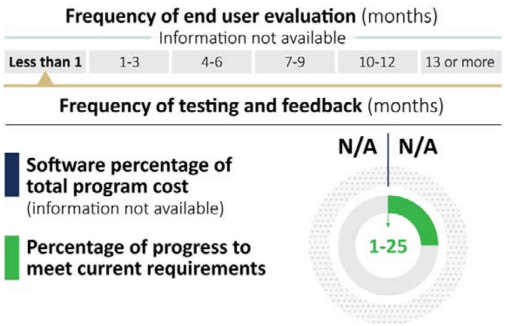
[a]GAO-22-105230

Program Background and Transition Plan

SDA initiated the T1 TRK rapid prototyping effort in April 2022. T1 TRK is intended to be an incremental evolution from the Tranche 0 Tracking Layer, according to SDA. The Tranche 0 Tracking Layer aims to demonstrate the feasibility of the architecture and advanced missile detection and tracking, while T1 TRK is expected to provide initial operational warfighting capability. SDA established other transaction agreements in July 2022 with two vendors. Each vendor will deliver 14 space vehicles for T1 TRK. The program plans to demonstrate T1 TRK with tests against representative targets in March 2026, prior to transitioning to operations. Program officials said that they are considering use of an MTA pathway for subsequent tranches.

Software Development as of January 2023

Approach: Agile, DevOps, and DevSecOps



The program reported that end users will begin evaluating and providing feedback on software in March 2026. According to the program, software development cost for both the Tracking and Transport layers is $88.5 million, but this cost cannot be broken out for each layer.

Program Essentials

Prime contractors: L3Harris and Northrop Grumman

Contract type: FFP

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	●	●
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	●	●

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

Tranche 1 Tracking Layer Program

Key Elements of Program Business Case

T1 TRK had all five business case elements developed at initiation. Prior to initiation, the Air Force Cost Analysis Agency completed an independent assessment of the program office cost estimate and provided funding recommendations. In addition, the program identified cost, schedule, and technical performance risks and mitigation steps. The SDA Risk Oversight and Management Board continues to evaluate multiple types of risk on a monthly basis.

There are no critical technologies for T1 TRK, according to program officials, because the technologies are already used commercially. However, program officials acknowledged that vendors deemed two sensors immature at the time of proposal because they had yet to be developed at scale. The officials added that they do not consider these sensors to be high risk. We previously found that leading commercial companies do not introduce unproven technologies into new products until they prove the technologies can be produced at scale.

SDA has yet to launch the Tranche 0 predecessor tranche, which is delayed until March 2023 because of supply chain issues and technical problems it found during testing, according to program officials. Program officials stated that they do not expect the T1 TRK schedule to be affected because several programs other than Tranche 0 are also informing T1 TRK. Given that T1 TRK already began development, this delay will limit the extent to which the program could obtain early knowledge from Tranche 0 and reduce design risk for T1 TRK.

Software and Cybersecurity

SDA is managing software development for T1 TRK and T1TL together as part of an enterprise effort. Program officials reported that they began software development in September 2022 and expect to complete a minimum viable product for software by December 2023. Program officials identified software development as a medium risk, driven, in part, by the effort proving to be more difficult than expected.

SDA's cybersecurity strategy encompasses the full PWSA, which includes T1 TRK and T1TL. SDA delivered a draft cyber security strategy in April 2022 and an updated, final version of the strategy in February 2023 to the Under Secretary of Defense for Acquisition and Sustainment. SDA plans to require vendors to conduct their own cyber testing and evaluation and to support planned SDA-led efforts, such as cooperative vulnerability and penetration testing.

Key Product Development Principles

SDA indicated that it plans to implement certain practices aligned with key product development principles used by leading companies. For example, SDA stated that it uses modern design tools and regularly engages a warfighter council on program requirements and performance. We previously found that these approaches enable efficiencies during development and help inform improvements to systems. We have ongoing work to define metrics associated with our leading principles for product development, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

SDA plans to use a modular open systems approach across the PWSA that leverages commercial capabilities. It anticipates that this approach will enable competition for new tranches and a stable market for sustainment. Prior to realizing those potential benefits, however, SDA faces challenges with integrating a complex system of multiple vendors and segments into a proliferated constellation of hundreds of satellites, intended to be enhanced every 2 years.

Program officials told us they expect SDA's use of communications and networking standards for vendors to help facilitate integration of the various components of the PWSA. However, program officials said that they are also monitoring any supply chain risks that could affect T1 TRK and T1TL.

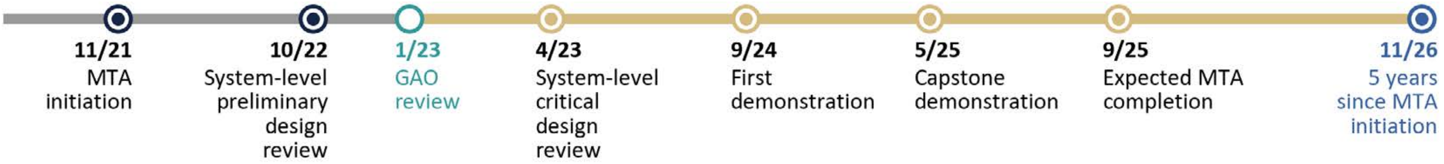
Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that SDA is delivering resilient, responsive, threat-driven space-based capabilities to the warfighter. It also noted that SDA is accelerating development and fielding of next-generation capabilities. It added that SDA values schedule and speed, while also focusing on cybersecurity, interoperability, and risk management. According to the program office, SDA leverages innovative commercial technologies, encourages experimentation and competition, and enhances warfighting capabilities through a spiral development approach. This approach repeats development phases in a "spiral" until completed in an effort to reduce cost and increase opportunities to deliver new capability.

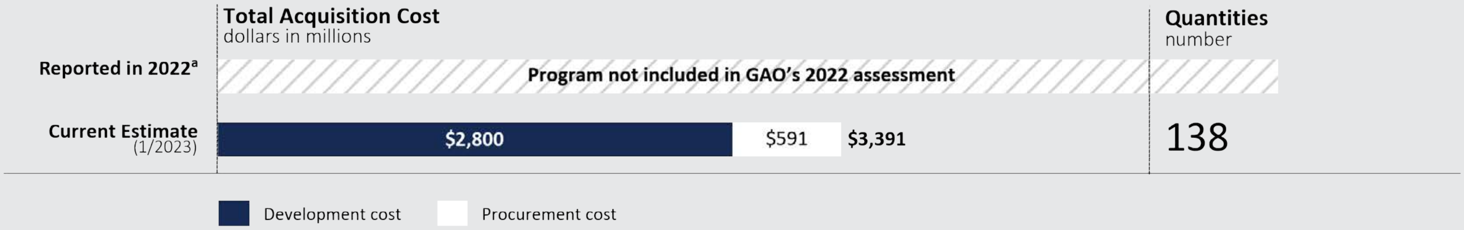
Tranche 1 Transport Layer (T1TL)

Source: Avantus/Qinetiq on contract to the Space Development Agency. | GAO-23-106059

The Space Force's Space Development Agency's (SDA) T1TL—an MTA rapid prototyping effort—is one of several layers of SDA's planned Proliferated Warfighter Space Architecture. T1TL plans to launch space vehicles into low Earth orbit. The intent of T1TL is to provide regional coverage for continuous communication and connectivity for quick user targeting for mission payloads. We also evaluated the Proliferated Warfighter Space Architecture's Tranche 1 Tracking Layer (T1 TRK) in a separate assessment.



Estimated Middle Tier of Acquisition Cost and Quantities fiscal year 2023 dollars in millions



The program is in the process of updating the estimated cost for launch.

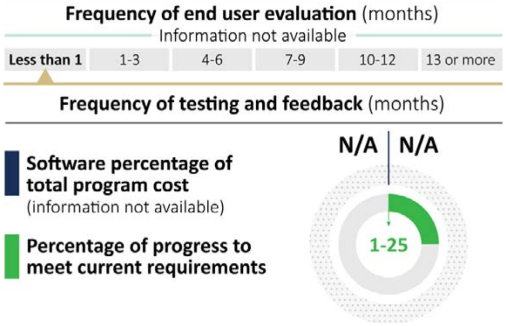
ªGAO-22-105230

Program Background and Transition Plan

SDA initiated the T1TL rapid prototyping effort in November 2021. T1TL plans to demonstrate data communications on a persistent regional basis, building off a preceding effort, Tranche 0. SDA established other transaction agreements in February 2022 for T1TL with three vendors for the space vehicles. SDA intends to transition the rapid prototyping effort to operations and sustainment if it successfully completes a planned capstone demonstration in May 2025. Program officials stated that T1TL may use the MTA pathway for future Transport Layer program tranches.

Software Development as of January 2023

Approach: Agile, DevOps, and DevSecOps



The program reported that end users will begin evaluating and providing feedback on software in August 2025. According to the program, software development cost for both the Tracking and Transport layers is $88.5 million, but this cost cannot be broken out for each effort.

Program Essentials

Prime contractors: York Space Systems; Lockheed Martin; Northrop Grumman

Contract type: FFP

Attainment of Business Case Knowledge as of January 2023

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle tier of acquisition strategy	●	●
Formal technology risk assessment	●	●
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	●	●

● Knowledge attained ○ Knowledge not attained … Information not available NA - Not applicable

T1TL Program

Key Elements of Program Business Case

T1TL had all key business case elements developed at program initiation, with schedule and risk evaluations continuously updated on a monthly basis through their Risk Management Oversight Board. Program officials stated that an independent cost estimate assessment was also completed at that time. They told us in December 2022, however, that they believed the results of the independent cost estimate did not accurately reflect program costs because it was over the program office's estimate and actual contractor offers.

Program officials said that they assessed technology risk and maturity as part of reviewing vendor proposals. Our prior work showed that schedule and technology assessments completed at program initiation provide information to decision makers about the program's likelihood of achieving its objectives.

The program stated that it does not have critical technologies. When considering vendors, program officials stated that they target technologies used in the commercial market that are mature or approaching maturity. Program officials stated that they integrated such mature technology, but they clarified that not all of the technologies that will be in the T1TL have gone to space.

SDA described T1TL as an incremental evolution of Tranche 0, intended to be a minimum viable product that, in part, demonstrates low-latency data transfer. Program officials said that the first of two planned Tranche 0 launches were delayed twice, now planned for March and June 2023, because of supply chain issues and a technical issue identified during testing. They noted that lessons learned to date from T0 were incorporated into T1TL requirements and they do not expect the delays to affect T1TL. However, additional issues discovered at Tranche 0's launch could result in T1TL rework.

Software and Cybersecurity

Software development for T1TL is part of an enterprise effort, including the T1 TRK. Program officials reported that the program began software development in September 2022 and expects to complete a minimum viable product for software by December 2023. SDA identified software development as a medium risk, driven in part by the effort proving to be more difficult than expected.

SDA's cybersecurity strategy encompasses the full Proliferated Warfighter Space Architecture, which includes T1TL and T1 TRK. SDA delivered a draft cyber security strategy in April 2022 and an updated, final version of the strategy in February 2023 to the Under Secretary of Defense for Acquisition and Sustainment. SDA plans to require vendors to conduct their own cyber testing and evaluation and to support planned SDA-led efforts, such as cooperative vulnerability and penetration testing.

Key Product Development Principles

SDA plans to utilize certain key product development principles used by leading companies. For example, T1TL interacts regularly with its end user, the joint warfighters in the combatant commands. SDA formed a warfighter council to receive end user feedback monthly to develop and refine SDA's minimum viable products and capabilities. We previously found that ongoing engagement with customers is an important aspect of iterative development that leading companies use to prioritize features and identify improvements to the product.

We have ongoing work to define metrics associated with our leading principles for product development, which we expect will help refine our evaluation of programs' use of them.

Other Program Issues

According to program officials, T1TL faces a complex integration for its planned space vehicles into a constellation that will be enhanced every 2 years. However, they introduced standards into the marketplace to help facilitate this integration. Also, SDA acknowledged that Tranche 0's supply chain problems in sourcing computer chips could affect T1 and subsequent tranches.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that SDA is delivering resilient, responsive, threat-driven, space-based capabilities to the warfighter. It also noted that SDA is accelerating development and fielding of next-generation capabilities. It added that SDA values schedule and speed, while also focusing on cybersecurity, interoperability, and risk management. According to the program office, SDA leverages innovative commercial technologies, encourages greater experimentation and competition, and enhances warfighting capabilities through a spiral development approach. This approach repeats development phases in a "spiral" until completed in an effort to reduce cost and increase opportunities to deliver new capability.

JOINT DOD

Program Assessments

▲ F-35 Lightning II (F-35)

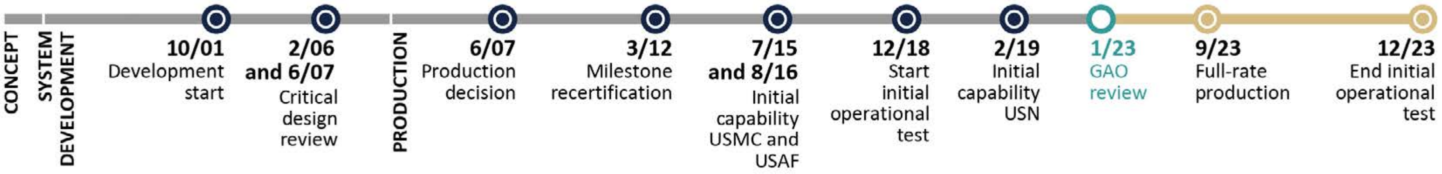
Assessment type	Program name
MDAP	F-35 Lightning II (F-35)

Source (previous page image): U.S. Navy photo courtesy Lockheed Martin/Dane Wiedmann. | GAO-23-106059

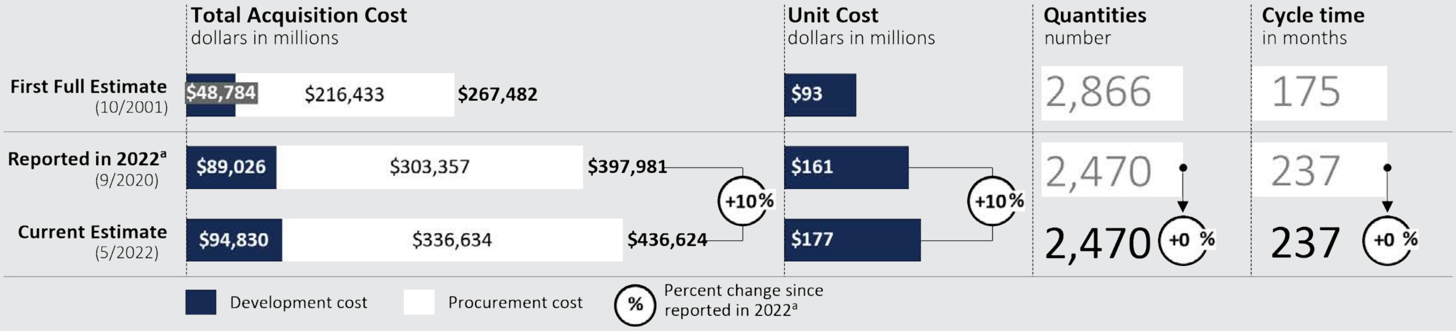
Source: Department of Defense. | GAO-23-106059

F-35 Lightning II (F-35)

DOD is developing three fighter aircraft variants integrating stealth technologies, advanced sensors, and computer networking for the U.S. Air Force (USAF), Marine Corps (USMC), and Navy (USN); international partners; and foreign military sales customers. The Air Force's F-35A variant will replace the F-16 and A-10's air-to-ground attack capabilities. The Marine Corps' F-35B variant will replace its F/A-18A/C/D and AV-8B aircraft. The Navy's F-35C will complement its F/A-18E/F aircraft. DOD is 5 years into a development effort to modernize the F-35 aircraft's capabilities, known as Block 4.



Program Performance fiscal year 2023 dollars in millions

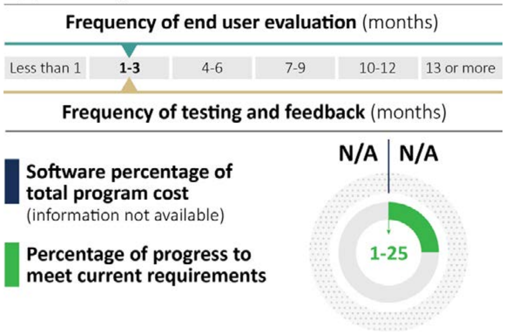


Total quantities comprise 14 development quantities and 2,456 procurement quantities. The graphic bars depict only research and development, and procurement costs. However, total acquisition costs may also include costs for military construction, as well as acquisition operation and maintenance.

[a] GAO-22-105230

Software Development as of January 2023

Approach: Agile



The program reported the percentage complete for development of the Block 4 modernization effort.

Program Essentials

Prime contractor: Lockheed Martin (Lot 12-14 Production contract; Block 4 Phase 2.3 contract); Pratt & Whitney (engine contract)

Contract type: CPIF/CPAF (Block 4 Phase 2.3 contract) (procurement, development), majority FPIF (Lot 12-14 Production contract; engine contract) (procurement)

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current Status
Demonstrate all critical technologies in a relevant environment	○	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	○	●
Product design is stable	Design Review	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	Production Start	
Demonstrate critical processes on a pilot production line	○	●
Test a production-representative prototype in its intended environment	○	●

● Knowledge attained ○ Knowledge not attained ... Information not available NA - Not applicable

F-35 Program

Technology Maturity, Design Stability, and Production Readiness

Development challenges with the F-35 simulator continue to delay the program's full-rate production decision. Although all open-air flight tests needed for initial operational testing and evaluation were completed as of June 2021, ongoing challenges with developing the joint simulation environment—used to conduct virtual tests unreproducible in a real flight—delayed the program's remaining 64 simulated flight tests.

The program expects to receive final accreditation for the simulator from the Air Force Operational Test and Evaluation Command in mid-year 2023. Subsequently, it plans to conduct the remaining tests. The program currently plans to make the full-rate production decision in late 2023.

Program officials reported that, in 2022, the contractor continued to face parts shortages and low workforce staffing, among other things, resulting in late aircraft deliveries. According to DOD officials, an incident in December 2022 led the program to pause engine deliveries, which resulted in aircraft delivery delays. While engine deliveries resumed in mid-February 2023, program officials stated that they are still working through a recovery plan.

Software and Cybersecurity

The program continues to face software development challenges with its Block 4 modernization effort, a challenge we also highlighted in our last assessment. As of August 2022, according to DOD officials, the program delivered Block 4 capabilities late to flight testers and software defects remain a problem.

The program made some software development improvements over the past year. These include increasing automated testing and conducting more tests to ensure that new or updated software does not affect existing software and to identify issues earlier while maintaining the current software testing frequency. The program also improved the computer system used to track and analyze Block 4 software development metrics.

The program is also transitioning from a 6-month to a 12-month software delivery cycle to the fleet with, according to DOD officials, the goal of allowing more time to improve software quality and to train pilots between software releases. However, as this initiative is not yet complete, it is too soon to evaluate its effectiveness.

The program and contractor continue to make progress in integrating cybersecurity into its software development process, including investing in cyber range testing facilities and developing an updated cyber strategy.

Other Program Issues

Since our last assessment, the program's cost increased by a total of approximately $38.6 billion dollars (10 percent). In part, the cost growth resulted from increasing modernization costs and rising procurement costs driven by delaying aircraft deliveries into the future.

Testing delays and development issues compressed testing time frames for Technology Refresh 3, a hardware processor update needed to implement many Block 4 capabilities. The program plans to integrate Technology Refresh 3 hardware onto production line aircraft for delivery beginning in July 2023 as scheduled. However, a one year testing delay and ongoing software development issues give the program less time than originally planned to ensure that Technology Refresh 3 is ready for delivery.

The program is also evaluating engine modernization options to address engine power and cooling limitations in which future Block 4 capabilities will need to operate. As of October 2022, the program office is developing a business case analysis to assess future engine alternatives but has yet to identify updated engine requirements.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate.

Appendix II: Objectives, Scope, and Methodology

This report responds to title 10, section 3072 of the United States Code.[80] Specifically, this report assesses (1) the characteristics of the Department of Defense's (DOD) costliest weapon programs and how these programs have performed according to selected cost and schedule measures; (2) the extent to which major defense acquisition programs (MDAP) have implemented knowledge-based acquisition practices; (3) the extent to which middle tier of acquisition (MTA) programs and future major weapon acquisitions are using practices aligned with selected leading principles for product development; (4) the extent to which programs have implemented modern software development approaches and recommended cybersecurity practices; and (5) recent legislative, organizational, and policy changes pertaining to modular open system approaches (MOSA) and the extent to which selected programs report they are implementing a MOSA.

This report also presents individual knowledge-based assessments of 65 MDAPs, future major weapon acquisitions, and MTA programs (see appendix I for GAO's assessments).

Program Selection

To identify DOD's most expensive weapon programs, we took the following steps.

- **MDAPs.** We retrieved DOD's list of MDAPs from the Defense Acquisition Visibility Environment (DAVE) system as of April 2022. To identify MDAPs for individual assessments, using the Defense Acquisition Executive Summary (DAES) data obtained from DAVE, we narrowed our list to those that were either between the start of development and the early stages of production or well into production

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[80] Title 10, section 3072 of the U.S. Code was enacted by section 833 of the John S. McCain National Defense Authorization Act for Fiscal Year 2019. See Pub. L. No. 115-232, § 833 (2018). This statute was later amended by section 813 of the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 and section 812 of the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023. See Pub. L. No. 116-283, § 813 (2021) and Pub. L. No. 117-263, § 812 (2022). This statute includes a provision for us to submit to the congressional defense committees an annual assessment of selected DOD acquisition programs and efforts by March 30 of each year from 2020 through 2026. Our assessment of the performance of DOD's IT programs is included in a separate report, which we also prepared in response to title 10, section 3072 of the U.S. Code. We plan to issue a report later this year.

but introducing new increments of capability or significant changes expected to exceed the cost threshold for designation as an MDAP.[81]

- **Future major weapon acquisitions.** We retrieved the list of programs from DOD's DAVE system that were identified by DOD as pre-MDAPs—programs planning to develop their systems on the major capability acquisition pathway—as of April 2022. We also reviewed budget documentation to identify other programs that had yet to be formally initiated on an Adaptive Acquisition Framework (AAF) pathway with costs expected to exceed thresholds for designation as a MDAP.
- **MTA programs.** We obtained a list of programs using the MTA rapid prototyping or rapid fielding path from DAVE that were reported by the military departments, as of May 2022, as having a cost for the current MTA effort above the equivalent threshold cost for designation as an MDAP—$525 million for Research, Development, Test, and Evaluation (RDT&E) or $3.065 billion in procurement (fiscal year 2020 constant dollars) or were included in our scope last year.[82] In some instances, current MTA efforts represent one of multiple planned

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[81] MDAPs generally include programs that are not a highly sensitive classified program and that are either (1) designated by the Secretary of Defense as a MDAP; or that are (2) estimated to require an eventual total expenditure for research, development, test, and evaluation, including all planned increments or spirals, of more than $525 million in fiscal year 2020 constant dollars or, for procurement, including all planned increments, of more than $3.065 billion in fiscal year 2020 constant dollars. See 10 U.S.C. § 4201(a); DOD Instruction 5000.85, *Major Capability Acquisition* (Aug. 6, 2020) (incorporating change 1, Nov. 4, 2021) (reflecting statutory MDAP cost thresholds in fiscal year 2020 constant dollars).

[82] We selected 19 MTA efforts for review, of which 15 met the acquisition category (ACAT) I threshold. Twenty MTA programs initially reported costs in the budget at or above the ACAT I threshold that met the scope of the engagement. Three of those 20 programs (Indirect Fire Protection Capability Increment 2-1 [IFPC Inc 2-1], B-52 Commercial Engine Replacement Program [CERP] Rapid Virtual Prototype [RVP], and Family of Advanced Beyond Line-of-Sight Terminals Force Element Terminal) reported costs slightly above the ACAT I threshold. However, when program costs were deflated to fiscal year (FY) 2020 dollars, these programs' costs did not meet the ACAT I criteria. We included IFPC Inc 2-1 and B-52 CERP RVP as well as Protected Tactical Enterprise Service that did not meet the ACAT I designation as they were included in our 2022 assessment. Family of Advanced Beyond Line-of-Sight Terminals Force Element Terminal was removed due to classification issues. Integrated Visual Augmentation System (IVAS) Rapid Prototyping reported costs above the ACAT I threshold, but had transitioned to a follow-on rapid fielding effort, which did not meet the ACAT I threshold. However, we included only the IVAS Rapid Fielding effort in our scope because it was the follow-on effort the IVAS Rapid Prototyping effort. Two programs (Mobile Protected Firepower and F-15EX) met the criteria to be included as an MTA. However, both programs subsequently transitioned to a major capability pathway and are included as MDAP assessments.

efforts that are planned as part of a program's overall acquisition strategy. Our assessment focused on the current MTA effort.

We excluded the Missile Defense Agency's Missile Defense System and its elements from all analyses due to the lack of an integrated long-term baseline. We also excluded classified programs and programs considered sensitive from our analyses. For our portfolio analysis, we selected 75 MDAPs, 19 programs using the MTA pathway, and seven future major weapon acquisitions.

Standardization of Terminology and Cost Comparisons

To make DOD's acquisition terminology consistent across programs we reviewed, we standardized the terminology for key program events.

- For most MDAPs and future major weapon acquisitions in our assessment, "development start" refers to the initiation of an acquisition program as well as the start of either engineering and manufacturing development or system development. This date generally coincides with DOD's milestone B for non-shipbuilding programs on the major capability acquisition pathway.

  A few MDAPs or future major weapon acquisitions in our assessment have a separate program start date, which begins a pre-system development phase for program definition and risk-reduction activities. This program start date generally coincides with DOD's milestone A for non-shipbuilding programs on the major capability acquisition pathway, which denotes the start of technology maturation and risk reduction.

  The production decision generally refers to the decision to enter the production and deployment phase, typically with low-rate initial production. This decision generally coincides with milestone C for non-shipbuilding programs on the major capability acquisition pathway. The initial capability refers to the initial operational capability, which some programs refer to as their first unit equipped or required asset availability.

- For shipbuilding programs, the schedule of key program events in relation to acquisition milestones varies for each program. Our work on shipbuilding leading practices has identified the detailed design contract award and the start of lead ship fabrication as the points in the acquisition process roughly equivalent to development start and design review for other programs.
- For programs using the MTA pathway, the program start date for programs designated on or after December 30, 2019, is generally the

date an acquisition decision memorandum was signed, initiating an MTA rapid prototyping or rapid fielding program. MTA programs designated before December 30, 2019, and certain programs designated after this date, generally maintain their MTA program start date as the date funds were first obligated.

- Programs using the MTA pathway also develop transition plans, which refer to the point at which the program begins another effort using the MTA pathway or another acquisition pathway. For each MTA program using the rapid prototyping path, DOD policy directs DOD components to develop a process for transitioning successful prototypes and programs to new or existing acquisition programs for production, fielding, and operations and sustainment.[83] For each MTA program using the rapid fielding path, DOD components are required to develop a process for transitioning successful programs to operations and sustainment.

Additionally, for all programs we reviewed, we converted all cost information to fiscal year 2023 dollars using conversion factors from DOD Comptroller's National Defense Budget Estimates for Fiscal Year 2023.[84]

Data Collection and Reliability

To assess current costs and changes in costs of the MDAPs and MTA programs we reviewed, we took steps to collect and assess the reliability of this year's data.

- For MDAPs, we obtained and analyzed cost data from each program's December 2021 Selected Acquisition Report. We compared the 2023 portfolio with the programs that issued Selected Acquisition Reports in December 2019 (i.e., the 2021 portfolio) to identify the programs that exited and entered the 2023 portfolio, and the total cost and number of programs in the 2023 portfolio compared with DOD's 2021 MDAP portfolio.[85] Programs enter the portfolio when they start Selected Acquisition Report reporting, which typically occurs at milestone B. Programs exit the portfolio when Selected Acquisition

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[83] Department of Defense, *Operation of the Middle Tier of Acquisition (MTA)*, DOD Instruction 5000.80 (Dec. 30, 2019).

[84] Department of Defense, Office of the Under Secretary of Defense (Comptroller), *National Defense Budget Estimates for Fiscal Year 2023* (July 2022), 76-77.

[85] We were not able to compare this data with DOD's 2022 MDAP portfolio because DOD did not include a Future Years Defense Program as part of its fiscal year 2022 President's Budget request. As a result, DOD did not issue comprehensive Selected Acquisition Reports for fiscal year 2021, so we used the most recent preceding year's Selected Acquisition Reports for this report's comparison.

Report reporting ends, which typically occurs when the program has expended 90 percent of total estimated program cost. For our assessment of cost changes within the portfolio of MDAPs for which we produced two-page assessments, we also used DAES data—primarily from September 2022—and acquisition program baselines in instances where programs established new cost and schedule baselines that were not reflected in the DAES.

- For MTA programs, we obtained and analyzed data from each MTA effort's program identification documents submitted to the Office of the Secretary of Defense (OSD) during fiscal year 2022.

We also distributed a questionnaire to 65 selected program offices:

- 35 MDAPs in development or early production;
- four new increments of MDAPs that introduce capability or significant changes to the MDAP, although the MDAP is well into production (we refer to these new increments as MDAP Increments);
- seven future major weapon acquisitions; and
- 19 MTA programs.

We used the questionnaire to obtain information on programs' schedule and implementation of knowledge-based acquisition practices, MOSA, key principles for product development, and selected software and cybersecurity practices, among other things. For future major weapon acquisitions, MDAPs introducing new increments, and MTA programs, we obtained cost and funding information through a data collection instrument submitted by program offices. We received responses from August 2022 through October 2022.

To help ensure the reliability of the data collected through our questionnaire, we took a number of steps to reduce measurement and non-response error. These steps included:

- Conducting pretests of new questions prior to distribution to ensure our questions were clear, unbiased, and consistently interpreted. Our pretests of questionnaires covered new questions to better ensure the questionnaire could be understood by officials.
- Collecting and analyzing supplemental program information, such as budget submissions, acquisition decision memorandums, acquisition strategies, program cost and schedule estimates, service cost positions or independent cost estimates, risk assessments, and documents relating to technology maturity, software development, and

cybersecurity. We also interviewed or received written responses from program officials to supplement and clarify this information.

To assess the reliability of the DAES data and the DAVE system that houses the data, we relied on a full data reliability assessment of DAES and DAVE conducted in August 2022 as part of this review.

For that assessment, we sent questions to DOD related to DAVE, the DAES data in DAVE, and the custodians of the data. Specifically, we asked how DOD monitors and updates DAVE, how the data is updated over time, and what quality assurance steps are taken to ensure data accuracy, among other topics.

To assess the reliability of the Selected Acquisition Report data, we conducted electronic testing for missing data and discrepancies between reports submitted in multiple formats. We followed up with DOD officials as necessary to resolve issues identified during testing.

To assess the reliability of MTA cost data, we issued a supplemental data collection instrument to each MTA program to cross-check data from the program identification documents submitted to the Office of the Secretary of Defense for the fiscal year 2023 President’s Budget and solicit any updates to the numbers, with explanation.

Based on these efforts, we determined that the data retrieved from DAVE, Selected Acquisition Reports, and MTA program cost data were sufficiently reliable for the purposes of this report.

Assessment of MDAP Cost and Schedule Performance and Knowledge-Based Practices

MDAP Cost and Schedule Performance

Our analysis of the 2023 portfolio includes comparisons of cost and schedule changes as compared with the last year that complete Selected Acquisition Report cost reporting was available (December 2019) and from baseline estimates (first full estimates) from the programs’ initial Selected Acquisition Report submissions. We compared total cost, schedule performance, and number of programs in the 2023 portfolio with the 2021 portfolio. To analyze cost changes, we compared combined procurement, RDT&E, and total acquisition costs from the December

2021 Selected Acquisition Reports with those individual and combined costs reported in December 2019 Selected Acquisition Reports. We also calculated the total cost changes from programs that were included in both the December 2019 and December 2021 Selected Acquisition Reports, and that were both attributable and not attributable to quantity changes (increases or decreases in total quantity of units a program plans to order).

In a departure from prior years, the December 2021 Selected Acquisition Reports did not include detailed explanations for factors contributing to each program’s cost changes. Consequently, we were unable to analyze factors affecting costs across all of the programs that produced a December 2021 Selected Acquisition Report. Instead, we focused our analysis on cost changes among the 32 MDAPs for which we produced two page assessments in both this report and our 2022 report. The data used in this analysis were drawn from DAES reporting or new acquisition program baselines. Of those 32 programs, we examined the 15 programs reporting cost increases and 17 programs reporting cost reductions and analyzed the factors that programs reported drove their cost changes. We also analyzed the extent to which changes in planned total unit order quantities affected total costs for these programs.

To analyze MDAP schedule performance, we identified 27 MDAPs in the 2023 portfolio that had yet to declare initial operational capability, as of their December 2021 Selected Acquisition Reports. We compared the average cycle time of these programs, defined as the number of months between program start and the achievement of initial operational capability or an equivalent fielding date, with the average cycle time reported in their December 2019 Selected Acquisition Reports. Of the 35 MDAPs for which we produce two-page assessments, we identified 28 for which our assessments reflected either a prior change to their cycle time or a new change in cycle time this year. We compared the extent of the new cycle time change with the changes reported from the program’s original cycle time date, and identified the driving factors from the assessments for the five programs with the largest schedule change since our prior report. The data for this analysis were drawn primarily from DAES reporting and program offices’ questionnaire responses.

Analysis of MDAP Adherence to Knowledge-Based Acquisition Practices

Our analysis of how well MDAPs adhere to a knowledge-based acquisition approach focuses on knowledge attained by key decision points:

- system development start for non-shipbuilding programs or detail design contract award for shipbuilding programs;
- critical design review for non-shipbuilding programs or lead ship fabrication start for shipbuilding programs; and
- production start.[86]

Factors we analyzed at each key decision point included those that we have previously identified as underpinning a knowledge-based acquisition approach, including technology maturity, design stability, and production readiness. Additional information on how we collected these data is in the assessment of MDAPs' Attainment of Product Knowledge section of this appendix. Appendix IV includes a list of the practices that are associated with a knowledge-based acquisition approach.

To assess the knowledge attained by key decision points, we collected data using our questionnaire from 35 MDAPs in development or the early stages of production about their knowledge at each point. We did not verify the data provided by the program offices. Rather, we reviewed the data and performed various checks to determine that they were reliable for our purposes. Where we discovered discrepancies, we clarified the data accordingly with program offices.

We reassessed programs' knowledge in cases where the information underpinning the attainment of knowledge had since changed. For example, if we previously assessed a program as having released at least 90 percent of design drawings, but obtained information from the program this year that clarified it had not obtained this knowledge, we changed our score this year to reflect that knowledge was not attained. We also provided examples of knowledge attainment for MDAPs entering our portfolio for the first time and of programs that did not attain knowledge on time to inform key decisions and realized schedule delays this year. These examples were drawn from our two-page assessments.

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[86] We assessed the CVN 78 *Gerald R. Ford* Class Nuclear Aircraft Carrier's resources and requirements knowledge metrics at the time of the construction preparation contract award, rather than the detail design contract award, because that is the point at which the program began CVN 78 development. In addition, we assessed the F-15EX and Mobile Protected Firepower systems' knowledge attainment at the time of the programs' transitions from the MTA pathway to the major capability acquisition pathway.

Assessment of MTA Program Cost and Schedule and Critical Technologies

Cost and Schedule

To determine the planned costs for current MTA efforts, we provided data collection instruments for the program offices to provide updated cost and quantity data for MTA efforts. To assess the accuracy of and supplement that cost data, we reviewed the cost data in the program identification documents that the military departments submitted to OSD for the fiscal year 2023 President's Budget request. To determine one-year MTA cost changes, we compared costs reported for our prior assessment in June 2022 against costs reported for this assessment.[87] We converted all cost information to fiscal year 2023 dollars using conversion factors from the DOD Comptroller's National Defense Budget Estimates for Fiscal Year 2023.[88]

We reviewed schedule data from program identification documents and program questionnaires, including program start and planned end dates. To assess the extent to which planned operational demonstrations have shifted earlier or later since MTA program start, we compared a) the planned operational demonstration date reported in the program's first data submission to OSD following program start; and b) the planned demonstration date reported in the program's Budget Estimate Submission for 2024, which were reported by the programs in August 2022 or September 2022.

Critical Technologies

To collect data on the maturity of MTA programs' critical technologies, in our questionnaire we asked MTA programs to identify their critical technology elements, the current technology readiness level (TRL) for each critical technology, and projections for the technologies' TRLs at completion of the current MTA effort. We assessed the extent to which programs that reported having immature technologies last year increased their TRLs over the past year. We identified the critical technologies and associated TRLs reported to us for our prior report, and determined whether the MTA programs reported a different TRL for these technologies for this report. We also identified the lowest current TRL and

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[87] GAO*, Weapon Systems Annual Assessment: Challenges to Fielding Capabilities Faster Persist*, GAO-22-105230 (Washington, D.C.: June 8, 2022).

[88] Department of Defense, Under Secretary of Defense (Comptroller), *National Defense Budget Estimates for FY 2023* (July 2022), 76-77.

lowest projected TRL at the completion of each MTA effort to understand the amount of expected maturation work that remains before the end of the current effort.

Leading Principles for Product Development

To assess the extent to which MTA programs and future major weapon acquisitions used approaches generally aligned with our leading principles for product development, our program questionnaires included questions related to a selection of sub-principles identified in our prior work.[89] For example, we asked whether the MTA programs and future major weapon acquisitions use or plan to use modern design tools—such as digital engineering, 3D modeling, and artificial intelligence—to enable multiple design iterations, or whether they have established a process to prioritize or defer capabilities to meet schedule or cost goals. We reviewed this information to determine which sub-principles programs reported implementing and to identify program examples to highlight for each of our selected sub-principles.

Implementation of Software Development Approaches and Cybersecurity Practices

To report on programs' software development approaches, we included a number of software-related questions in our questionnaire.[90] We identified programs that reported the use of a modern software development approach—which we define for this assessment as either Agile, DevOps, DevSecOps, or an iterative development (other than Agile) approach. We summarized the number of programs that reported using any modern approach, those that reported only non-modern approaches, and those that did not report a specific approach, and compared this with data from our 2021 and 2022 reports.[91]

To assess selected programs' progress in implementing software development and acquisitions practices recommended by the Defense

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[89] GAO*, Leading Practices: Agency Acquisition Policies Could Better Implement Key Product Development Principles,* GAO-22-104513 (Washington, D.C.: Mar. 10, 2022).

[90] We also sent questionnaires to future major weapon acquisitions covering software approach, frequency of end user evaluation, and software costs. We did not include aggregate future major weapon acquisitions software data in our analysis because programs reported this information was largely unavailable, in part, because programs were early in their life cycles.

[91] In our 2023 assessment, we modified our questionnaire to exclude "mixed" as one of the response options for the software development approach. We found four programs that had previously reported "mixed" to be using a modern software development approach. For these four programs, we adjusted all analyses accordingly for assessment years 2021 and 2022.

Science Board it its 2018 report, we included a question on the practices used in our questionnaire.[92] We compared the portion of our assessed programs that reported they were implementing these practices with the portion of programs reporting implementation in our 2021 and 2022 reports—with the exception of the practice of creation of a software factory as a key source selection criterion. This year was our first time including that practice in our questionnaire. We analyzed these trends and reported whether the progress from 2022 improved or declined.

To report on modular contracting, we reviewed related DOD policy and guidance, and our *Agile Assessment Guide*.[93] We used our questionnaire data to assess the extent selected programs reported that they had implemented this acquisition strategy.

To assess the extent to which selected programs were soliciting early and regular feedback on software from the intended end users of their systems, we included questions in the questionnaire on several aspects of feedback. These questions included whether the programs reported obtaining any end user feedback, the frequency with which they solicited and received feedback, and the date at which they started receiving user feedback. We compared the feedback start date with the date programs reported starting software development, and measured the time elapsed. We then aggregated program responses on when end user feedback began as well as the frequency of this feedback.

To report on selected programs' use of the software acquisition pathway, we reviewed DOD Instruction 5000.87, *Operation of the Software Acquisition Pathway*—which establishes policies and procedures for the establishment of the software acquisition pathway—and included questions in the questionnaire on programs' current and future plans to

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[92] Defense Science Board, *Design and Acquisition of Software for Defense Systems* (Washington, D.C.: Feb. 14, 2018).

[93] Department of Defense, *Operation of the Software Acquisition Pathway*, DOD Instruction 5000.87 (Oct. 2, 2020); Office of the Under Secretary of Defense for Acquisition and Sustainment, *Contracting Considerations for Agile Solutions, Key Agile Concepts and Sample Work Statement Language*, Version 1.0 (Washington, D.C.: Nov. 18, 2019). See also GAO, *Agile Assessment Guide: Best Practices for Agile Adoption and Implementation,* GAO-20-590G (Washington, D.C.: Sept. 28, 2020).

use the pathway for their software efforts as well as rationales for their plans.[94]

To determine the extent to which selected programs' cybersecurity practices generally aligned with DOD's established cybersecurity policy and guidance, we identified specific DOD policy guidance pertaining to cybersecurity in weapon systems, including DOD Instruction 5000.89, *Test and Evaluation*, effective November 2020, and DOD's *Cybersecurity Test and Evaluation Guidebook*, issued July 2015 and last updated in February 2020.[95] We included a number of cybersecurity-related questions in our questionnaire, including whether programs had approved cybersecurity strategies and had cybersecurity in requirements planning. We then summarized programs' responses and compared them with the DOD policy or guidance as appropriate.

We also assessed whether selected programs had completed or planned to complete specific cybersecurity assessments in time to inform key program events as recommended in the *Cybersecurity Test and Evaluation Guidebook*. We included questions in the questionnaire on the planned or actual date for each of the assessment types described in the guidebook; then compared these dates with the program schedule events we collected data on as part of the questionnaire's schedule section.[96]

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[94] Department of Defense, *Operation of the Software Acquisition Pathway*, DOD Instruction 5000.87 (Oct. 2, 2020).

[95] DOD Instruction 5000.89; Department of Defense, *Cybersecurity Test and Evaluation Guidebook 2.0, Change 1* (February 2020).

[96] For example, we compared a program's reported completion or planned date for its Cooperative Vulnerability Identification assessment with the program's production start date (Milestone C) to determine if the assessment was completed or planned before the production start date, as recommended by DOD guidance. Our analysis excluded program events that occurred before the Department of Defense originally published its *Cybersecurity Test and Evaluation Guidebook* on July 1, 2015. For program schedule event dates reported as a fiscal year or fiscal year quarter, we used the last date of the fiscal year or fiscal year quarter for our analysis. For example, for an Initial Operational Test and Evaluation date reported by a program as fiscal year 2024, we used the date of September 30, 2024 for our analysis.

We then separated these responses based on whether the relevant key program schedule event had passed or was in the future.[97]

Assessment of Information Related to Implementation of a MOSA

To describe recent legislation related to implementing a MOSA, we reviewed the National Defense Authorization Act (NDAA) from fiscal years 2017 to 2022 to identify provisions related to DOD's MOSA implementation.[98] We reviewed DOD acquisition policy and guidance to determine how key aspects of MOSA implementation were applied to MDAPs and MTA programs, as well as guidance from the military departments.[99] We also met with officials from USD(R&E) and USD(A&S) to obtain their perspectives on the current state of DOD's MOSA policy.

To report on the extent to which programs we reviewed reported implementing a MOSA, we included questions related to MOSA implementation in our questionnaires sent to future major weapon acquisitions, MDAPs, and MTA programs. We relied on program office responses to these questions to determine the number of programs implementing a MOSA, the open standards they were using in their systems, the types of implementation challenges tracked by programs, and the number of programs that conducted or planned to conduct verification testing. We also drew explanatory responses from the questionnaires to highlight common themes on why programs had or had not decided to pursue a MOSA.

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[97] We only analyzed whether a program planned its first assessment before the relevant program event. For example, if a program already completed an Adversarial Cybersecurity Development Test and Evaluation assessment, we did not evaluate whether the program planned its second assessment before the start of production.

[98] National Defense Authorization Act for Fiscal Year 2017 (NDAA), Pub. L. No. 114–328 (2016); National Defense Authorization Act for Fiscal Year 2018, Pub. L. No. 115–91 (2017); John S. McCain National Defense Authorization Act for Fiscal Year 2019, Pub. L. No. 115–232 (2018); National Defense Authorization Act for Fiscal Year 2020, Pub. L. No. 116–92 (2019), William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Pub. L. No. 116-283 (2021), and National Defense Authorization Act for Fiscal Year 2022, Pub. L. No. 117–81 (2021). We assessed changes starting with the NDAA for fiscal year 2017 because it established the statutory requirement for MDAPs to be designed and developed with a MOSA to the maximum extent practicable.

[99] See Department of Defense, *Engineering of Defense Systems*, DOD Instruction 5000.88 (Nov. 18, 2020); Department of Defense, Office of the Under Secretary of Defense for Research and Engineering, *Modular Open Systems Approach (MOSA) Reference Frameworks in Defense Acquisition Programs* (May 2020); Office of the Under Secretary of Defense for Research and Engineering, *Engineering of Defense Systems Guidebook* (February 2022); Office of the Under Secretary of Defense for Research and Engineering *Systems Engineering Guidebook* (February 2022); and Secretary of the Air Force, Air Force Policy Directive 63-1, Air Force Policy Directive 20-1 (August 2018).

To assess the extent to which MDAPs that reported implementing a MOSA planned to verify that their systems conform to their intended open standards before entering production, we analyzed questionnaire responses on the timing of MOSA verification testing as it relates to major program milestones. We grouped these responses into programs planning to conduct verification before the production milestone, after, and those that did not report timing; and compared the relative sizes of each group. We discussed these results with officials from USD (R&E) to determine factors leading to programs not completing MOSA verification before entering production.

Individual Assessments of Weapon Programs

This report presents individual knowledge-based assessments of 65 current and future weapon programs. Appendix I contains these assessments. Of the 65 assessments:

- 35 assess MDAPs—in development or early production—in a two-page format discussing each program's knowledge about technology, design, and manufacturing as well as software and cybersecurity, and other program issues.
- 11 assess future major weapon acquisitions or current MDAPs in a one-page format that describes the program's current status. Those one-page assessments include (1) seven future major weapon acquisitions that have not been formally initiated on an AAF pathway; and (2) four MDAPs that are well into production but introducing new increments of capability or significant changes.
- 19 assess MTA programs in a two-page format that discusses each program's completion of business case elements or updates to the program's business case; software development and cybersecurity; transition plan; leading principles for product development; and other program issues.

For all assessments, we obtained the information from sources such as DOD's DAES reports, MTA program identification documents, and program office questionnaire responses. For some data fields, like contract type, we relied on information from previous years unless we received new information. This information is presented in the Program Essentials section as well as the cost and quantities sections (MDAP Program Performance, MTA, MDAP Increment, and Future Major Weapon Acquisition Cost and Quantities), and Software Development graphics in each one- and two-page assessment. We did not review individual contract documents to verify information in the Program Essentials section.

We obtained the information in the Software and Cybersecurity section of the two-page assessments from program office responses to questionnaires, program office documents, and communications with program officials. In their questionnaire responses, program offices self-identified the software development approach used by the program, frequency of end user evaluation, frequency of testing and feedback, the software percentage of total program cost, and the percentage of progress to meet current requirements.

The paragraphs below provide supplemental information on how we identified and assessed cost and schedule for MDAPs and future major weapon acquisitions, as well as how we assessed attainment of product knowledge for MDAPs. For MTA programs, we used the approach described earlier to summarize cost and quantity data for 19 MTA programs. For these programs, we reported costs for the current MTA effort only, as reported by the programs. For the 17 MTA programs included in both our current and prior assessment, we determined the change in cost since our June 2022 report. We converted all cost information to fiscal year 2023 dollars using conversion factors from the DOD Comptroller's National Defense Budget Estimates for Fiscal Year 2023.[100]

Cost and Schedule Data for MDAPs and Future Major Weapon Acquisitions

For each MDAP we assessed in a two-page format, we present cost, schedule, and quantity data at the program's first full estimate. The first full estimate is generally the cost estimate established at milestone B—development start. However, for a few programs that did not have such an estimate, we used the estimate at milestone C—production start—instead. For shipbuilding programs, we used their planning estimates when available. For programs that have passed a key decision point and have since been restructured, we continue to assess them against their original cost and schedule estimates. Additionally, we present cost, schedule, and quantity data, primarily from the September 2022 DAES reporting or a new acquisition program baseline, if applicable, compared with that reported in our 2022 report to show the one-year cost change.[101] Cost data was deflated to 2023 dollars using conversion factors, as described above. For MDAPs and future major weapon acquisitions

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[100] Department of Defense, Under Secretary of Defense (Comptroller), *National Defense Budget Estimates for Fiscal Year 2023* (July 2022), 76-77.

[101] GAO-22-105230.

assessed in a one-page format, we present the latest available estimate of cost and quantity from the program office.

For the program performance data presented for each two-page MDAP assessment:

- We depicted only the program's main elements of acquisition cost—RDT&E and procurement. However, the total program cost also includes military construction and acquisition-related operation and maintenance costs. Because of rounding and these additional costs, in some situations total cost may not match the exact sum of the research and development and procurement costs.
- The program unit costs are calculated by dividing the total program cost by the total quantities planned in the acquisition program baseline or the DAES. These costs are often referred to as program acquisition unit costs.
- The quantities listed refer to total quantities, which include both procurement and development quantities.
- The schedule information is presented as Acquisition Cycle Time, which is defined as the number of months between program start and the planned or actual achievement of initial operational capability or an equivalent fielding date. In some instances, cycle time is not applicable and we annotate this by using the term NA. In one instance, planned initial operational capability dates have been delayed, but a new planned date had yet to be determined. We annotate this by using the term "to be determined" (TBD). For programs that had yet to determine an initial capability date by the time of our 2022 report, the 2022 cycle time reflects the program's reported initial capability date from 2021.

Cost and quantity information presented in the MDAP increment and future major weapon acquisitions "Estimated Cost and Quantities" figures is drawn from funding stream information from the program office.

Attainment of MTA Business Case Knowledge

To determine whether MTA programs established a sound business case prior to program initiation, we reviewed prior GAO reports that identified elements that would provide a sound business case for MTA programs. These elements include cost estimates based on an independent assessment, requirements, acquisition strategies, and formal schedule and technology risk assessments.[102] Our decision to use the program start date as a key knowledge point was based on prior work on business cases that demonstrated that the most significant point of leverage for a decision maker is before the decision to start a program.[103]

In our questionnaire, we asked the program offices whether they had these business case elements in place and, if so, when they had been completed. We then compared dates the program offices provided for completion of the five business case elements above against the program's initiation date to determine whether the program had completed the respective elements prior to initiation or afterwards.[104] For current status, we assessed whether or not the program had completed the above five elements as of January 2023, the end of our review period. We clarified the program's reported completion status of business case elements in instances in which the program reported information that was inconsistent with information reported elsewhere in the questionnaire or program documentation.

Assessment of MDAP's Attainment of Product Knowledge

For our attainment of product knowledge tables, we assessed MDAPs' current status in implementing the knowledge-based acquisition practices criteria, as well as the programs' progress in meeting the criteria at the time they reached the three key knowledge points during the acquisition cycle.

- **Knowledge Point 1: Match between requirements and resources.** We asked program officials to report TRLs for their program's critical technologies (see appendix V for TRL definitions). Our knowledge-based acquisition practices work shows that a TRL 7—demonstration of a technology in its form, fit, and function within a realistic environment—is the level of technology maturity that constitutes a low

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

[103] GAO-19-439; and *Defense Acquisitions: Joint Action Needed by DOD and Congress to Improve Outcomes*, GAO-16-187T (Washington, D.C.: Oct. 27, 2015).

[104] For status at program start date, if a program stated it had conducted any of the five activities above within 30 days of its start date, we considered that as having achieved the knowledge for that metric.

risk for starting a product development program.[105] For shipbuilding programs, we have recommended that this level of maturity be achieved by the contract award for detailed design.[106] In our assessment, the technologies that have reached TRL 7 are referred to as mature or fully mature. Those technologies that have reached TRL 6, a prototype very close to final form, fit, and function demonstrated within a relevant environment, are referred to as approaching or nearing maturity.[107] In addition, we asked program officials to provide the date of the system-level preliminary design review. We compared this date with the system development start date. Where practicable, we compared technology assessments provided by the program office with Independent Technology Risk Assessments.

- **Knowledge Point 2: Design stability.** We asked program officials to provide the number of design drawings completed or projected for completion by the critical design review, the production decision, and as of our current assessment in our questionnaire. Completed drawings were defined as the number of drawings released or deemed releasable to manufacturing that can be considered the “build to” drawings. For shipbuilding programs, we asked programs to provide the total number of ship design zones, number of design zones complete at lead ship fabrication, and current estimate of number of design zones complete. To gain greater insights into design stability, we also asked programs to provide the date they planned to first integrate and test all key subsystems and components into a system-level integrated prototype. We compared this date with

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[105] *GAO, Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects*, GAO-20-48G (Washington, D.C.: Jan. 7, 2020); *Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes*, GAO-01-288 (Washington, D.C.: Mar. 8, 2001); and *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, D.C.: July 30, 1999). While GAO’s leading practices work shows that a TRL 7 is the level of technology maturity that constitutes a low risk for starting development, DOD’s guidance generally permits development to start at TRL 6. DOD’s guidance is based on a statute that generally prohibits an MDAP from receiving approval for development start until the milestone decision authority certifies—based on an independent review and technical risk assessment—that the technology in the program has been demonstrated in a relevant environment. 10 U.S.C. § 4252(a)(2).

[106] GAO, *Best Practices: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding*, GAO-09-322 (Washington, D.C.: May 13, 2009).

[107] Satellite technologies that have achieved TRL 6 are assessed as fully mature due to the difficulty of demonstrating maturity in a realistic environment—space.

the date of the critical design review. We did not assess whether shipbuilding programs had completed integrated prototypes.

- **Knowledge Point 3: Production maturity.** To gain insights into production maturity, we asked whether programs planned to demonstrate critical manufacturing processes on a pilot production line before beginning low-rate production. We also asked programs on what date they planned to begin system-level developmental testing of a fully configured, production-representative prototype in its intended environment. We compared this date with the production start date. We did not assess production maturity for shipbuilding programs because the Navy does not generally produce ships on production lines or prototype a whole ship due to cost.

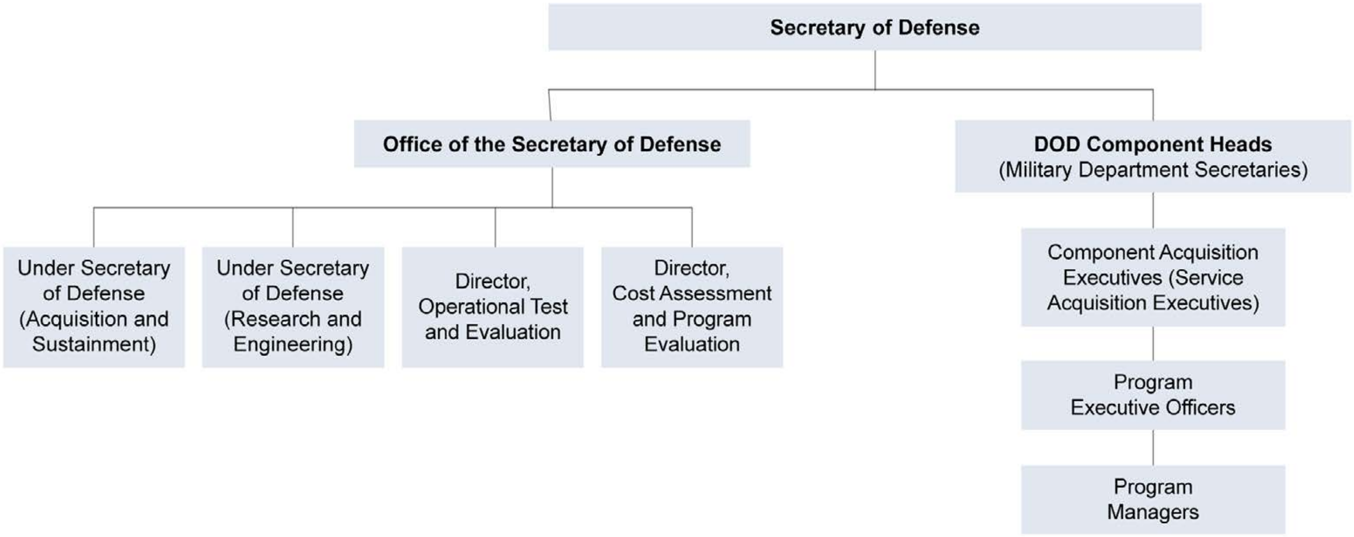
We conducted this performance audit from May 2022 to June 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix III: Department of Defense (DOD) Responsibilities for Weapon System Acquisitions

Oversight of the department's costliest weapon systems is shared between several entities within the Office of the Secretary of Defense (OSD) and the military departments. Entities within OSD are responsible for overarching oversight of weapon systems across the department. This includes developing policies and supervising all elements of DOD related to acquisition and sustainment; providing capabilities to enable reporting and data analysis; conducting or approving independent cost estimates and cost analyses covering the life cycle of major defense acquisition programs (MDAP); and overseeing operational and live fire tests and evaluations.

At the military department level, the component acquisition executives, also referred to as the service acquisition executives, are responsible for implementing DOD acquisition policy within their respective department and serve as the milestone decision authority for most MDAPs. Service acquisition executives at the military department level are also decision authorities for programs using the middle tier of acquisition (MTA) and software acquisition pathways, with some exceptions. Figure 36 depicts the relationship between offices and officials with acquisition oversight responsibilities for the systems we reviewed.

Figure 36: Selected Department of Defense (DOD) Offices and Officials with Acquisition Oversight Roles



Source: GAO analysis of Department of Defense Information. | GAO-23-106059

Table 7 provides more detailed overviews of roles and responsibilities for DOD and military department officials in weapons systems acquisitions.

Table 8: Summary of DOD Oversight Roles and Responsibilities for Weapon System Acquisitions

Entity	Responsibilities
Office of the Secretary of Defense	
Under Secretary of Defense for Acquisition and Sustainment (USD(A&S))	Establishes policies on and supervises the performance of all matters relating to acquisition (including system design, development, production, and procurement of goods and services) and sustainment (including logistics, maintenance, and materiel readiness). This office has certain oversight responsibilities throughout the acquisition process, such as leading acquisition and sustainment data management and providing capabilities to enable reporting and data analysis. The Under Secretary is the Defense Acquisition Executive and is accountable for the pathways through the defense acquisition system and serves as the milestone decision authority for certain major defense acquisition programs (MDAP). The Under Secretary also approves the use of the middle tier of acquisition (MTA) pathway for programs that exceed the cost thresholds for designation as an MDAP and maintains responsibility for prototyping activities within the MTA pathway.
Under Secretary of Defense for Research and Engineering (USD(R&E))	Establishes policies on and advises on all aspects of defense research and engineering, technology development, technology transition, developmental prototyping, experimentation, and developmental testing activities and programs. Responsibilities also include advising the USD(A&S) on prototypes that transition to or support acquisition pathways and establishing guidance on the allocation of resources for defense research and engineering. For certain MDAPs, the Under Secretary establishes policy and guidance for the conduct of statutorily-required Independent Technical Risk Assessments, which may address areas such as critical technologies. The Under Secretary's office also is to advise USD(A&S) on MTA program technologies, program protection, developmental testing, program risks, and MTA program performance and execution metrics, among other things; and, in relation to the software acquisition pathway, guides the development of science and technology activities related to next generation software and software reliant systems.
Director, Cost Assessment and Program Evaluation	Conducts or approves independent cost estimates, and cost analyses covering the life cycle of MDAPs in support of milestone reviews, sustainment reviews, congressional certifications, and budget requests. The Director, Cost Assessment and Program Evaluation also advises USD(A&S) on schedule, resource allocation, affordability, systems analysis, cost estimation, and the performance implications of proposed MTA programs; establishes policies and prescribes procedures for MTA cost data and cost estimates; and conducts an estimate of life-cycle costs for certain MTA programs.
Director, Operational Test and Evaluation	Submits reports of operational and live fire tests and evaluations carried out on MDAPs to the USD(A&S) and USD(R&E) and other senior officials as needed, among other duties.
Military departments	
Military Department Secretaries	Aligns the management of acquisition programs with the principal DOD processes to support affordable design, development, production and sustainment of mission effective capability and services, among other things.

Entity	Responsibilities
Component Acquisition Executive (also referred to as the Service Acquisition Executive)	Implements DOD acquisition policy within a respective component. In the military departments, the officials delegated as Component Acquisition Executives are respectively the Assistant Secretary of the Army for Acquisition, Logistics, and Technology; the Assistant Secretary of the Navy for Research, Development and Acquisition; and the Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics. Component Acquisition Executives serve as the decision authority for many MDAPs and MTA programs.
Program Executive Officer	Balances the risk, cost, schedule, performance, interoperability, sustainability, and affordability of a portfolio of acquisition programs; and delivers an integrated suite of mission effective capability to users.
Program Manager	Under the supervision of the Program Executive Officer and Component Acquisition Executive, plans acquisition programs, prepares programs for key decisions, and executes approved acquisition and production support strategies.

Source: GAO analysis of Department of Defense (DOD) documents. I GAO-23-106059

Appendix IV: Knowledge-Based Acquisition Practices

Our prior work on knowledge-based acquisition practices found that successful programs take steps to gather knowledge that confirms their technologies are mature, their designs stable, and their production processes are in control. These programs ensure a high level of knowledge is achieved at key junctures in development. We characterize these junctures as knowledge points. The Related GAO Products section at the end of this report includes references to the body of work that helped us identify these practices and apply them as criteria in weapon system reviews. Table 8 summarizes these knowledge points and associated practices.

Table 9: Leading Practices for Knowledge-based Acquisitions That GAO Has Identified

Knowledge Point 1: Technologies, time, funding, and other resources match customer needs. Decision to invest in product development.
Demonstrate technologies to a high readiness level—technology readiness level 7—to ensure technologies are fit, form, function, and work within a realistic environment[a]
Ensure that requirements for product increment are informed by system-level preliminary design review, using system engineering process (such as prototyping of preliminary design)
Establish cost and schedule estimates for product on the basis of knowledge from system-level preliminary design using system engineering tools (such as prototyping of preliminary design)
Constrain development phase (5 to 6 years or less) for incremental development
Ensure development phase is fully funded (programmed in anticipation of milestone)
Align program manager tenure to complete development phase
Use a contract strategy that separates system integration and system demonstration activities
Conduct independent cost estimate
Conduct independent program assessment
Conduct major milestone decision review for development start
Knowledge Point 2: Design is stable and performs as expected. Decision to start building and testing production-representative prototypes.
Complete system critical design review
Complete 90 percent of engineering design drawing packages
Complete subsystem and system design reviews
Demonstrate with system-level integrated prototype that design meets requirements
Complete failure modes and effects analysis
Identify key system characteristics
Identify critical manufacturing processes
Establish reliability targets and growth plan on the basis of demonstrated reliability rates of components and subsystems
Conduct independent cost estimate
Conduct independent program assessment
Conduct major milestone decision review to enter system demonstration

Knowledge Point 3: Production meets cost, schedule, and quality targets. Decision to produce first units for customer.
Demonstrate manufacturing processes on a pilot production line
Build and test production-representative prototypes to demonstrate product in intended environment
Test production-representative prototypes to achieve reliability goal
Collect statistical process control data
Demonstrate that critical processes are capable and in statistical control
Conduct independent cost estimate
Conduct independent program assessment
Conduct major milestone decision review to begin production

Source: GAO. │ GAO-23-106059

[a] Department of Defense guidance generally permits development to start at a technology maturity level commensurate with technology readiness level 6—demonstration of program technology in a relevant environment. Moreover, title 10, section 4252 of the U.S. Code states that a major defense acquisition program may not receive Milestone B approval until the milestone decision authority certifies that the technology in the program has been demonstrated in a relevant environment. Therefore, we have assessed programs against this measure as well.

We have recently undertaken a new body of work to ensure that our approach to assessing weapon programs keeps up with evolving challenges facing DOD and other federal agencies. This work is focused on assessing the practices used by leading companies to develop innovative products. We issued our first report in March 2022 highlighting key principles leading companies use to drive innovation and speed.[1] We have ongoing work in this area examining the metrics and measures associated with the key principles.

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[1] GAO, *Leading Practices: Agency Acquisition Policies Could Better Implement Key Product Development Principles,* GAO-22-104513 (Washington, D.C.: Mar. 10, 2022).

Appendix V: Technology Readiness Levels

Table 10: Technology Readiness Levels (TRL)

TRL	Definition	Description
1.	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2.	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative, and there may be no proof or detailed analysis to support the assumption. Examples are still limited to analytical studies.
3.	Analytical and experimental function or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4.	Component or breadboard validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively low fidelity compared to the eventual system. Examples include integration of ad hoc hardware in a laboratory.
5.	Component or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that they can be tested in a simulated environment. Examples include high fidelity laboratory integration of components.
6.	System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated realistic environment.
7.	System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment (e.g., in an aircraft or a vehicle).
8.	Actual system completed and qualified through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9.	Actual system proven through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational conditions.

Source: GAO analysis of Department of Defense information. | GAO-23-106059

Appendix VI: Summary of Selected Statutory Provisions That Pertain to a Modular Open Systems Approach

We identified seven provisions from the National Defense Authorization Acts for Fiscal Years 2017, 2018, 2020, 2021, and 2022 specifically related to modular open systems approaches (MOSA). Table 10 provides brief summaries of the selected provisions.

Table 11: Selected Statutory Provisions That Pertain to a Modular Open Systems Approach

Section and title of provision	Brief description of provision
Provisions contained in the National Defense Authorization Act for Fiscal Year 2017	

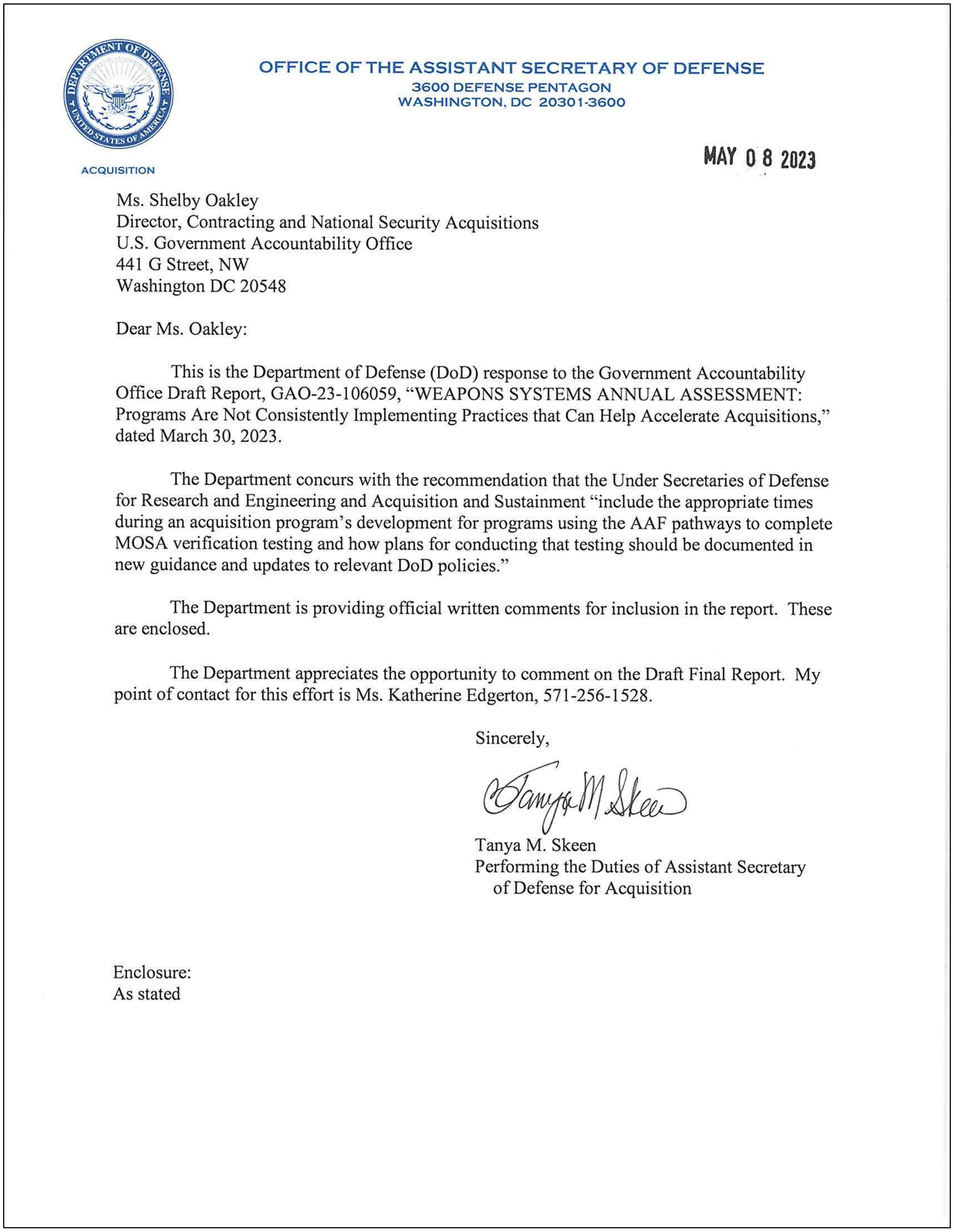
Sec. 805. Modular Open System Approach in Development of Major Weapon Systems	• Requires major defense acquisition programs (MDAPs) that receive Milestone A or Milestone B approval after January 1, 2019, to be designed and developed with a modular open system approach (MOSA) to the maximum extent practicable, and to document it as follows:
	  • **Selected acquisition reports:** Include a brief summary description of the key MOSA elements or a rationale for not using the approach.
	  • **Program capability document:** Identifies and characterizes the extent to which requirements for system performance are likely to evolve over the program's life cycle because of evolving technology, threat, or interoperability needs; and the minimum acceptable capability that is necessary for the MDAP's initial operating capability for requirements that are expected to evolve.
	  • **Acquisition strategy:** differentiates between the major system platform and major system components being developed under the program, as well as major system components developed outside the program that will be integrated into the MDAP, and clearly describes the system's integration approach that will be used, among other things.
	  • **Requests for proposals for the development or production phases:** Describe the MOSA and the minimum set of major system components that must be included in the MDAP's design.
	  • **Analysis of alternatives:** Includes consideration of evolutionary acquisition, prototyping, and a MOSA.
	• Establishes MOSA the following definitions.
	  • Defines a major system platform as the highest level structure of a major weapon system that is not physically mounted or installed onto a higher level structure and on which a major system component can be physically mounted or installed.
	  • Defines a major system component as a high level subsystem or assembly, including hardware, software, or an integrated assembly of both, that can be mounted or installed on a major system platform through well-defined major system interfaces; and includes a subsystem or assembly that is likely to have additional capability requirements, is likely to change because of evolving technology or threat, is needed for interoperability, facilitates incremental deployment of capabilities, or is expected to be replaced by another major system component.
	  • Defines a major system interface as a shared boundary between a major system platform and a major system component, between major system components, or between major system platforms, defined and characterized by certain attributes.

Section and title of provision	Brief description of provision
	• Defines a MOSA as an integrated business and technical strategy that, among other things, employs a modular design that uses major system interfaces between a major system platform and a major system component, between major system components, or between major system platforms; and is subject to verification to ensure that major system interfaces comply with widely supported, consensus-based standards if available and suitable. • Directs milestone decision authorities not to grant Milestone B approval without a written determination that either (a) a program using a MOSA has taken certain steps implementing a MOSA; or (b) the program is not using a MOSA, and MOSA is not practicable for the program. • Directs the secretaries of the military departments to take certain steps related to the availability of major system interfaces and support for MOSA by, among other things, coordinating with certain government and private entities regarding the specification, identification, development, and maintenance of major system interfaces and standards for use in major system platforms, when practicable; ensures that major system interfaces incorporate both commercial standards and widely supported, consensus based standards that meet certain requirements; and ensures that adequate training in using a MOSA is provided to members of the requirements and acquisition workforce.
Sec. 807. Cost, Schedule, and Performance of Major Defense Acquisition Programs	Among other things, requires that before funds are obligated for technology development, systems development, or production of an MDAP, the Secretary of Defense shall, by establishing certain goals, ensure that the milestone decision authority for the MDAP approves a program that will meet certain objectives related to affordability, program planning, and fielding. The goals to be established are goals for program cost targets, fielding targets, technology maturation, prototyping, and a MOSA to evolve system capabilities and improve interoperability.
Sec. 808. Transparency in Major Defense Acquisition Programs	Requires the Milestone Decision Authority to submit a report to the congressional defense committees no later than 15 days after granting Milestone A, Milestone B, and Milestone C approval. The Milestone B report must include, among other things, a statement of whether a MOSA is being used for the program.
Sec. 809. Amendments Relating to Technical Data Rights	Among other things, requires the Department of Defense (DOD) to prescribe regulations including a provision that the United States shall have government purpose rights in technical data pertaining to interfaces between an item or process and other items or processes, which are developed with mixed private and federal funds; and in technical data pertaining to the major system interface developed with mixed federal and private funding, or exclusively with private funding and used in a MOSA; unless the Secretary of Defense determines that negotiation of different rights in such technical data would be in the best interest of the United States. For major system interfaces developed exclusively at private expense for which the United States asserts government purpose rights, the Secretary must negotiate appropriate and reasonable compensation for the technical data.
Provisions contained in the National Defense Authorization Act for Fiscal Year 2020	
Sec. 840. Implementation Guidance for Use of a Modular Open System Approach	Requires the Secretaries of the Military Departments to issue guidance on implementing certain statutory requirements (currently codified at 10 U.S.C. §§ 4402-4403) (relating to the use of modular open system approaches).
Provisions contained in the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021	

Section and title of provision	Brief description of provision
Sec. 804. Implementation of Modular Open System Approaches	• Expands the statutory requirement first established in section 805 the National Defense Authorization Act for Fiscal Year 2017 for MDAPs by requiring all other defense acquisition programs to be designed and developed, to the maximum extent practicable, with a modular open system approach to enable incremental development and enhance competition, innovation, and interoperability. • Redefines a MOSA as an integrated business and technical strategy that, among other things, employs a modular design that uses modular system interfaces between major systems, major system components, and modular systems, and is subject to verification to ensure relevant modular system interfaces either (1) comply with, if available and suitable, widely supported and consensus-based standards; or (2) are delivered pursuant to certain statutory requirements. • Requires the Under Secretary of Defense for Acquisition and Sustainment, in coordination with certain officials, to issue regulations and guidance applicable to certain entities which accomplish the following: (1) facilitate access to and use of modular system interfaces, (2) facilitate the implementation of MOSA across MDAPs and other relevant acquisition programs, and (3) advance DOD's efforts to generate diverse and recomposable kill chains. Among other things, the regulations and guidance must require each relevant DOD contract to include requirements for delivering modular system interfaces for modular systems deemed relevant, including certain requirements specified by law. • Requires the Under Secretary of Defense for Acquisition and Sustainment to direct the Secretaries concerned and appropriate DOD components to establish and maintain repositories for interfaces, syntax and properties, documentation, and communication implementations delivered pursuant to certain statutory requirements. • Requires the Under Secretary of Defense for Acquisition and Sustainment to establish and maintain a comprehensive index for interfaces, syntax and properties, documentation, and communication implementations delivered pursuant to certain statutory requirements and maintained in repositories: and, if practicable, establish and maintain an alternate reference repository for these resources.
Provisions contained in the National Defense Authorization Act for Fiscal Year 2022	
Sec. 833 Pilot Program on Acquisition Practice for Emerging Technologies	Requires the Secretary of Defense, acting through the Under Secretary of Defense for Acquisition and Sustainment or their designee, to establish a pilot program that will develop and implement unique acquisition mechanisms for emerging technologies in order to achieve certain goals. In carrying out the pilot program, the Under Secretary of Defense for Acquisition and Sustainment must, among other things, develop a unique acquisition plan for each identified project that is significantly novel from standard DOD acquisition practices, including the use of alternative intellectual property strategies, such as activities that support MOSA.

Source: GAO analysis of National Defense Authorization Act for Fiscal Year 2017, Pub. L. No. 114–328 (2016); National Defense Authorization Act for Fiscal Year 2018, Pub. L. No. 115–91 (2017); National Defense Authorization Act for Fiscal Year 2020, Pub. L. No. 116–92 (2019); William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Pub. L. No. 116-283 (2021); and National Defense Authorization Act for Fiscal Year 2022, Pub. L. No. 117–81 (2021). I GAO-23-106059

Appendix VII: Comments from the Department of Defense



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

ACQUISITION

MAY 08 2023

Ms. Shelby Oakley
Director, Contracting and National Security Acquisitions
U.S. Government Accountability Office
441 G Street, NW
Washington DC 20548

Dear Ms. Oakley:

This is the Department of Defense (DoD) response to the Government Accountability Office Draft Report, GAO-23-106059, "WEAPONS SYSTEMS ANNUAL ASSESSMENT: Programs Are Not Consistently Implementing Practices that Can Help Accelerate Acquisitions," dated March 30, 2023.

The Department concurs with the recommendation that the Under Secretaries of Defense for Research and Engineering and Acquisition and Sustainment "include the appropriate times during an acquisition program's development for programs using the AAF pathways to complete MOSA verification testing and how plans for conducting that testing should be documented in new guidance and updates to relevant DoD policies."

The Department is providing official written comments for inclusion in the report. These are enclosed.

The Department appreciates the opportunity to comment on the Draft Final Report. My point of contact for this effort is Ms. Katherine Edgerton, 571-256-1528.

Sincerely,

Tanya M Skeen

Tanya M. Skeen
Performing the Duties of Assistant Secretary
of Defense for Acquisition

Enclosure:
As stated

Appendix VIII: GAO Contact and Staff Acknowledgments

GAO Contact

Shelby S. Oakley, (202) 512-4841 or oakleys@gao.gov

Staff Acknowledgments

Principal contributors to this report were Anne McDonough, Assistant Director; Nathaniel Vaught, Portfolio Analysis Analyst-in-Charge; Anh Nguyen, Program Assessments Analyst-in-Charge; Vinayak K. Balasubramanian, Brandon Booth, Rose Brister, Tana M. Davis, Lori Fields, Nathan P. Foster, Beth Reed Fritts, Jaeyung Kim, Michael H. Moran, Wendy P. Smythe, Rachel Steiner-Dillon, and Christine Stenglein. Other key contributors included Cheryl K. Andrew, David B. Best, Robert Bullock, Raj Chitikila, Desiree Cunningham, Christopher R. Durbin, Laurier R. Fish, Gina Flacco, Dina Girma, Gina M. Hoover, Justin M. Jaynes, J. Kristopher Keener, James Madar, Travis J. Masters, Diana Moldafsky, Ronald E. Schwenn, Daniel Singleton, Jenny Shinn, Hunter Stephen, James P. Tallon, Sarah Tempel, Nathan A. Tranquilli, Abby C. Volk, Alyssa B. Weir, Lauren Wright, and Khristi A. Wilkins.

Table 11 lists the staff responsible for individual program assessments.

Table 12: GAO Staff Responsible for Individual Program Assessments

Program name	Primary staff
Air Force and Space Force Programs	
Air Launched Rapid Response Weapon (ARRW)	Patrick Breiding, Evan Ismail
B-52 Commercial Engine Replacement Program Rapid Virtual Prototype (B-52 CERP RVP)	Megan Setser, Alexis Olson
B-52 Radar Modernization Program (B-52 RMP)	William Reed, Don Springman
Deep Space Advanced Radar Capability (DARC)	Jaeyung Kim, Heather Barker Miller
Evolved Strategic SATCOM (ESS)	Mary Diop, Megan Stewart
F-15 Eagle Passive Active Warning Survivability system (F-15 EPAWSS)	Matthew Drerup, Aliza Brown
F-15EX (F-15EX)	Jeff Hartnett, Megan Setser
F-22 Rapid Prototyping	Dennis A. Antonio, Sean Seales
Future Operationally Resilient Ground Evolution (FORGE)	Andrew Berglund, Claire Buck
Global Positioning System III Follow-On (GPS IIIF)	Jonathan Mulcare, Kimberly Schuster
HH-60W Jolly Green (HH-60W)	Sean Seales, Jenny Shinn
KC-46A Tanker Modernization (KC-46A)	Matthew M. Shaffer, Ashley Rawson, Emma O’Shea
LGM-35A Sentinel	Jasmina Clyburn, Ryan Stott, John Crawford
Long Range Standoff (LRSO)	Don Springman, Brandon Booth
Military Global Positioning System (GPS) User Equipment Increment 1 (MGUE Inc 1)	Matthew Ambrose, Andrew Redd
Military Global Positioning System (GPS) User Equipment Increment 2 (MGUE Inc 2)	Leslie Ashton, Bonnie Binggeli, Andrew Redd

Program name	Primary staff
Multi-Mission Helicopter (MH-139A)	Gina Flacco, Holly Williams
National Security Space Launch (NSSL)	Erin R. Cohen, Margaret Fisher, Douglas Luo
Next Generation Operational Control System (OCX)	Kimberly Schuster, Jonathan Mulcare
Next Generation Overhead Persistent Infrared Block 0-Geosynchronous Earth Orbit Satellites (Next Gen OPIR Block 0-GEO)	Claire Buck, Andrew Berglund
Protected Tactical Enterprise Service (PTES)	Brian D. Fersch, Mary Anne Sparks, Walker Adams
Protected Tactical SATCOM (PTS)	Mary Anne Sparks, Brian D. Fersch
Small Diameter Bomb Increment II (SDB II)	Leigh Anne Haydon, Miranda J. Wickham
T-7A Red Hawk (T-7A)	Andrew Redd, Patricia Broadbent
Tranche 1 Tracking Layer (T1 TRK)	Brenna Derritt, Claire Buck, Dinah Girma
Tranche 1 Transport Layer (T1TL)	Hunter Stephan, Brenna Derritt, Andrew Berglund
VC-25B Presidential Aircraft Recapitalization (VC-25B)	LeAnna Parkey, Adriane Kline
Weather System Follow-On (WSF)	Nicole Warder, Albirio A. Madrid
Army Programs	
CH-47F Block II Modernized Cargo Helicopter (CH-47F Block II)	Wendy Smythe, Megan Graves
Extended Range Cannon Artillery (ERCA)	Alexis S. Olson, Leslie Ashton
Future Attack Reconnaissance Aircraft Program (FARA)	Steve Marchesani, Joseph Shir
Future Long-Range Assault Aircraft (FLRAA)	Joe Hunter, Steve Marchesani
Integrated Air and Missile Defense (IAMD)	Michael H. Moran, Helena Johnson, Ian Reed
Indirect Fire Protection Capability Increment 2 (IFPC Inc 2)	Brian Smith, Brian Tittle
Improved Turbine Engine Program (ITEP)	Jasmina Clyburn, Wendy Smythe
Integrated Visual Augmentation System (IVAS)	Hans Eggers, Megan Stewart, Carmen Yeung
Long Range Hypersonic Weapon System (LRHW)	Matthew L. McKnight, Patrick Breiding
Lower Tier Air and Missile Defense Sensor (LTAMDS)	John Rastler-Cross, Michael H. Moran, Eric Smith
Mobile Protected Firepower (MPF)	Jessica Berkholtz, Sameena Ismailjee, Kelsey Kestenbaum
Optionally Manned Fighting Vehicle (OMFV)	Kya Palomaki, Jennifer Dougherty
Precision Strike Missile (PrSM)	Meghan Kubit, Alexandra Wilk, Joshua Timko
Joint Department of Defense Programs	
F-35 Lightning II (F-35)	Jillena Stevens, Aaron Rochow, Daniel Chandler
Navy and Marine Corps Programs	
Advanced Anti-Radiation Guided Missile - Extended Range (AARGM-ER)	Adriana Aldgate, Marcus C. Ferguson
Air and Missile Defense Radar (AMDR)	Eli Stiefel, Nathan P. Foster
CH-53K Heavy Replacement Helicopter (CH-53K)	Victoria Klepacz, Andrew Ringlee
Constellation Class Frigate (FFG 62)	Cale Jones, Sean Merrill
Conventional Prompt Strike (CPS)	Adrianne Lewis, Matthew L. McKnight
CVN 78 Gerald R. Ford Class Nuclear Aircraft Carrier (CVN 78)	Jessica Karnis, Burns C. Eckert
DDG 1000 Zumwalt Class Destroyer (DDG 1000)	Timothy Moss, Sean Merrill

Program name	Primary staff
DDG 51 Arleigh Burke Class guided Missile Destroyer - Flight III (DDG 51 Flight III)	Nathan P. Foster, Eli Stiefel
DDG(X) Guided Missile Destroyer (DDG(X))	Anh Nguyen, Lindsey Cross
F/A-18E/F Infrared Search and Track (IRST)	Zachary J. Sivo, James Cora
John Lewis Class Fleet Replenishment Oiler (T-AO 205)	Miranda Wickham, Jeffrey Carr
Light Amphibious Warship (LAW)	Jillian C. Schofield, Marcus Ferguson, Anne Kolesnikoff
Light Unmanned Surface Vehicle (LUSV)	Desiree Cunningham, Amanda Parker
Littoral Combat Ship Mission Modules (LCS Packages)	Brendan K. Orino, Tom Twambly
LPD 17 San Antonio Class Amphibious Transport Dock, Flight II (LPD 17 Flight II)	Ann Halbert Brooks, Jaeyung Kim
Mk 54 Mod Advanced Lightweight Torpedo (ALWT)	Erin Carson, Nicolaus R. Heun, Ian Toller-Clark
MQ-25 Unmanned Aircraft System (MQ-25 Stingray)	Jennifer Leone Baker, James Kim
MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)	Tana Davis, Charlie Shivers
Next Generation Jammer Mid-Band (NGJ MB)	Claire Li, Daniel Glickstein, Maura Sullivan
Orca Extra Large Unmanned Undersea Vehicle (XLUUV)	Joseph Neumeier, Kya Palomaki
Ship to Shore Connector Amphibious Craft (SSC)	Andrew H. Burton, Tammy Beltran
SSBN 826 Columbia Class Ballistic Missile Submarine (SSBN 826)	Lindsey Cross, Nathaniel Vaught, Claire Liu
SSN 774 Virginia Class Submarine Block V (VCS Block V)	Nathaniel Vaught, Christine Stenglein

Source: GAO. | GAO-23-106059

Appendix IX: Additional Source Information for Images and Figures

This report and appendix contains credit, copyright, and other source information for images, tables, or figures in this product when that information was not listed adjacent to the image, table, or figure.

Front Cover and Highlights Banner:

T-AO 205 John Lewis Class Fleet Replenishment Oiler
Source: General Dynamics NASSCO.

Air and Missile Defense Radar (AMDR)
Source: Raytheon Company.

F-35 Lightening II (F-35)
Source: U.S. Navy photo courtesy Lockheed Martin/Dane Wiedmann, respectively.

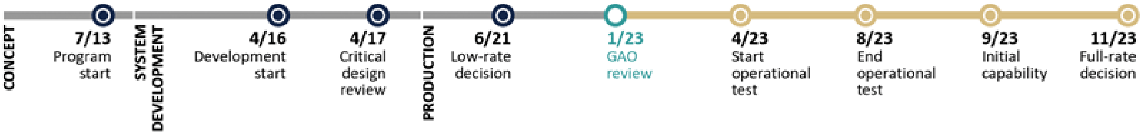
Integrated Visual Augmentation System (IVAS)
Source: U.S. Army.

P. 43: Key Principle Icons

Source: GAO

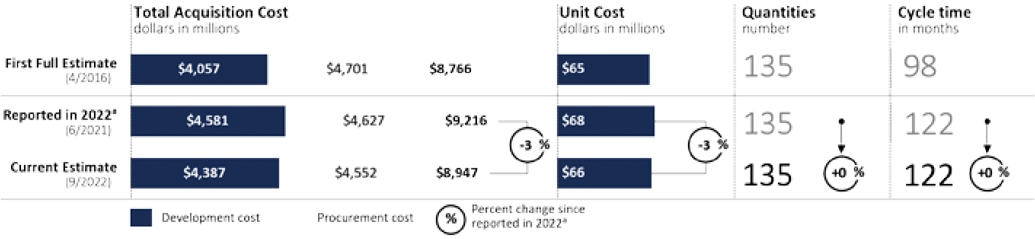
Assessments Graphics

Timeline:



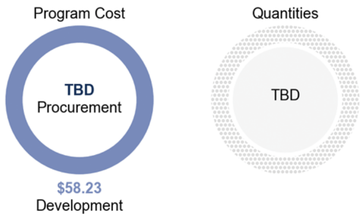
Source: GAO analysis of Department of Defense data.

Program Performance:



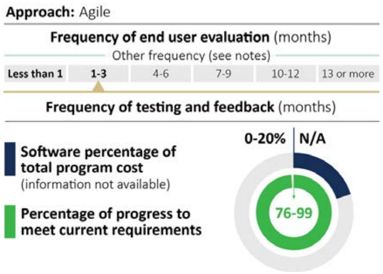
Source: GAO analysis of Department of Defense data.

Estimated Cost and Quantities:



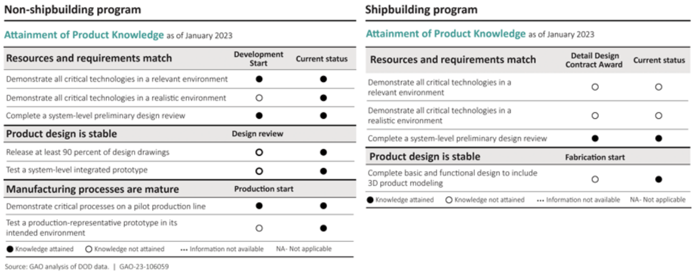
Source: GAO analysis of Department of Defense data.

Software Development:



Source: GAO analysis of Department of Defense data.

Knowledge Table:



Non-shipbuilding program

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Development Start	Current status
Demonstrate all critical technologies in a relevant environment	●	●
Demonstrate all critical technologies in a realistic environment	○	●
Complete a system-level preliminary design review	●	●
Product design is stable	**Design review**	
Release at least 90 percent of design drawings	○	●
Test a system-level integrated prototype	○	●
Manufacturing processes are mature	**Production start**	
Demonstrate critical processes on a pilot production line	●	●
Test a production-representative prototype in its intended environment	○	●

● Knowledge attained ○ Knowledge not attained ··· Information not available NA- Not applicable

Source: GAO analysis of DOD data. | GAO-23-106059

Shipbuilding program

Attainment of Product Knowledge as of January 2023

Resources and requirements match	Detail Design Contract Award	Current status
Demonstrate all critical technologies in a relevant environment	○	○
Demonstrate all critical technologies in a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	**Fabrication start**	
Complete basic and functional design to include 3D product modeling	○	●

● Knowledge attained ○ Knowledge not attained ··· Information not available NA- Not applicable

Source: GAO analysis of Department of Defense data.

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