United States Government Accountability Office

Report to Congressional Committees

JUNE 2021

Weapon Systems Annual Assessment

Updated Program Oversight Approach Needed

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GAO-21-222

GAO Highlights

Highlights of GAO-21-222

A Report to Congressional Committees | June 2021

Weapon Systems Annual Assessment

Updated Program Oversight Approach Needed

Why GAO Did This Study

Title 10, section 2229b of the U.S. Code contains a provision for GAO to review DOD's weapon programs. This report assesses the following aspects of DOD's costliest weapon programs: their characteristics and performance, planned or actual implementation of knowledge-based acquisition practices, and implementation of selected software and cybersecurity practices. The report also assesses oversight implications of DOD's changes to its foundational acquisition guidance.

GAO identified programs for review based on cost and acquisition status; reviewed relevant legislation, policy, guidance, and DOD reports; collected program office data; and interviewed DOD officials.

What GAO Recommends

GAO recommends DOD develop a reporting strategy to improve oversight of those weapon systems developed using multiple efforts or pathways. DOD concurred with our recommendation.

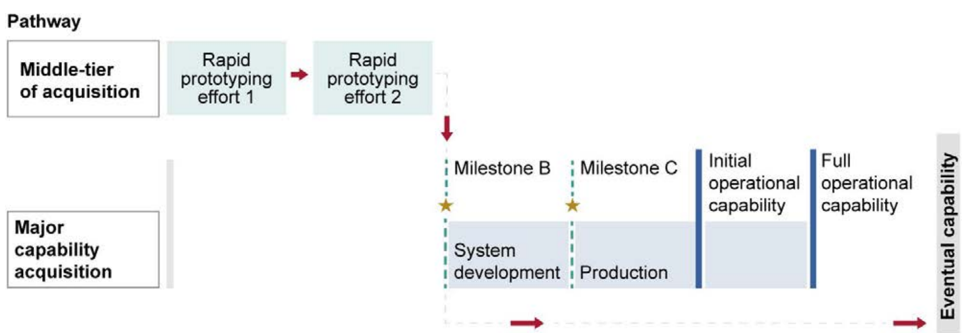
View GAO-21-222. For more information, contact Shelby S. Oakley at (202) 512-4841 or oakleys@gao.gov.

What GAO Found

GAO's 19th annual assessment of the Department of Defense's (DOD) weapon programs comes at a time of significant internal changes to the department's acquisition process. Specifically, DOD began implementing its new acquisition framework intended to, among other things, deliver solutions to the end user in a timely manner. However, GAO found that many programs have planned acquisition approaches that, unless properly managed and overseen, could result in cost and schedule challenges similar to those GAO has reported on for nearly the past 2 decades.

DOD's new acquisition framework allows program managers to use one or more of six acquisition pathways—including the major capability acquisition and middle-tier acquisition (MTA) pathways used by the programs GAO reviewed. Each pathway is governed by separate policies for milestones, cost and schedule goals, and reporting. Program managers can tailor, combine, and transition between pathways based on program goals and risks associated with the the weapon system being acquired (see figure).

Notional Use of Multiple Efforts and Multiple Pathways



Source: GAO analysis of Department of Defense data. I GAO-21-222

DOD's framework also introduces new considerations to program oversight. In particular, DOD has yet to develop an overarching data collection and reporting strategy for programs transitioning between acquisition pathways or conducting multiple efforts using the same pathway to deliver the intended capability. The lack of a strategy not only limits DOD's visibility into these programs but also hinders the quality of its congressional reporting and makes the full cost and schedule of the eventual weapon system more difficult to ascertain.

DOD Plans to Invest Over $1.79 Trillion in Its Costliest Weapon Programs, but Not All Costs Are Reported

DOD's reported costs primarily reflect major defense acquisition program (MDAP) investments (see table). However, DOD is increasingly using the MTA pathway to acquire weapon programs. The totals do not include all expected costs because, among other things, MTA estimates do not reflect any potential investments after the current MTA effort, and cost figures do not include programs that have yet to formally select a pathway or are classified or sensitive.

Department of Defense Total Investments in Selected Weapon Programs GAO Reviewed (fiscal year 2021 dollars in billions)

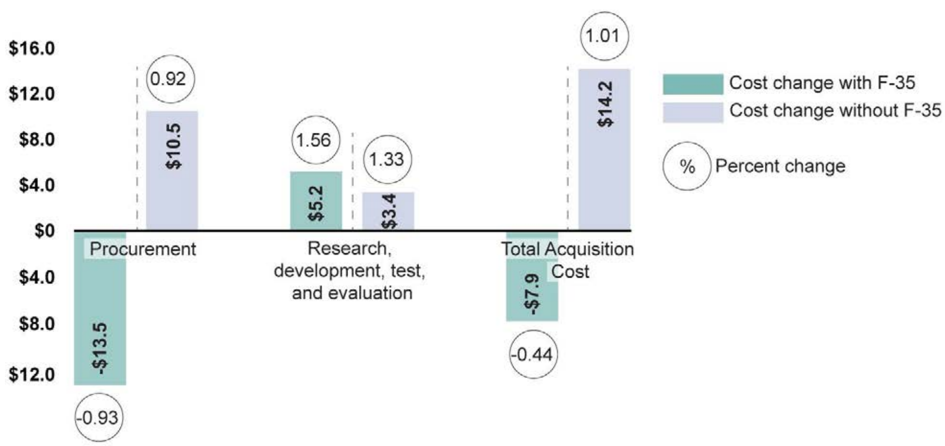
	Number of programs reviewed	Total Planned investment	Air Force	Navy	Army	Dept. of Defense
Major defense acquisition programs	84	$1,791.4	27	39	17	2
Future major defense programs	6	$15.1+	1	2	3	0
Middle tier acquisition programs	17	$30.5	11	1	5	0

Procurement reductions in DOD's costliest program—the F-35—drove an MDAP portfolio cost decrease since GAO's last annual report (see figure). Excluding this program, quantity changes and other factors such as schedule delays contributed to one-year portfolio cost growth. Sixteen MDAPs also showed schedule delays since GAO's 2020 report. Such delays are due, in part, to delivery or test delays and poor system performance.

Source: Department of Defense. | GAO-21-222

F-35 reported an overall procurement cost decrease of $23.9 billion in fiscal year 2020, primarily due to lower prime and subcontractor labor rates.

Major Defense Acquisition Program One-Year Cost Change Including and Excluding the F-35 Program (fiscal year 2021 dollars in billions)



Source: GAO analysis of Department of Defense data. | GAO-21-222

Weapon Programs Do Not Consistently Plan to Attain Knowledge That Could Limit Cost Growth and Deliver Weapon Systems Faster

As GAO found last year, DOD continues to expand its portfolio of the costliest MTA programs, expecting to spend $30.5 billion on current efforts. Due to inconsistent cost reporting by MTA programs, GAO could not assess cost trends across the MTA portfolio. However, GAO observed examples of cost changes on certain MTA programs compared with last year.

Most MDAPs continue to forgo opportunities to improve cost and schedule outcomes by not adhering to leading practices for weapon system acquisitions. Some MTA programs also reported planning to acquire only limited product knowledge during program execution, leading to added risks to planned follow-on efforts.

Further, while both MDAPs and MTA programs increasingly reported using modern software approaches and cybersecurity measures, they inconsistently implemented leading practices, such as frequently delivering software to users and conducting certain types of cybersecurity assessments during development.

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Abbreviations

AAF	Adaptive Acquisition Framework
ACAT	acquisition category
ADVANA	Advanced Analytics
COVID-19	Coronavirus Disease 2019
C3I	Command, Control, Communications and Intelligence
CDD	capabilities development document
CDR	critical design review
DAES	Defense Acquisition Executive Summary

DAMIR	Defense Acquisition Management Information Retrieval
DOD	Department of Defense
DODI	Department of Defense Instruction
IOC	initial operational capability
IOT&E	initial operational test and evaluation
IT	information technology
JCIDS	Joint Capabilities Integration and Development System
JROC	Joint Requirements Oversight Council
KPP	key performance parameter
KSA	key system attribute
MDAP	major defense acquisition program
MRL	manufacturing readiness level
MTA	middle-tier acquisition
MVP	minimum viable product
NA	not applicable
NDAA	National Defense Authorization Act
OSD	Office of the Secretary of Defense
PDR	preliminary design review
RDT&E	research, development, test, and evaluation
RFP	request for proposal
RMF	Risk Management Framework
TBD	to be determined
T&E	test and evaluation
TRL	technology readiness level
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment
USD(R&E)	Under Secretary of Defense for Research and Engineering

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A Century of Non-Partisan Fact-Based Work
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June 8, 2021

Congressional Committees

I am pleased to present our 19th annual assessment of the Department of Defense's (DOD) acquisition of weapon systems, an area on GAO's High-Risk List. This year's report offers observations on the performance of 107 of DOD's most expensive weapon programs—the department expects these to cost more than $1.8 trillion in total. These programs include 84 major defense acquisition programs (MDAP), six future MDAPs, and 17 programs using the middle-tier acquisition (MTA) pathway.

This year continued to be one of significant changes for DOD weapon program execution and oversight. Since our last review, DOD issued additional guidance on its Adaptive Acquisition Framework (AAF) and its six associated acquisition pathways—intended to, among other things, deliver solutions to the end user in a timely manner.[1] However, DOD must contend with a number of hurdles to ultimately be successful in leveraging this acquisition process to yield a decisive and sustained military advantage.

DOD's new AAF has many potential benefits for weapon system acquisitions, including a more modern approach to software acquisition and a cybersecurity emphasis throughout the acquisition life cycle. It also allows program managers additional flexibility to tailor the acquisition process to the specific goals and risk profile of their programs. For example, programs may leverage a combination of pathways to provide value not otherwise available through use of a single pathway. In addition, a program manager can undertake multiple distinct efforts using the same pathway, such as two or more rapid prototyping efforts using the middle-tier acquisition pathway.

[1]DOD issued policy documents to address each of these six acquisition pathways from December 2019 to October 2020 and has issued or plans to issue additional functional policy documents, in areas such as engineering and test and evaluation. GAO, *Defense Acquisitions Annual Assessment: Drive to Deliver Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight,* GAO-20-439 (Washington, D.C.: June 3, 2020); Department of Defense Directive 5000.01, *The Defense Acquisition System* (Sept. 9, 2020); DOD Instruction 5000.02, *Operation of the Adaptive Acquisition Framework* (Jan. 23, 2020).

However, even with the fundamental changes introduced by the AAF, DOD has yet to determine how key program oversight aspects will be conducted, particularly for capabilities developed using multiple efforts within an AAF pathway or multiple pathways. Program execution is already well underway for several programs planning to use multiple efforts or pathways. Unless action is taken, DOD's lack of a comprehensive oversight approach will likely hinder insight into program performance and could thus increase the risk of unexpected cost and schedule growth. A cohesive approach to oversight within and across pathways is essential. This would allow decision makers in the department and in Congress to understand whether programs are achieving overall goals of delivering timely, affordable capabilities to the warfighter.

Although the environment for DOD weapon system acquisitions is evolving, the fundamental need for knowledge at key points during the acquisition process—such as understanding whether resources meet requirements before deciding to invest in product development or whether the design is stable before building and testing prototypes—remains unchanged. For the fourth year in a row, our statistical analysis reaffirms a linkage between the attainment of knowledge and the real-life cost and schedule outcomes that weapon programs deliver. Over the past 4 years, our analyses show that programs that attained certain knowledge at key points were associated with lower cost and schedule growth than programs that did not.

This year's analysis continues to show that DOD's MDAPs did not fully implement knowledge-based practices at key points during the acquisition process, and, consequently, may face increased risk of cost growth and schedule delays. Further, these knowledge-based practices have likely benefits for programs using the MTA pathway, but we observed that those programs also did not consistently plan to attain related knowledge. Any challenges experienced by these programs in prototyping efforts could result in lower than expected maturity when programs transition to system development or production. This could have lasting effects on the department's ability to deliver capabilities within planned cost, schedule, and performance expectations.

DOD's most costly weapon programs also continue to execute in an environment that emphasizes the importance of software and the ability to respond effectively to global cybersecurity threats more than ever before. DOD has made efforts to improve in these areas since our last assessment, such as updating its software and cybersecurity instructions.

However, we found that the majority of programs continued to face challenges in executing Agile software development, which hinges on rapid delivery of software to users. We also identified many programs that did not report conducting cybersecurity vulnerability assessments throughout system development. The absence of such assessments increases the risk of missed opportunities to improve cyber survivability and operational resilience early in system development. This in turn can lead to more costly retrofits to address cyber requirements after systems have been developed and fielded.

We acknowledge the significant commitment of DOD leadership in establishing a new acquisition framework in order to improve the department's ability to quickly deliver needed capabilities to the warfighter. It is imperative, however, that DOD's leaders sustain that commitment into the implementation phase to address identified challenges and help ensure that the new framework delivers promised results to the taxpayer and the warfighter.

DOD's weapon programs also faced unprecedented upheaval over the past year as a result of the need to quickly respond to emerging Coronavirus Disease 2019 (COVID-19)-related challenges. Our report provides some insight into initial challenges and anticipated effects on program cost and schedule as reported by individual programs. Given the timing of our report, these responses reflect early effects of COVID-19, and programs may face continued cost or schedule pressures for some time. These challenges further emphasize the importance of effective oversight to ensure that DOD mitigates these disruptions to the extent possible to avoid delays in delivery of critical capabilities.

Gene L. Dodaro
Comptroller General of the United States

June 8, 2021

Congressional Committees

Title 10, section 2229b of the United States Code, contains a provision that GAO review DOD's weapon programs. This report provides insight into 107 of the Department of Defense's (DOD) most costly weapon programs.[2] Specifically, this report covers three sets of programs:

- 84 major defense acquisition programs (MDAP),
- 6 future MDAPs,[3] and
- 17 programs currently using the middle-tier acquisition (MTA) pathway.

In this report, we refer to programs currently using the MTA pathway as "MTA programs," although some of these programs may also plan to subsequently use one or more other pathways before fielding an eventual capability.[4] Also, we collectively refer to MDAPs (current and future) and MTA programs as "weapon programs."[5] This report assesses (1) the

[2]Title 10, section 2229b of the United States Code was enacted by section 833(a) of the John S. McCain National Defense Authorization Act for Fiscal Year 2019, Pub. L. No. 115-232 (2018), and later amended by section 813 of the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Pub. L. No. 116-283 (2021). Our assessment of the performance of major information technology (IT) programs is included in a separate report, which we also prepared in response to title 10, section 2229b of the United States Code and will issue later this year.

[3]Historically, DOD guidance stated that future MDAPs should be registered in a DOD database once a program completed its first program decision. DOD maintained this list of programs that were not formally designated as MDAPs but which planned to enter system development, or bypass development and begin production, at which point DOD would likely designate them as MDAPs. For this year's report, we refer to programs we have historically reported on from this list as future MDAPs.

[4]For the purposes of this report, we use the word "effort" to refer specifically to the activities undertaken using a single 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.

[5]Under DOD Instruction 5000.02, DOD's major capability acquisition pathway is designed to support MDAPs, major systems, and other complex acquisitions. Under DOD Instruction 5000.80, the MTA pathway is intended to fill a gap in the defense acquisition system for those capabilities that have a level of maturity to allow them to be rapidly prototyped within an acquisition program or fielded, within 5 years of MTA program start.

characteristics of the portfolio of 107 of DOD's most costly weapon programs and how these programs have performed according to selected cost and schedule measures; (2) the extent to which programs implemented or planned for knowledge-based acquisition practices; (3) the extent to which programs have implemented modern software development approaches and recommended cybersecurity practices; and (4) the extent to which DOD has planned for potential program execution and oversight implications of changes to its foundational acquisition instruction.

To assess the characteristics of the portfolio of DOD's most costly weapon programs and how these programs performed according to selected cost and schedule measures, we identified programs and analyzed data from multiple DOD sources:

- For MDAPs, we included 84 programs that issued an unclassified Selected Acquisition Report in December 2019.[6] We obtained and analyzed cost, schedule, and quantity data from those Selected Acquisition Reports—which detail initial cost, schedule, and performance baselines and changes from those baselines—and from other reports contained in the Defense Acquisition Management Information Retrieval (DAMIR) system, a DOD repository for program data. We assessed data reliability for these sources by electronically testing data for missing values, outliers, or data outside of a reasonable range. We determined that the data were sufficiently reliable for the purposes of our report.
- We also assessed additional information for a subset of 42 MDAPs—35 of which were between the start of development and early stages of production as of the issuance of the program's December 2019 Selected Acquisition Report, and seven of which were in full-rate production but introduced new increments of capability.[7] For these programs, we developed a questionnaire to obtain information on the extent to which programs were following knowledge-based acquisition practices for technology maturity, design stability, and production

[6]MDAPs generally include those programs designated by DOD as such or that have a dollar value for all increments estimated to require eventual total expenditure for research, development, test, and evaluation of more than $525 million, or for procurement of more than $3.065 billion, in fiscal year 2020 constant dollars. Certain programs that meet these thresholds, including MTA programs, are not considered MDAPs.

[7]We do not include assessments of MDAPs that are past the early stages of production, unless the program is developing new increments of capability or has other significant changes.

readiness. We also used the questionnaire to collect data about software development approaches, cybersecurity practices, and Coronavirus Disease 2019 (COVID-19) effects on program cost and schedule. We received questionnaire responses from July 2020 through September 2020.

- For future MDAPs, we included six programs—five programs that were identified by DOD as pre-MDAPs and one program we identified based on budget documentation, all of which were not considered sensitive and expected to conduct a milestone decision event within the next 2 fiscal years. We provided a questionnaire to program offices to obtain information on schedule events, costs, COVID-19 effects on program cost and schedule, among other information. We received responses from all six programs from August 2020 through September 2020.
- For MTA programs, we included 17 programs that DOD identified through its acquisition database as of March 2020 as using the middle-tier acquisition pathway and exceeding the cost thresholds for MDAP designation.[8] We obtained and analyzed data from program submission forms that the military departments provided to DOD in February, March, and September 2020. This data included program start and end dates and program funding estimates. We also provided a questionnaire to program offices to obtain information on key schedule milestones, transition plans, technology readiness, business case documentation, software development approaches and cybersecurity practices, and COVID-19 effects on program cost and schedule. We received responses from all 17 programs from August

[8]DOD reported costs exceeding the MDAP cost threshold in then-year dollars. Section 804 of the National Defense Authorization Act (NDAA) for Fiscal Year 2016 required DOD to establish guidance for a middle tier of acquisitions that are intended to be completed within 2 to 5 years, covering rapid prototyping and rapid fielding pathways. See National Defense Authorization Act for Fiscal Year 2016, Pub. L. No. 114–92, § 804 (2015). Programs using this authority are generally to be exempt from some of DOD's traditional acquisition and requirements development policies. In the NDAA for Fiscal Year 2017, Congress amended the statutory definition of an MDAP to exclude acquisition programs or projects that are carried out using the rapid fielding or rapid prototyping acquisition pathway described in section 804 of the NDAA for Fiscal Year 2016. We initially identified 20 MTA programs with costs greater than the ACAT I threshold that met the scope of the engagement. We subsequently removed three programs: Deep Space Advanced Radar Capability, because it had yet to be initiated as an MTA program; Family of Advanced Beyond Line-of-Sight Terminals Force Element Terminal due to the presence of classified material; and Unified Platform, because the program transitioned to the software acquisition pathway.

2020 through September 2020.

This report also includes an analysis of cost growth of MDAPs in response to a provision of the conference report accompanying the National Defense Authorization Act (NDAA) for Fiscal Year 2020.[9]

To assess how these programs implemented or plan to implement knowledge-based acquisition practices, software development approaches, and cybersecurity practices, we collected information from 42 MDAPs, six future MDAPs, and 17 MTA programs. We used questionnaire data to obtain information on and assess the extent to which (1) MDAPs and future MDAPs were following knowledge-based acquisition practices, and (2) MTA programs plan to obtain acquisition knowledge and conduct key activities in preparation for the MTA's planned pathway following completion, as well as the extent to which these programs were initiated with sound business cases.[10] We also compared program responses to software and cybersecurity questions from our questionnaire to selected industry practices for software development as identified by the Defense Science Board and Defense Innovation Board, DOD policy and legislative requirements, and our past work related to cybersecurity.[11]

To assess the reliability of the data we used to support the findings of this report, we took appropriate steps based on program type and data source. For MDAPs, we assessed data reliability by comparing Selected Acquisition Report data and DAMIR data. We also, through the course of the audit, verified data with program officials through alternate data collection efforts, and program offices' reviews of draft assessments. For MTA programs, we assessed the reliability of the program data by

[9]H.R. Rep. No. 116-333 (2019).

[10]Under DOD Instruction 5000.80, the program start date for programs designated on or after December 30, 2019 is the date an acquisition decision memorandum is signed, initiating the effort as an MTA rapid prototyping or rapid fielding program.

[11]Defense Science Board, *Final Report of the Defense Science Board Task Force on the Design and Acquisition of Software for Defense Systems* (February, 2018); Defense Innovation Board, *Software is Never Done: Refactoring the Acquisition Code for Competitive Advantage* (May, 2019); GAO, *Weapon Systems Cybersecurity: DOD Just Beginning to Grapple with Scale of Vulnerabilities,* GAO-19-128 (Washington, D.C.: Oct. 9, 2018); DOD Instruction 5000.89, *Test and Evaluation* (Nov. 19, 2020); John S. McCain National Defense Authorization Act for Fiscal Year 2019, Pub. L. No. 115-232, § 868 (2018).

comparing the data included in submission forms that the military departments provided to DOD with supplemental information collected from the program. Where we identified discrepancies, we followed up with programs to obtain explanations. To ensure the reliability of the data collected through our questionnaires, we took a number of steps to reduce reporting error and non-response error, including pre-testing the questionnaires with program officials and cross-checking questionnaire responses with other program documents.

To assess the potential implications for program execution and oversight of DOD's changes to its foundational acquisition instruction, we reviewed updates to DOD policies and guidance made between December 2019 and December 2020 and compared these updates with prior policy.[12] We analyzed DOD documentation related to the department's efforts to identify metrics for cost, schedule, and performance for programs executing within the MTA, major capability acquisition, and software acquisition pathways. We also conducted interviews with officials from the Offices of the Under Secretary of Defense for Acquisition and Sustainment, Director of Cost Assessment and Program Evaluation, and Director, Operational Test and Evaluation.

In addition, this report presents individual knowledge-based assessments of 64 programs.[13] For presentation purposes, we grouped the individual assessments by lead service—Air Force and Space Force, Army, Navy and Marine Corps, and DOD-wide. We included separator pages for the Air Force, Army, and Navy at the start of each departmental grouping. These three separator pages present aggregated information about selected programs' acquisition phases, knowledge attainment, cost and schedule performance, software and cybersecurity characteristics, and business case documentation.

[12]DOD Instruction 5000.02, *Operation of the Adaptive Acquisition Framework* (Jan. 23, 2020); Department of Defense Directive 5000.01, *The Defense Acquisition System* (Sept. 9, 2020); DOD Instruction 5000.85, *Major Capability Acquisition* (Aug. 6, 2020); DOD Instruction 5000.80, *Operation of the Middle Tier of Acquisition (MTA)* (Dec. 30, 2019); DOD Instruction 5000.87, *Operation of the Software Acquisition Pathway* (Oct. 2, 2020); DOD Instruction 5000.73, *Cost Analysis Guidance and Procedures* (Mar. 13, 2020); DOD Instruction 5000.89, *Test and Evaluation* (Nov. 19, 2020); DOD Instruction 5000.90, *Cybersecurity for Acquisition Decision Authorities and Program Managers* (Dec. 31, 2020).

[13]We additionally sent a questionnaire to Joint Precision Approach and Landing but removed this program from the scope of our assessments because it attained operational capability.

Of the 64 assessments:

- Thirty-four 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.
- Thirteen assess future or current MDAPs in a one-page format that describes the program's current status. Those one-page assessments include (1) six future MDAPs that have yet to begin development, and (2) seven MDAPs that are well into production, but are introducing new increments of capability or significant changes.
- Seventeen assess MTA programs in a two-page format discussing each program's plan to obtain acquisition knowledge about technology and design during the current MTA effort as well as the extent to which these programs were initiated with sound business cases.

Appendix I provides these individual assessments.

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

We conducted this performance audit from May 2020 to June 2021 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

DOD Acquisition Principles and Authorities

The overarching management principles that govern the defense acquisition system are described in DOD Directive 5000.01 and DOD Instruction 5000.02.[14] The objective of the defense acquisition system, as defined by DOD Directive 5000.01, 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. DOD Directive 5000.01 further states that the acquisition system will be designed to acquire products and services that satisfy user needs with measurable and timely improvements to mission capability. Further, delivering performance at the speed of relevance is one of the overarching policies governing the defense acquisition system. To achieve these goals, DOD established an Adaptive Acquisition Framework (AAF) in January 2020 that emphasizes several principles that include simplifying acquisition policy, tailoring acquisition approaches, and conducting data-driven analysis. DOD Directive 5000.01 also sets acquisition-related responsibilities for various offices within the Office of the Secretary of Defense.[15]

DOD Instruction 5000.02 establishes the groundwork for the operation of the AAF. The AAF is comprised of six acquisition pathways, each tailored for the characteristics and risk profile of the capability being acquired. Programs, with approval of 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.[16]

[14]DOD Directive 5000.01,*The Defense Acquisition System* (Sept. 9, 2020); DOD Instruction No. 5000.02, *Operation of the Adaptive Acquisition Framework* (Jan. 23, 2020).

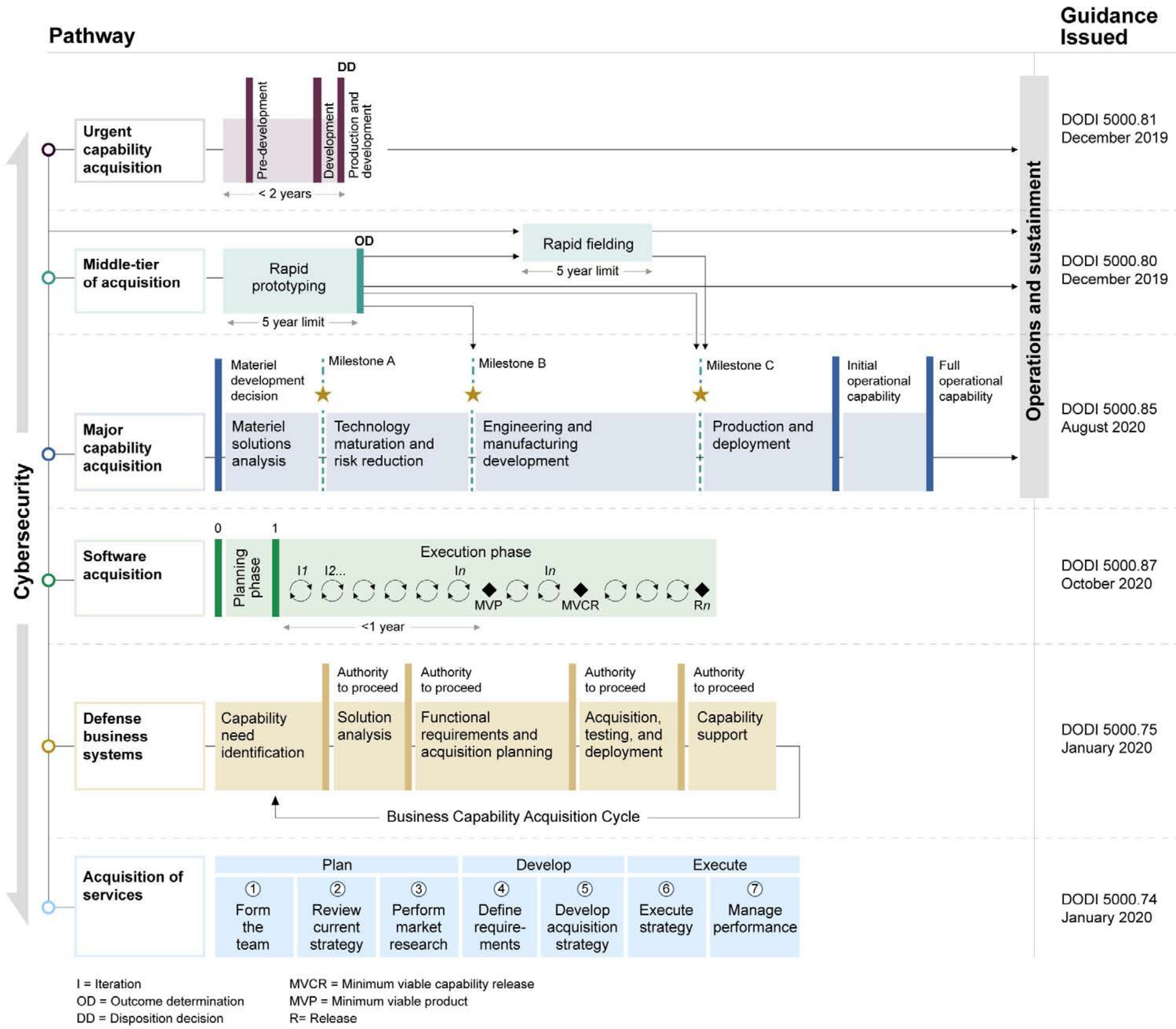
[15]DOD Directive 5000.01 sets responsibilities for Under Secretary of Defense offices for Acquisition and Sustainment, Research and Engineering, Intelligence and Security, and Personnel and Readiness, as well as the Chief Management Officer, Chief Information Officer, Director of Operational Test and Evaluation, Director of Cost Assessment and Program Evaluation, DOD Component Heads, and the Chairman of the Joint Chiefs of Staff.

[16]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.

DOD issued policy documents to address each of these six acquisition pathways from December 2019 to October 2020 and has issued or plans to issue additional functional policy documents, in areas such as engineering and test and evaluation.[17] According to DOD Directive 5000.01, security, cybersecurity, and protection of critical technologies at all phases of acquisition are the foundation for uncompromised delivery and sustainment of warfighting capability. Figure 1 shows the AAF and corresponding guidance specific to each pathway.

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

Figure 1: Adaptive Acquisition Framework Pathways and Related Department of Defense Instructions (DODI)



Source: GAO analysis of DOD data. I GAO-21-222

Note: According to DOD Instruction 5000.02, the purpose of the Defense Business System pathway is to acquire information systems that support DOD business operations. This pathway applies to defense business capabilities and their supporting business systems, such as financial, contracting, and logistics systems.

Two of these pathways relate to the programs we include in this report: (1) major capability acquisition, used to acquire MDAPs, and (2) MTA, used for rapid prototyping and rapid fielding efforts.

MDAPs

Under DOD Instruction 5000.02, DOD's major capability acquisition pathway is designed to support MDAPs, major systems, and other complex acquisitions. Software-intensive components may be acquired via the software acquisition pathway, with the outputs and dependencies integrated with the overall major capability pathway. DOD Instruction 5000.85, released in August 2020, established the policy and prescribed procedures that guide acquisition programs using the major capability pathway.[18] Within this pathway, MDAPs and other complex acquisition programs generally proceed through a number of phases, the following three of which are most relevant to this report: (1) technology maturation and risk reduction, (2) engineering and manufacturing development, and (3) production and deployment. In this report, we refer to these three phases more simply 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.[19]

Our body of work on MDAPs has shown that attaining high levels of knowledge before programs make significant commitments during product development drives positive acquisition outcomes.[20] We have found that, in order to reduce risk, there are three key points at which programs should demonstrate critical levels of knowledge before

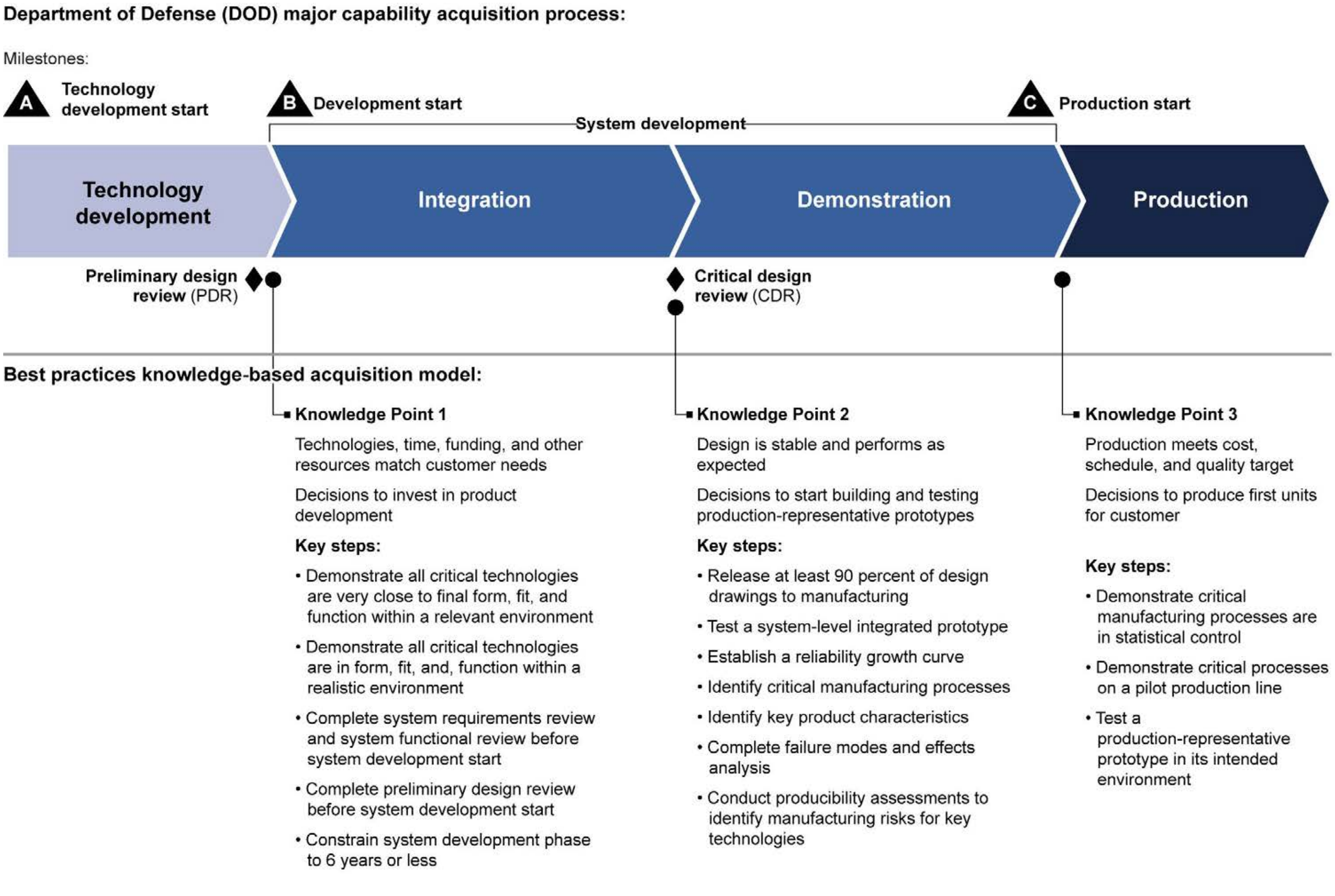
[18]DOD Instruction 5000.85, *Major Capability Acquisition* (Aug. 6, 2020).

[19]The procedures for these milestone reviews and key decision points are addressed in DOD Instruction 5000.85.

[20]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).

proceeding to the next acquisition phase: development start, system-level critical design review, and production start. Figure 2 aligns the acquisition milestones associated with the major capability acquisition pathway with these three key decision points.

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



Source: GAO analysis of DOD-provided data, DOD Instruction 5000.85, and best practices. | GAO-21-222

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

DOD major capability acquisition process:

1. Milestone A: Technology development start

2. Technology development
3. Preliminary Design Review, Knowledge Point 1
4. 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

5. Milestone B: Development Start
6. System Development – Integration
7. Critical Design Review
8. 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

9. System Development – Demonstration
10. Milestone C: Production Start
11. Knowledge Point 3:

- Production meets cost, schedule, and quality target
- Decisions to produce first units for customer
- Key steps:
    - Demonstrate critical manufacturing processes are in statistical control
    - Demonstrate critical processes on a pilot production line
    - Test a production-representative prototype in its intended environmen

12. Production

Source: GAO analysis of DOD-provided data, DOD Instruction 5000.85, and best practices. | GAO-21-222

Knowledge associated with these three points 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, leaving decision makers with less knowledge to support decisions about when and how to move into subsequent acquisition phases that require more budgetary resources. Under a knowledge-based approach, demonstrating technology maturity is a prerequisite for moving forward into system development, during 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 III provides additional details about key practices at each of the knowledge points.

MTA Programs

Under DOD Instruction 5000.02, DOD's MTA pathway includes paths for rapid prototyping and rapid fielding efforts. DOD Instruction 5000.80, released in December 2019, established the policy and prescribed procedures that guide these acquisition programs, including the distinctions between the two MTA paths:[21]

- The objective of a program using the rapid prototyping path is to field a prototype meeting defined requirements that can be demonstrated in an operational environment and provide for residual operational capability within 5 years of the MTA program start date. Virtual prototypes can meet this requirement if they result in a residual operational capability that can be fielded.
- The objective of a program using the rapid fielding path is to begin production within 6 months and complete fielding within 5 years of the MTA program start date.

DOD Instruction 5000.80 notes that not all programs are appropriate for the MTA pathway. For example, the instruction notes that major systems intended to satisfy requirements that are critical to a major interagency requirement, or are primarily focused on technology development, or have significant international partner involvement are discouraged from using the MTA pathway.

Programs using this pathway are exempted from the guidance in DOD Directive 5000.01 and the Chairman of the Joint Chiefs of Staff Instruction 5123.01H, which outlines processes to implement DOD's traditional requirements process.[22] Instead, each DOD component must develop a streamlined process that results in a succinct requirement document within 6 months from the time the operational needs process is initiated. Approval authorities for each capability requirement is delegated to a level that promotes rapid action.[23]

[21]DOD Instruction 5000.80, *Operation of the Middle Tier of Acquisition (MTA)* (Dec. 30, 2019). Prior to the issuance of DOD Instruction 5000.80, the Office of the Under Secretary of Defense for Acquisition and Sustainment issued interim guidance in April 2018, and updated with supplemental interim guidance in October 2018 and March 2019. Some programs in our review are grandfathered under this guidance since they were initiated prior to December 2019.

[22]Chairman of the Joint Chiefs of Staff Instruction 5123.01H, *Charter of the Joint Requirements Oversight Council (JROC) and Implementation of the Joint Capabilities Integration and Development System (JCIDS)* (Aug. 31, 2018).

[23]Programs exceeding the dollar thresholds for a major defense acquisition program pursuant to Title 10, section 2430 of the United States Code require written approval from the Under Secretary of Defense for Acquisition and Sustainment prior to using the MTA pathway.

For each MTA program using the rapid prototyping pathway, DOD components are directed by DOD guidance to 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 pathway or another acquisition pathway, including the major capability acquisition pathway.

Additionally, DOD guidance requires MTA programs that are major systems have the following documents at program initiation: approved requirements; cost estimate; a life-cycle sustainment plan for programs using the rapid fielding pathway; and an acquisition strategy that addresses security, schedule, and technical or production risks, and includes a test strategy or an assessment of test results, and a transition plan. Our prior work has shown 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 middle-tier program initiation, including whether the program is likely to meet certain statute-based objectives for MTA programs.[24]

DOD Weapon Program Oversight Roles and Responsibilities

In response to a provision in the NDAA for Fiscal Year 2016, decision-making authority for many MDAPs has shifted from the Office of the Secretary of Defense to the military departments.[25] Component Acquisition Executives within the military services are also decision authorities for programs using the MTA and software pathways. Several

[24]GAO, *DOD Acquisition Reform: Leadership Attention Needed to Effectively Implement Changes to Acquisition Oversight*, GAO-19-439 (Washington, D.C.: June 5, 2019). According to section 804 of the NDAA for Fiscal Year 2016, the objective of a program using the rapid prototyping pathway is to field a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of the development of an approved requirement, and the objective of a program using the rapid fielding pathway is to begin production within 6 months and complete fielding within 5 years of the development of an approved requirement. See National Defense Authorization Act for Fiscal Year 2016, Pub. L. No. 114–92, § 804 (2015).

[25]Section 825 of the NDAA for Fiscal Year 2016 required that the service acquisition executive of the military department concerned be designated as the milestone decision authority for MDAPs that reach milestone A after October 1, 2016 unless the Secretary of Defense designates an alternate milestone decision authority under certain circumstances outlined in statute, such as the program being critical to a major interagency requirement or technology development effort.

entities within the Office of the Secretary of Defense play a role in the oversight and budgeting for DOD weapon programs. In general, at the enterprise level, the acquisition and budgeting processes are managed by subordinate offices within the Office of the Secretary of Defense. In particular:

- **The Under Secretary of Defense for Acquisition and Sustainment (USD(A&S))** is responsible for establishing policies on and supervising the performance of all matters relating to acquisition (including (1) system design, development, and production; and (2) 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. The Under Secretary also approves the use of the MTA pathway for programs that exceed the MDAP thresholds for designation as an MDAP, maintains responsibility for prototyping activities within the MTA pathway, and serves as the decision authority for special interest programs in the software acquisition pathway on a by-exception basis. The Under Secretary also is to direct programs to use another pathway if the software acquisition pathway is not deemed appropriate.
- **The Under Secretary of Defense for Research and Engineering (USD(R&E))** is responsible for establishing policies on and supervising all aspects of defense research and engineering, technology development, technology transition, prototyping, experimentation, and developmental testing activities and programs, including advising the USD(A&S) on prototypes that transition to or support acquisition pathways and the allocation of resources for defense research and engineering. For certain MDAPs, the Under Secretary is to conduct and approve statutorily-required Independent Technical Risk Assessments, which may address areas such as technology maturity, interoperability, and cybersecurity. The Under Secretary's office also is to advise USD(A&S) on MTA program technologies, program protection, developmental testing, program risks, and other areas, such as MTA program performance and execution metrics; and guides the development of science and technology activities related to next generation software and software reliant systems.

- **The Director, Cost Assessment and Program Evaluation and the Under Secretary of Defense (Comptroller)** is responsible for managing the annual budget preparation process for acquisition programs. These organizations have cost assessment and budgetary responsibilities, respectively, for MDAPs leading up to each milestone and once these programs have been fielded. The Director, Cost Assessment and Program Evaluation also is to advise USD(A&S) on schedule, resource allocation, affordability, systems analysis, cost estimation, and the performance implications of proposed MTA programs; establish policies and prescribes procedures for MTA cost data and cost estimates; and conduct an estimate of life-cycle costs for certain MTA programs. This organization also conducts independent cost estimates before the program begins execution for programs using the software acquisition pathway for programs likely to exceed the ACAT I or II thresholds.
- **The Director, Operational Test and Evaluation**, is to submit 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.

Over the past year, DOD has continued to refine these acquisition oversight roles and responsibilities. In July 2020, the department issued charters for the USD(R&E) and USD(A&S) outlining the specific duties of each office.[26] These two new offices responsible for acquisition oversight were established by a provision of the NDAA for Fiscal Year 2017 and replaced the Office of the Under Secretary for Defense for Acquisition, Technology and Logistics.[27]

Software Development and Acquisition

DOD Instruction 5000.87, issued October 2020, establishes policy and procedures for software acquisition for programs using the software pathway. DOD stated in a 2020 report to Congress that the software pathway represents a major component of modernizing DOD's approach to software acquisition. The pathway was established in response to

[26]DOD *Directive* 5135.02, *Under Secretary of Defense for Acquisition and Sustainment (USD(A&S))* (July 15, 2020) and DOD Directive 5137.02, *Under Secretary of Defense for Research and* Engineering *(USD(R&E))* (July 15, 2020).

[27]National Defense Authorization Act for Fiscal Year 2017, Pub. L. No. 114-328, § 901(a)-(b) (2016).

recommendations made by the Defense Science Board in February 2018, which advised DOD to adopt continuous iterative development and empower programs to immediately adopt a modern approach to software development.[28] The software acquisition pathway instruction also addresses recommendations we made in 2019 that DOD ensure its software development guidance provides specific, required direction on the timing, frequency, and documentation of user involvement and feedback.[29]

The Defense Science Board study found that DOD can, and should, leverage today's commercial software development best practices to its advantage, including on its weapon systems. In addition to recommendations implemented through DOD Instruction 5000.87, DOD is continuing to address the other recommendations made by the Defense Science Board on how to improve software acquisitions in defense systems, including the delivery of a minimum viable product, the inclusion of a software factory, and software acquisition training for program managers.[30]

DOD reported it is also addressing the numerous recommendations made by a 2019 Defense Innovation Board study that emphasized, among other things, speed and delivery time, hiring and retaining qualified staff, and focusing on continuous improvement throughout the software life cycle.[31] In February 2020, DOD issued an Agile Software Acquisition Guidebook that shares Agile and iterative development lessons learned from a congressionally directed Agile software pilot program that included

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

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

[30]DOD 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. The Defense Science Board defines the software factory as low-cost, cloud-based computing used to assemble a set of tools enabling developers, users, and management to work together on a daily tempo.

[31]Defense Innovation Board, *Software Is Never Done: Refactoring the Acquisition Code for Competitive Advantage* (May 3, 2019).

software-intensive warfighting systems.[32] These lessons learned note that Agile is built around frequent, small batch delivery of working functionality into the hands of end users to gain fast feedback. The best practices and lessons learned from pilot programs included, among other things, that the biggest risk reducing factor in an Agile framework is frequent delivery of a product or capability.

In September 2020, we published our *Agile Assessment Guide: Best Practices for Agile Adoption and Implementation*, which found that the most well-known feature of Agile software development is its emphasis on iterative product development and delivery; that is, development of software in iterations that are being continuously evaluated on their functionality, quality, and customer satisfaction.[33] We reported that transitioning to Agile software development methods requires practitioners to do more than implement new or modify existing tools, practices, and processes. A successful transition is predicated on practitioners adopting the values of the Agile Manifesto, which includes rapid, frequent delivery of production-quality software. The guide identifies best practices in adopting Agile values, including practices that address team dynamics and activities, program operations, and organization environment.

Our past work has found that DOD acquisition programs employ a wide range of software development models, including Agile frameworks and various incremental models. Table 1 provides descriptions of selected software development models employed by DOD acquisition programs.

[32]Office of the Under Secretary of Defense for Acquisition and Sustainment, *Agile Software Acquisition Guidebook-Best Practices & Lessons Learned from the FY18 NDAA Section 873/874 Agile Pilot Program,* (Washington, D.C.: Feb. 27, 2020). See National Defense Authorization Act for Fiscal Year 2018, Pub. L. No. 115-91, § 873 (2017) and John S. McCain National Defense Authorization Act of Fiscal Year 2019, Pub. L. No. 115-232, § 869 (2018).

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

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

Software development life cycle model	Description
Waterfall	This model 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 model 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 model 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.
Spiral	This model takes ideas from the incremental model and its repetition but also combines the structured and systematic development of the waterfall model with a heavy emphasis on risk analysis. The project passes through four phases (identification, design, build and evaluation, and risk analysis) repeatedly in a "spiral" until completed, allowing for multiple rounds of refinement.
Agile	This model breaks a product into components where, in each cycle or iteration, a working model of a component is delivered. The model 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. The Agile model 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 methodology that combines development, security, and operations as key elements in delivering useful capability to the user of the software.
Hybrid/Mixed	This approach is a combination of two or more different methodologies or systems to create a new model.

Source: GAO-20-590G and GAO analysis of Department of Defense and software industry documentation. | GAO-21-222

Cybersecurity in DOD Weapon Programs

As we previously reported, cybersecurity for weapon systems has increasingly been recognized as a critical area in which DOD must improve.[34] We 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. In November 2020, DOD issued policy and procedures for test and evaluation across five of the six pathways of the AAF—including major capability acquisition, MTA, and software acquisition pathways—that addresses cybersecurity planning

[34] GAO-19-128

and execution.[35] In particular, the instruction requires all acquisition programs and systems, regardless of acquisition pathway, to execute an iterative cybersecurity process detailed in the DOD Cybersecurity Test and Evaluation Guidebook throughout the program's life cycle, including new increments of capability.[36] Table 2 outlines the DOD cybersecurity test and evaluation phases.

Table 2: 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 impacts 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.
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. | GAO-21-222

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.[37] The strategy generally details the cybersecurity practices the program will use to address

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

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

[37]Defense Acquisition University Milestone Document Identification tool identifies statutory and regulatory program information requirements, as referenced in DOD Instruction 5000.85 and DOD Instruction 5000.81, including milestone and phase information requirements, statutory program breach definitions, recurring program reports, and other requirements. See https://www.dau.edu/tools/t/Milestone-Document-Identification-Tool-(MDID).

cybersecurity risks and reduce the likelihood of severe impacts from a cyberattack. DOD guidance for MTAs requires that components include a test strategy, or assessment of test results, 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.[38] DOD also issued a functional policy on cybersecurity in December 2020, which aims to provide procedures to incorporate cybersecurity into all aspects of the defense acquisition system and operations.

[38]DOD Instruction 5000.80.

OVERVIEW

Fiscal Year 2021 Department of Defense Weapon Portfolio

Source: Microsoft, Redmond, WA. | GAO-21-222

DOD plans to spend at least $1.8 trillion for its costliest weapon programs, but the estimate excludes potentially significant program costs.

The portfolio of selected DOD weapon programs that we assessed consists of 107 programs: 84 MDAPs; six future MDAPs; and 17 programs using the MTA pathway (MTA programs). The way that DOD acquires its weapon systems has changed as a result of the introduction of new acquisition pathways over the last few years. DOD plans to invest over $1.8 trillion to acquire its most costly weapon programs, and is increasingly using MTA pathways to do so. However, this figure does not include all likely costs. For example, in most cases these MTA estimates do not reflect any investment that DOD will need after the current MTA effort, if it decides to further development and field the capabilities being prototyped. In addition, total portfolio costs do not include some programs with planned costs exceeding the threshold for MDAP designation in pathways other than the major capability acquisition or MTA pathways, or programs that have yet to select a pathway.

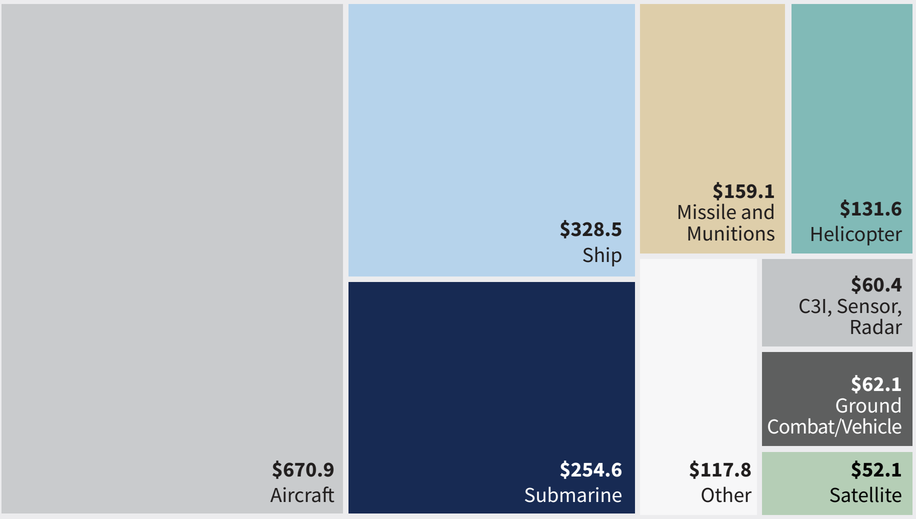
Our reporting also does not include total life-cycle sustainment costs or classified programs, which constitute a substantial portion of military department spending. For example, the Congressional Budget Office estimated in 2019 that DOD planned to expend approximately $290 billion from fiscal years 2019 to 2028 to fund the development and procurement of nuclear delivery systems and weapons, some of which is not reflected in our reported costs.

Table 3: Department of Defense Planned Investments in Selected Weapon Programs GAO Reviewed (fiscal year 2021 dollars in billions)

Type of program	Number of programs reviewed	Total planned investment	Air Force	Navy	Army	Department of Defense
Major defense acquisition programs	84	**$1,791.4**	27	38	17	2
Future major defense acquisition programs	6	**$15.1+**	1	2	3	0
Middle-tier acquisition programs	17	**$30.5**	11	1	5	0

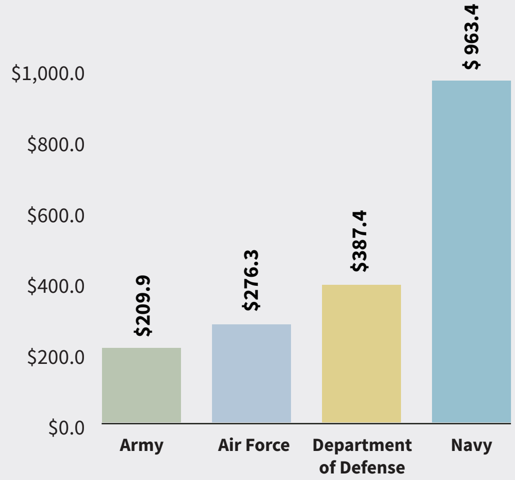
Source: GAO analysis of Department of Defense data. | GAO-21-222

Figure 3: Planned Investment by Commodity (fiscal year 2021 dollars in billions)



Source: GAO analysis of Department of Defense data. | GAO-21-222
C3I = Command, Control, Communications and Intelligence

Figure 4: Planned Investment by Military Department (fiscal year 2021 dollars in billions)



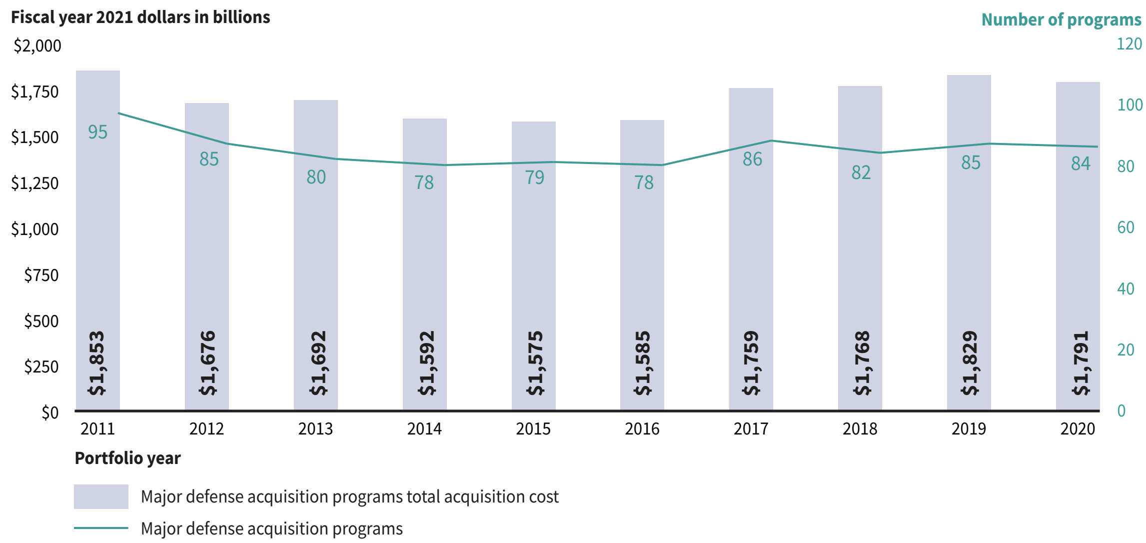
Source: GAO analysis of Department of Defense data. | GAO-21-222

DOD MDAP Portfolio

HISTORICAL TRENDS

DOD's MDAP portfolio decreased in the past year both in number of programs and planned total investment. DOD began reporting on three new MDAPs and stopped reporting on four MDAPs that had either neared completion or been canceled.

Figure 5: Historical Number and Cost of the Department of Defense's Major Defense Acquisition Programs from 2011 to 2020



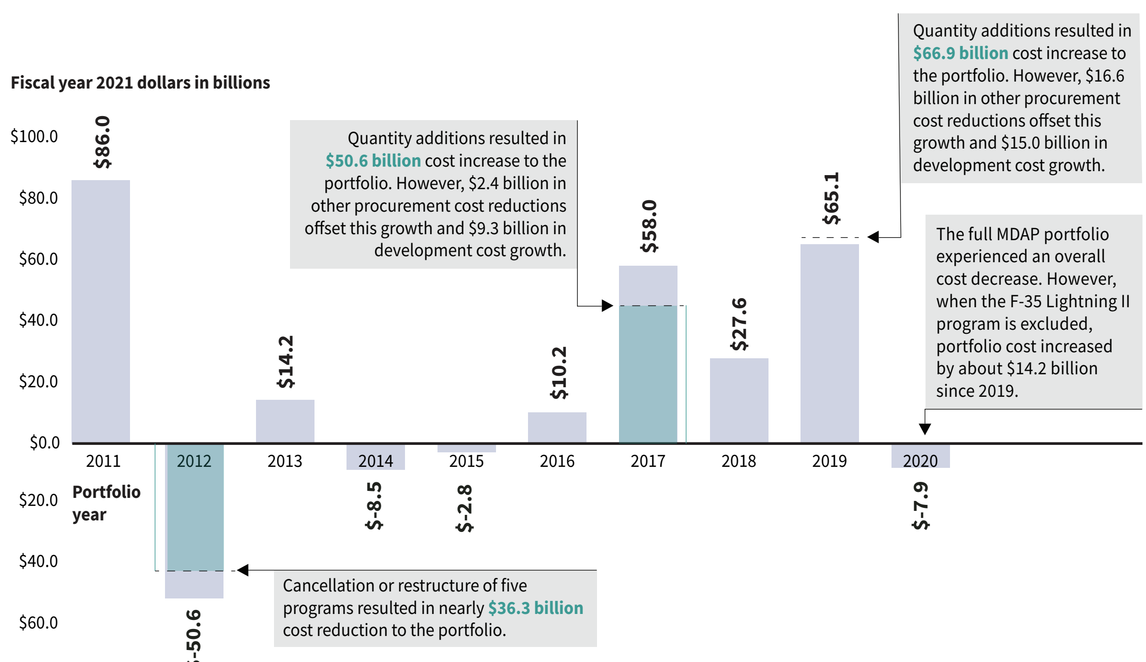
Source: GAO analysis of Department of Defense data. | GAO-21-222

DOD experienced billions of dollars in cost growth since initial estimates in the last 15 years.

Over the past 15 years, we have consistently reported that DOD's MDAP portfolio experienced substantial cost growth since initial estimates. For example, in 2008 and 2010, DOD saw significant cost growth of nearly $360 billion and over $475 billion from first full estimates, respectively. We previously found that, in some cases, these cost increases resulted in quantity reductions and trade-offs for other programs, among other things.

Since we began reviewing the effect of quantity changes on cost change, we have reported that quantity changes contributed to procurement cost change across the MDAP portfolio. As shown in figure 6 below, portfolio cost changes fluctuated yearly, and quantity changes have driven significant procurement cost change across the MDAP portfolio over the last 10 years.

Figure 6: Annual Cost Change in Major Defense Acquisition Programs Portfolio



Source: GAO analysis of Department of Defense data. | GAO-21-222

DOD MDAP Portfolio

ONE-YEAR COST CHANGES

Procurement cost reductions in the F-35 drove a MDAP portfolio cost decrease from 2019 to 2020.

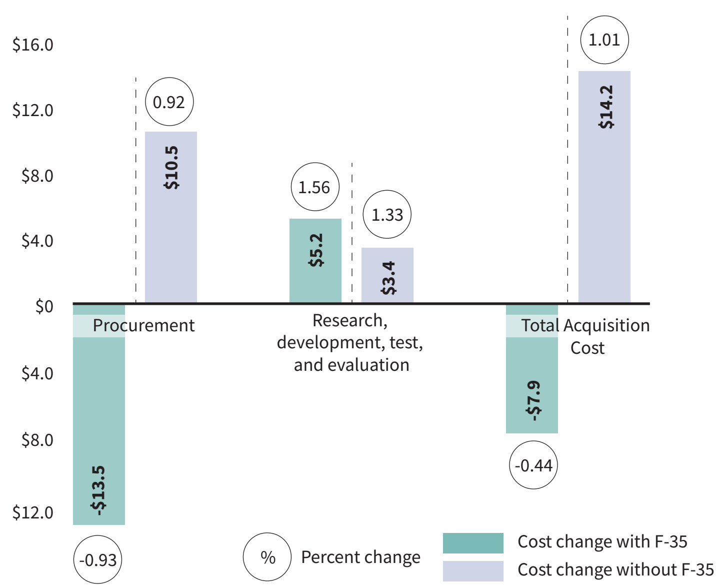
Since last year, total acquisition cost estimates for the 84 MDAPs in DOD's 2020 portfolio decreased by a combined $7.9 billion, largely due to a significant procurement cost decrease for the F-35 Lightning II (F-35)—the portfolio's costliest program. Procurement costs, which account for about 80 percent of the 2020 portfolio's estimated costs, decreased by $13.5 billion. Research, Development, Test, and Evaluation (RDT&E) costs, which account for about 20 percent of the portfolio's estimated costs, increased by $5.2 billion. Without the F-35, the rest of the portfolio showed a combined $10.5 billion increase in procurement and $3.4 billion increase in RDT&E.

F-35

Source: Department of Defense. | GAO-21-222

The F-35 program reported an overall procurement cost decrease of $23.9 billion in fiscal year 2020 primarily due to lower prime and subcontractor labor rates.

Figure 7: Major Defense Acquisition Program Cost Change Between 2019 and 2020 Including and Excluding the F-35 Program (fiscal year 2021 dollars in billions)



Source: GAO analysis of Department of Defense data. | GAO-21-222

Note: In addition to research and development and procurement costs, total acquisition cost includes acquisition-related operation and maintenance and system-specific military construction costs.

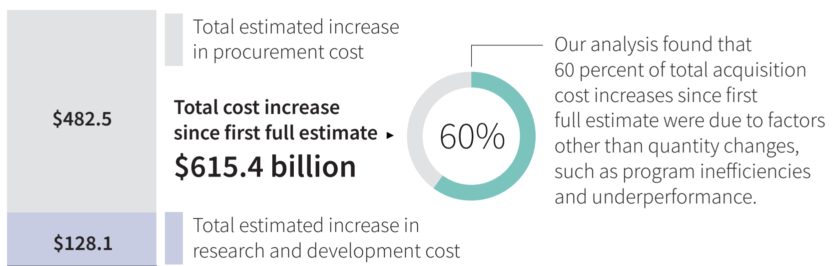
DOD MDAP Portfolio

FACTORS CONTRIBUTING TO COST CHANGES

While quantity increases have contributed significantly to cost increases, other factors also contributed to cost change.

Increases or decreases to total quantities procured, which we refer to as quantity changes, and other factors influenced cost changes from first full estimate and since last year. An equal number of MDAPs reported cost decreases and increases since last year. Schedule delays and decisions to add capabilities and increase planned quantities in some MDAPs contributed to one-year cost growth. For example, since our last assessment, the Handheld Manpack and Small Form Fit Radios program increased its planned quantities from 271,202 to 299,972, which contributed to the program's cost increase.

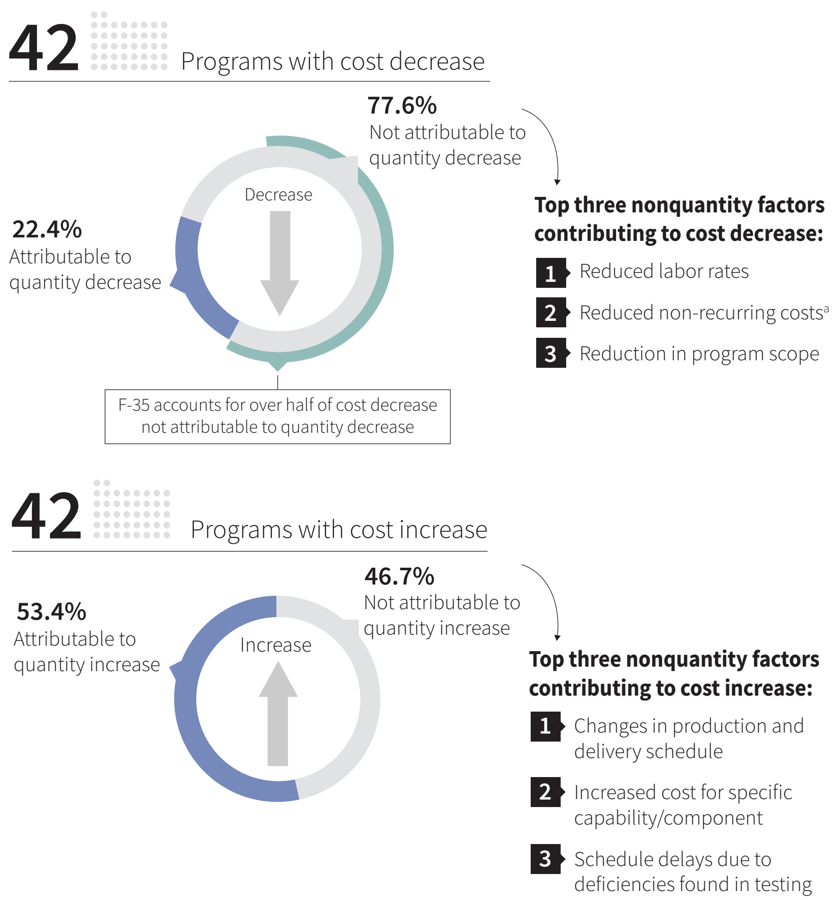
Figure 8: Quantity Changes and Other Factors Contributed to Cost Increases Since First Full Estimate for the Department of Defense's 2020 Major Defense Acquisition Program Portfolio



Source: GAO analysis of Department of Defense data. | GAO-21-222

Note: In addition to research and development and procurement costs, total acquisition cost includes acquisition-related operation and maintenance and system-specific military construction costs.

Figure 9: Percent of One-Year Cost Change in 2020 Major Defense Acquisition Program Portfolio Attributable to Change in Quantity Procured



Source: GAO analysis of Department of Defense data. | GAO-21-222

Note: In some cases, quantity changes result from decisions to buy more units of a weapon system and thus do not reflect changes in program approach. In other cases, quantity changes indicate Department of Defense decisions to introduce new capabilities through existing program additions rather than by starting new programs. For example, the Arleigh Burke Destroyer (DDG 51) program introduced a newly configured Flight III destroyer with increased ballistic missile and air defense capabilities, but did not create a separate program to do so. We recommended in our prior work that specific programs create and report separate baselines for new capability increments to improve insight into true program performance.

[a]Non-recurring costs are those that occur once or occasionally for a particular cost objective.

Examples of total acquisition cost change due to factors other than change to total quantities procured

(fiscal year 2021 dollars in billions)

Source: U.S. Navy photo courtesy of Huntington Ingalls Industries. | GAO-21-222

SSN 774 Virginia Class Submarine

$2.3

▲ Nonquantity cost change

Contributing factors:

- → Shifted construction of two ships to later years
- → Integration of new missile-launch mechanism
- → Infrastructure improvements

Source: BAE. | GAO-21-222

Armored Multi-Purpose Vehicle

$1.8

▲ Nonquantity cost change

Contributing factors:

- → Changes in funding contributed to a decision at the production milestone to decrease the rate of vehicle production over the full production phase.

Joint Light Tactical Vehicle

$1.9

▲ Nonquantity cost change

Contributing factors:

- → Increased cost for specific capability/component
- → Changes in production and delivery schedule

Combat Rescue Helicopter

$0.9

▲ Nonquantity cost change

Contributing factors:

- → Retrofits
- → Additional aircraft upgrades
- → Additional funding for mobile satellite communication

CH-53K King Stallion

$1.7

▲ Nonquantity cost change

Contributing factors:

- → Schedule delays due to deficiencies found in testing
- → Increased cost for specific capability/component

Note: Cost change and contributing factors are based on total acquisition costs reported in December 2018 to December 2019 Selected Acquisition Reports. When applicable, we also reviewed program exception Selected Acquisition Reports submitted within this time period.

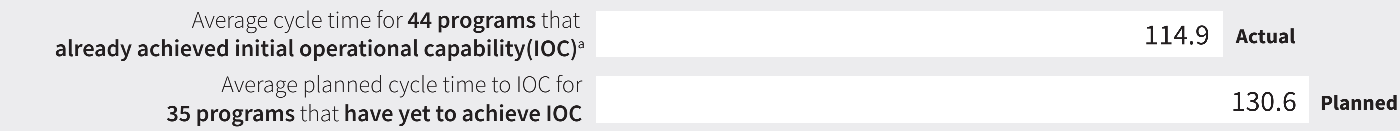
DOD MDAP Portfolio

SCHEDULE

Overall schedule delays increased for programs that have yet to achieve initial capability, including among some newer MDAPs

We analyzed 35 MDAPs that had yet to declare initial operational capability (IOC) as of their December 2019 Selected Acquisition Reports. IOC is generally a point in time when a system can meet the minimum operational capabilities for a user's stated need. On average, these programs are scheduled to deliver capability in 130.6 months—a 1.4 percent increase from the cycle times they reported in their December 2018 Selected Acquisition Reports. Figure 10 shows that the cycle time for programs that already achieved initial capability took over a year less time, on average, than the time planned for programs yet to achieve IOC. Of the 35 programs we analyzed, 19 programs reported no delays to IOC over the past year, including three programs that reported schedule accelerations, while 16 programs reported delays. We found that delivery delays, test delays, and performance deficiencies were among the contributing factors of schedule delays.

Figure 10: Average Major Defense Acquisition Program Reported Cycle Time (in months)

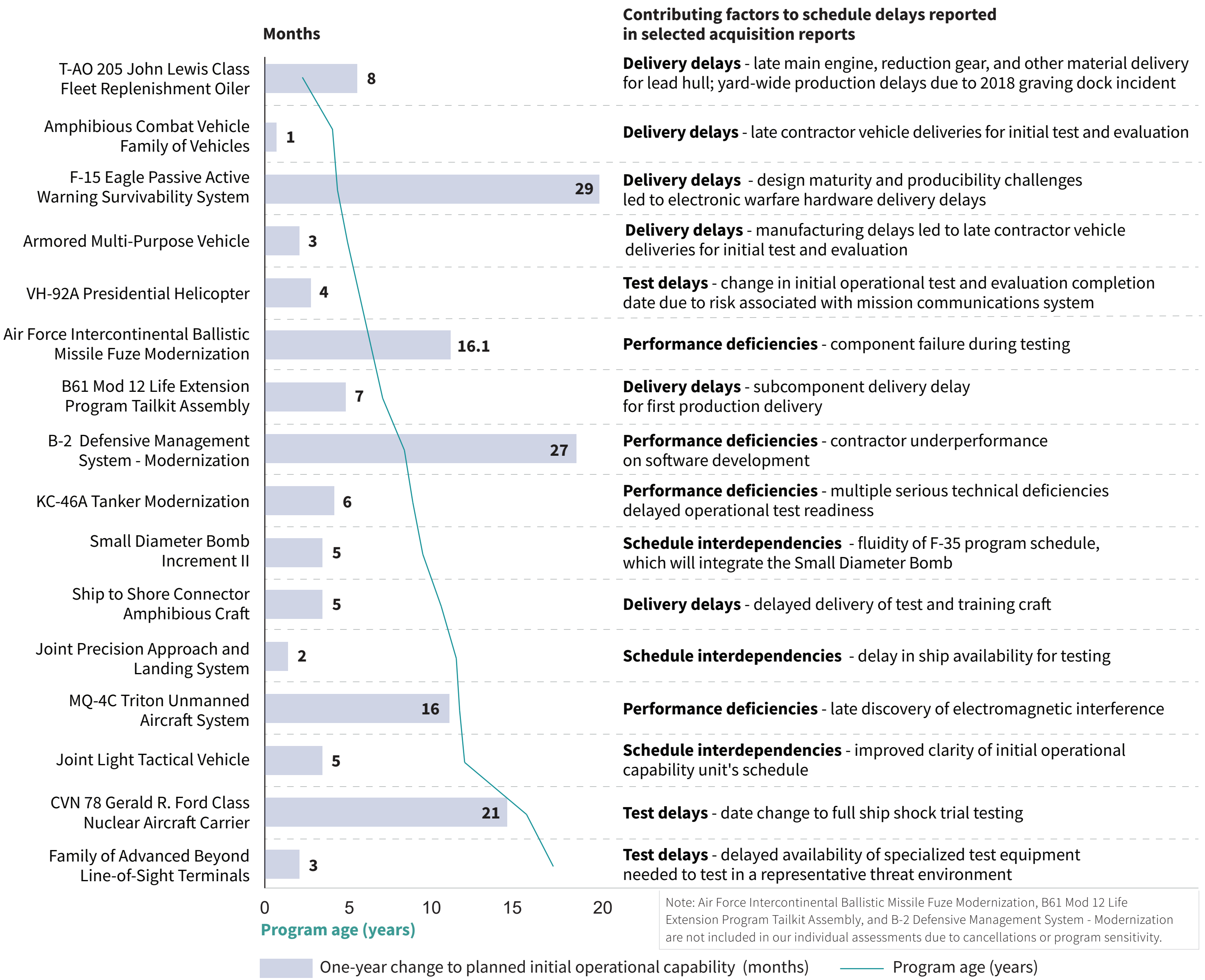


Source: GAO analysis of Department of Defense data. | GAO-21-222

[a]Five programs were not included in this analysis because IOC data were not available.

Similar factors contributed to schedule delays regardless of program age.

Figure 11: One-Year Increase to Planned Initial Operational Capability for 16 Programs that Reported a Schedule Delay Since 2019 (in Months)



Note: Air Force Intercontinental Ballistic Missile Fuze Modernization, B61 Mod 12 Life Extension Program Tailkit Assembly, and B-2 Defensive Management System - Modernization are not included in our individual assessments due to cancellations or program sensitivity.

Source: GAO analysis of Department of Defense data. | GAO-21-222

DOD MTA Portfolio

COST

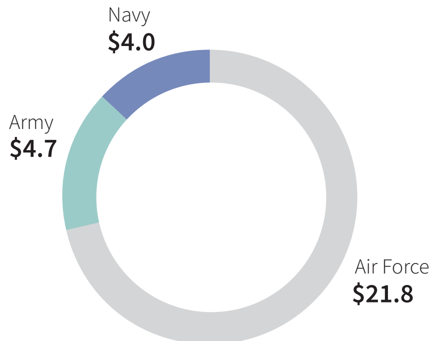
DOD expanded its MTA portfolio and plans to invest $30.5 billion in its current MTA efforts, though programs continued to report inconsistent cost data.

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

Source: U.S. Air Force. | GAO-21-222

Since our last assessment, DOD expanded its portfolio of MTA programs with estimated costs greater than the threshold for MDAP designation from 13 to 17 programs—14 rapid prototyping, two rapid fielding, and one combined rapid prototyping and rapid fielding. These programs provide critical capabilities that vary from aircraft hardware to satellite communication capabilities. The MTA portfolio we reviewed includes six new programs, while two programs exited the portfolio since we last reported.

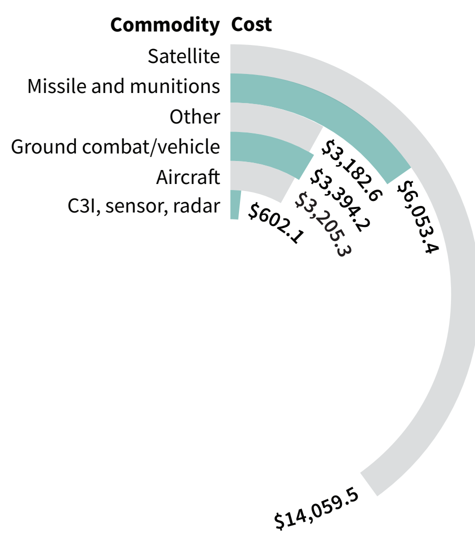
Figure 12: Planned Cost of Current Middle-Tier Acquisition Efforts (fiscal year 2021 dollars in billions)



Source: GAO analysis of Department of Defense data. | GAO-21-222

The planned cost estimates for the 17 current MTA efforts we reviewed is $30.5 billion. This reporting approach aligns with DOD guidance, which states that MTA programs should clearly and discretely report costs associated with the scope of the effort conducted under the current MTA pathway. However, we found that, as of March 2020, in some cases MTA programs continued to report inconsistent cost information to the Office of the Secretary of Defense (OSD) and Congress, limiting DOD and congressional insight into actual MTA effort costs. Programs reported cost data to us that was inconsistent with the cost data reported to OSD and Congress. For example, Next Generation Overhead Persistent Infrared Space Block 0 (Next Gen OPIR) plans to complete its current MTA rapid prototyping effort in early fiscal year 2024, but, in March 2020, its cost reporting included over $2 billion in planned spending for fiscal year 2025. In contrast, Next Gen OPIR reported to us funding through fiscal year 2031, which is several years after the current MTA effort ends. DOD officials told us that they expect that the accuracy of MTA program cost data will continue to improve as the data are increasingly used for oversight purposes.

Figure 13: Estimated Costs of Current Middle-Tier Acquisition Efforts by Commodity (fiscal year 2021 dollars in millions)



Source: GAO analysis of Department of Defense data. | GAO-21-222

C3I = Command, Control, Communications and Intelligence

Examples of MTA programs with reported cost changes since our last assessment

F-22 Capability Pipeline

- Since last year, the program reported an increase in development funding needs to address software development challenges and schedule delays. However, program costs remained within established cost parameters, according to program officials.
- To help avoid further software development delays, program officials said the program has taken action to address potential funding issues; however, the Air Force diverted needed funding to higher priority items. If the program does not secure sufficient funding, future development could be delayed.

Integrated Visual Augmentation System (IVAS)

- The program updated its completion date from November 2020 to September 2023 and **total estimated costs are now $26.4 million more than what was reported last year**.

  Program officials explained that the change in the completion date and cost were an error in their prior reporting, not a change to the program's planned schedule or cost.

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

- In March 2020, **the Air Force Cost Analysis Agency reassessed virtual prototype costs at more than $525 million, an increase of more than $240 million since 2018**. Program officials largely attributed this cost increase to the shift of work from the subsequent planned physical prototype development MTA effort to the current virtual prototype development MTA effort.

DOD MTA Portfolio

TRANSITION PLANS

MTA programs expect to transition to a variety of pathways, with nearly half of the programs reviewed planning transitions to a rapid fielding effort or the major capability acquisition pathway for production.

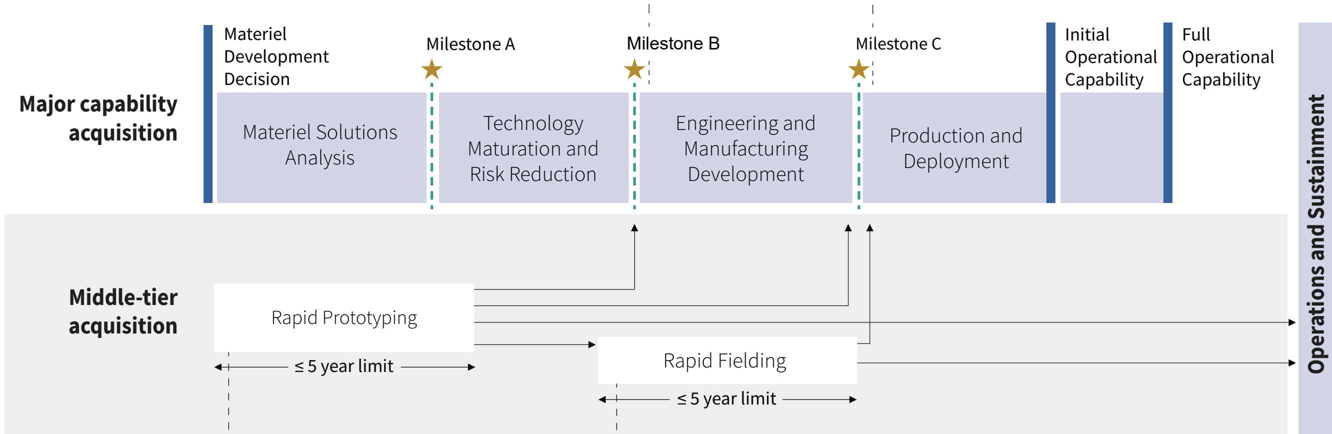
Following the current MTA effort, programs can further pursue development or production , for example, by transitioning successful prototypes to new or existing acquisition programs for production, fielding, and operations and sustainment under the rapid fielding pathway or other acquisition pathways.

Nearly half of the 17 MTA programs we reviewed plan to transition to a rapid fielding MTA pathway or enter the major capability acquisition pathway at production following the current MTA effort. In contrast, five programs plan to transition to a follow-on rapid prototyping effort or enter the major capability acquisition pathway at development, while the remaining four programs have yet to determine their transition pathways.

Figure 14: Planned Transition Pathway of Current Middle-Tier Acquisition (MTA) Effort for 17 MTA Programs GAO Reviewed

Three MTA programs plan to transition to the major capabiilty acquisition pathway at the **development milestone:**
- Next Generation Overhead Persistent Infrared (Next Gen OPIR)
- Optionally Manned Fighting Vehicle Inc. 1 (OMFV Inc. 1)
- Protected Tactical SATCOM (PTS)

Three MTA programs plan to transition to the major capability acquisition pathway at the **production milestone:**
- Extended Range Cannon Artillery (ERCA)
- F-15 EX
- Mobile Protected Firepower (MPF)



Two MTA programs plan to transition to another MTA **rapid prototyping effort:**
- B-52 Commercial Engine Replacement Program (CERP) Rapid Virtual Prototype (RVP)
- **Conventional Prompt Strike (CPS)**

CPS plans to conduct at least three phases that will include two rapid prototyping efforts and one rapid fielding effort.

The program plans to transition to the major capability acquisition pathway with entry at production once all MTA phases are complete sometime after 2028.

Five MTA programs plan to transition to an **MTA rapid fielding effort:**
- Air-launched Rapid Response Weapon (ARRW)
- Evolved Strategic SATCOM (ESS)
- Integrated Visual Augmentation System (IVAS)
- **Lower Tier Air and Missile Defense Sensor (LTAMDS)**
- Protected Tactical Enterprise Service (PTES)

LTAMDS plans to transition to a rapid fielding program to field 16 radars. Following the rapid fielding effort, the program plans to transition to the major capability acquisition pathway with entry at production to field the remaining 65 radars.

Four programs **have yet to determine a transition pathway**:
- Air Operations Center Weapon System Modifications (AOC WS Mods)
- Future Operationally Resilient Ground Evolution (FORGE)
- **F-22 Capability Pipeline**
- Military Global Positioning System GPS User Equipment Increment 2 (MGUE Inc. 2) Miniature Serial Interface (MSI)

F-22 Capability Pipeline is developing and fielding capabilities under both the rapid prototyping and the rapid fielding pathway, but has yet to identify a transition pathway following the completion of its current rapid prototyping and fielding effort.

Rapid prototyping
Rapid fielding

Source: GAO analysis of Department of Defense data. | GAO-21-222

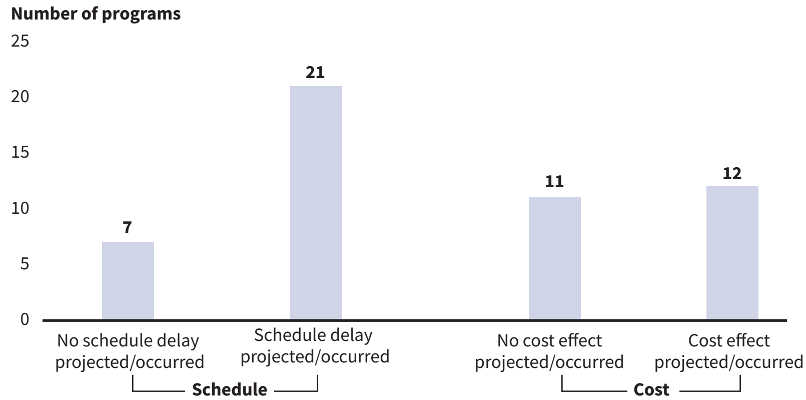
COVID-19

EARLY EFFECTS ON MDAPS

Nearly all programs reported early challenges associated with COVID-19 as of September 2020.

Forty of the 42 MDAPs we surveyed reported challenges associated with COVID-19 as of the last quarter of fiscal year 2020. About half of all MDAPs we surveyed reported the contractor is projecting or already experienced schedule delays and 12 programs reported the contractor is projecting or already experienced cost increases as a result of challenges associated with COVID-19. Thirty-four programs reported inefficiencies from production line shutdowns or slowdowns that resulted in delays. Additional challenges included temporary site shutdowns or reduced facilities, reduced labor, supplier delays, and travel restrictions.

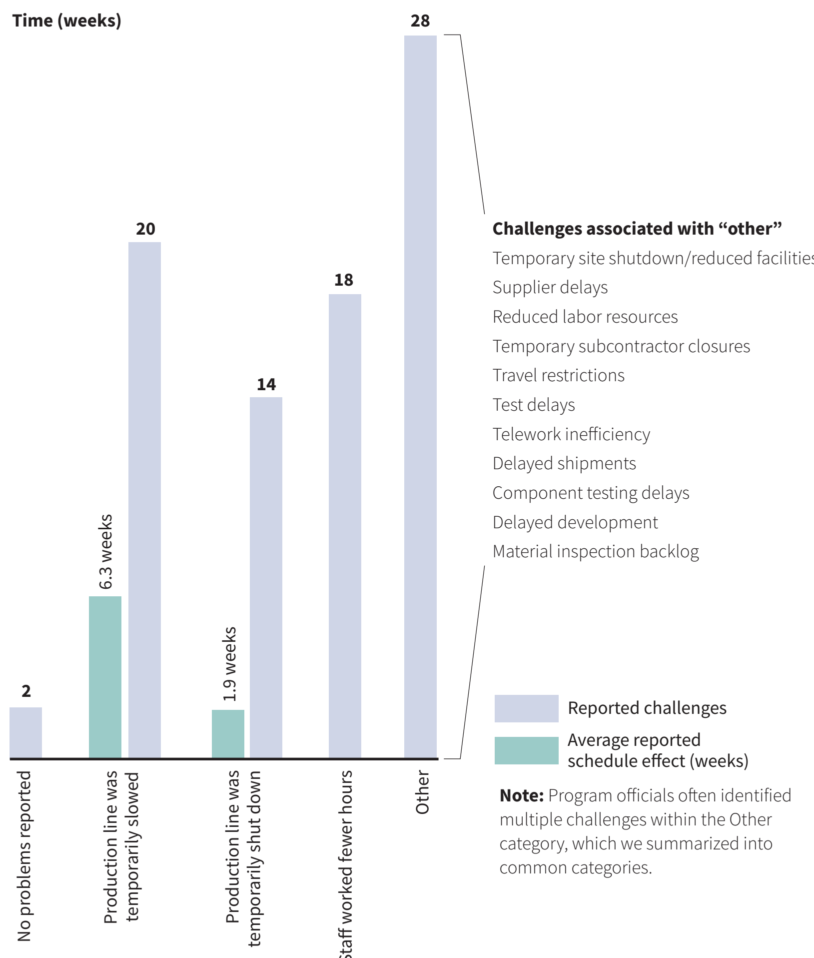
Figure 15: Programs Reporting Early Schedule Delays and Cost Increases due to Issues Associated with Coronavirus Disease 2019 (COVID-19)



Source: GAO analysis of Department of Defense data. | GAO-21-222

Note: In addition to the numbers above, 14 programs did not provide information on schedule delays due to COVID-19, and 19 programs did not provide information on cost increases due to COVID-19.

Figure 16: Reported Challenges due to Coronavirus Disease 2019 (COVID-19) as of September 2020



Note: Program officials often identified multiple challenges within the Other category, which we summarized into common categories.

Source: GAO analysis of Department of Defense data. | GAO-21-222

Examples of COVID-19-related challenges reported by MDAPs

HH-60W Jolly Green II

Source: Sikorsky Aircraft Company. | GAO-21-222

→ Program officials reported a 1- to 2-month production slowdown and estimated a 3-month delay due to initial COVID-19 effects, including contractor absenteeism, which affected the production line and could delay initial production dates.

→ Program officials also reported that government travel restrictions and quarantine requirements had programmatic effects.

Enhanced Polar System-Recapitalization (EPS-R)

Source: U.S. Air Force. | GAO-21-222

→ Program officials reported that staffing challenges and facility shutdowns affected schedule margin of the program's satellite payloads. The program is working with the contractor to implement mitigation strategies.

→ Despite COVID-19-related reductions to schedule margin, program officials stated they had yet to experience overall schedule delays related to COVID-19.

EARLY EFFECTS ON MTA PROGRAMS

Similar to MDAPs, most MTA programs reported early challenges associated with COVID-19.

Twelve of the 17 MTAs we surveyed reported challenges associated with COVID-19 as of September 2020. Programs reported instances of production line shutdowns or slowdowns that have already resulted in production inefficiencies as well as challenges such as staff working fewer hours, temporary site shutdowns and reduced facilities, supplier delays, and travel restrictions, among other things. Figure 17 shows additional reported cost and schedule implications due to COVID-19.

Examples of COVID-19-related challenges reported by MTA programs

Mobile Protected Firepower (MPF)

Source: U.S. Army. | GAO-21-222

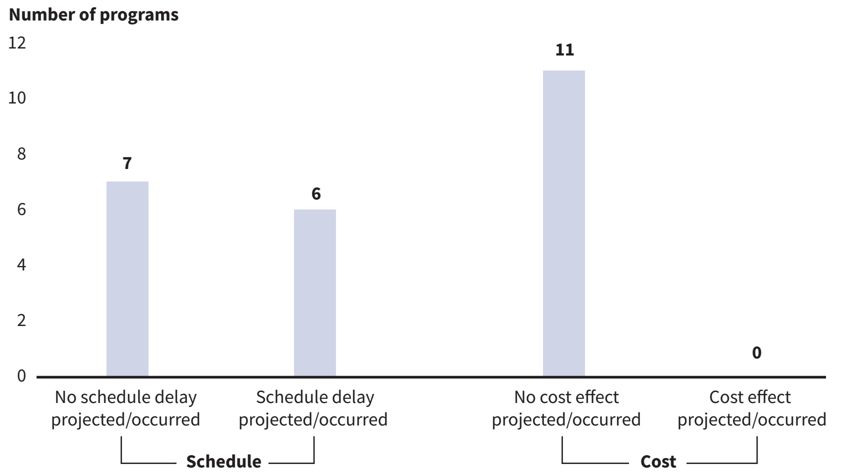
- Program experienced facility closures for 4 weeks, which slowed component testing.
- MPF also reported that subcontractors faced international travel restrictions and limited facility access due to COVID-19.
- Program officials estimated an overall schedule delay of 4 weeks as of August 2020, but stated that the estimate remains fluid.

Air-Launched Rapid Response Weapon (ARRW)

Source: U.S. Air Force. | GAO-21-222

- Program officials reported three instances of personnel exposure to COVID-19, which caused testing delays. For example, one facility experienced two instances of COVID-19-related quarantines that delayed test preparations. The delay caused the contractor to miss a scheduled October range time and required the program to secure another range window in in the first quarter of fiscal year 2021.
- ARRW estimated a schedule delay of 4 to 8 weeks, as of August 2020, but the overall delay is still being assessed.

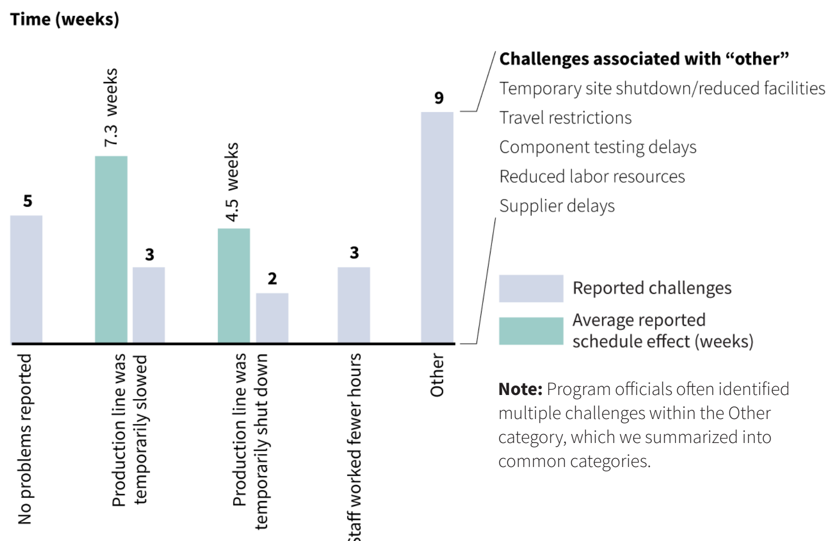
Figure 17: MTA Programs Reporting Early Schedule Delays and Cost Increases Due to Issues Associated with Coronavirus Disease 2019 (COVID-19)



Source: GAO analysis of Department of Defense data. | GAO-21-222

Note: In addition to the numbers above, four programs did not provide information on schedule delays due to COVID-19, and six programs did not provide information on cost increases due to COVID-19.

Figure 18: Reported Challenges Due to Coronavirus Disease 2019 (COVID-19)



Note: Program officials often identified multiple challenges within the Other category, which we summarized into common categories.

Source: GAO analysis of Department of Defense data. | GAO-21-222

DOD Weapon Programs Do Not Consistently Plan to Attain Knowledge That Could Limit Cost Growth and Deliver Weapon Systems Faster

We found that over half of MDAPs we surveyed proceeded with acquisition decisions without obtaining knowledge at least at two points that could minimize cost growth and schedule delays. This finding is similar to our results on MDAP knowledge attainment we reported in last year's assessment.[39] Future MDAPs we surveyed, in contrast, reported that they plan to attain recommended knowledge by development start. It will be important that they follow through on these plans to ensure the cost and schedule benefits of these practices.

This year we also assessed how MTA programs plan to obtain acquisition knowledge and conduct key activities in preparation for the MTA program's planned follow-on effort. We found that, of the MTA programs that planned to transition to the major capability acquisition pathway at system development or production, or to an MTA rapid fielding effort, only one of 11 programs planned to fully acquire knowledge before doing so.

MDAPs Continue To Forgo Knowledge Opportunities, although Future MDAPs Generally Plan to Attain Recommended Knowledge

We found that MDAPs continue to proceed with limited knowledge at the potential expense of improved knowledge-driven cost and schedule outcomes, although most future MDAPs we assessed reported they plan to attain recommended knowledge before development start.

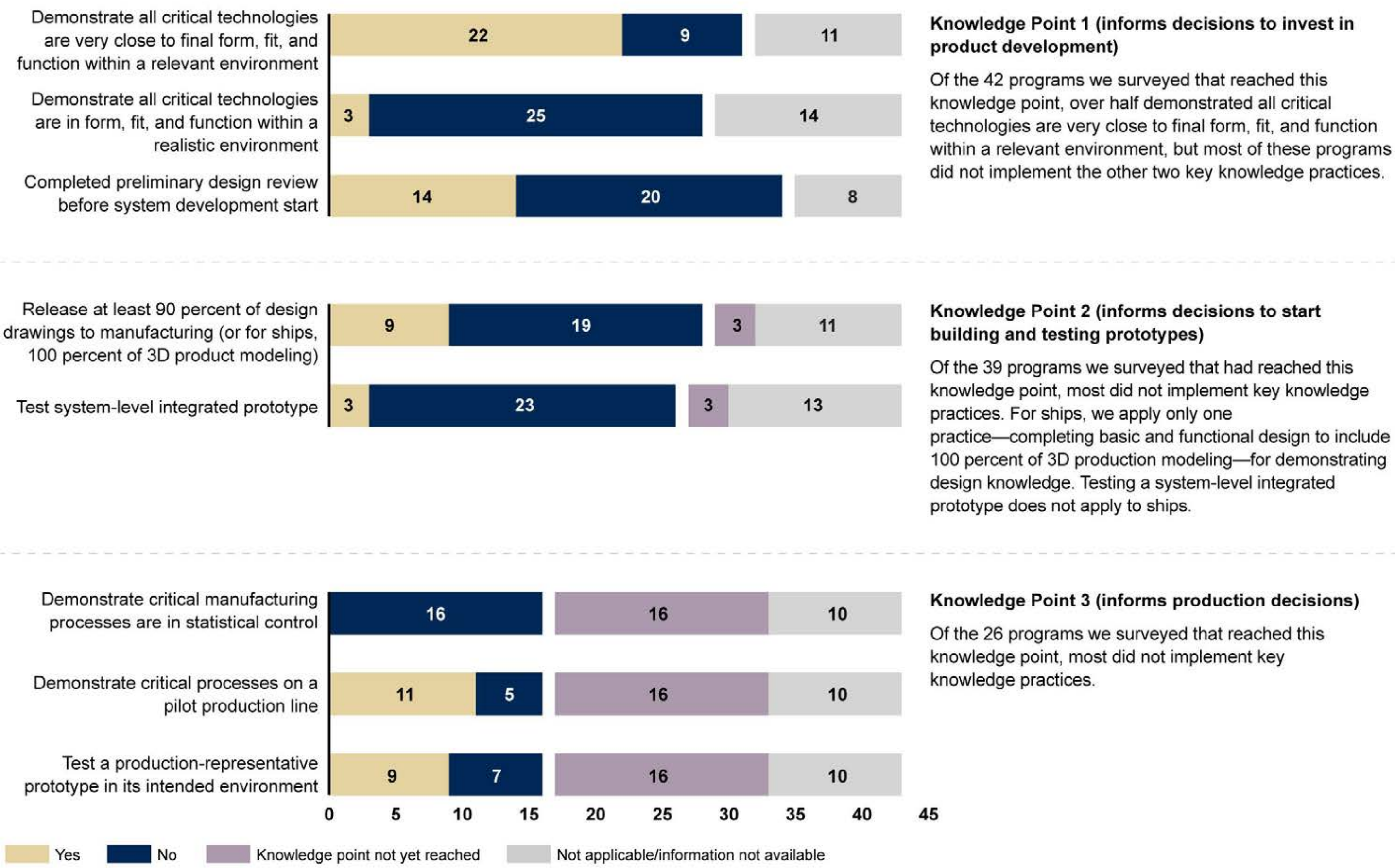
MDAPs

We analyzed 42 MDAPs that were either between the start of development and the early stages of production or well into production but introducing new increments of capability or significant changes. Our analysis this year again found that the majority of these programs did not fully implement knowledge-based practices at key points during the acquisition process, and, consequently, may face increased risk of cost

[39] GAO-20-439.

growth and schedule delays. For example, we found only one practice—demonstrating that critical technologies are in form, fit, and function within a relevant environment—where more than half the programs we surveyed demonstrated sufficient knowledge.[40] Figure 19 identifies the number of programs that have implemented key knowledge practices.

Figure 19: Extent to Which 42 Major Defense Acquisition Programs Implemented Key Knowledge Practices



Source: GAO analysis of questionnaire data. I GAO-21-222

[40]10 U.S.C. § 2366b(a)(2). Since enactment of the Weapon Systems Acquisition Reform Act of 2009 (WSARA), an MDAP generally may not receive approval for development start until the milestone decision authority has received a preliminary design review, conducted a formal post preliminary design review assessment, and certifies, based on that assessment, that the program demonstrates a high likelihood of accomplishing its intended mission. WSARA, Pub. L. No. 111-23, § 205(a)(3) (2009) (codified as amended at 10 U.S.C. § 2366b). Under certain circumstances, this requirement may be waived. 10 U.S.C. § 2366b(d).

Data table for Figure 19: Extent to Which 42 Major Defense Acquisition Programs Implemented Key Knowledge Practices

Description	yes	no	Knowledge point not reached	Not applicable/ information not available	Knowledge point details
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	22	9	0	11	Knowledge Point 1 (informs decisions to invest in product development) Of the 42 programs we surveyed that reached this knowledge point, over half demonstrated all critical technologies are very close to final form, fit, and function within a relevant environment, but most of these programs did not implement the other two key knowledge practices.
Demonstrate all critical technologies are in form, fit, and function within a realistic environment	3	25	0	14	
Completed preliminary design review before system development start	14	20	0	8	
Release at least 90 percent of design drawings to manufacturing (or for ships, 100 percent of 3D product modeling)	9	19	3	11	Knowledge Point 2 (informs decisions to start building and testing prototypes) Of the 39 programs we surveyed that had reached this knowledge point, most did not implement key knowledge practices. For ships, we apply only one practice—completing basic and functional design to include100 percent of 3D production modeling—for demonstrating design knowledge. Testing a system-level integrated prototype does not apply to ships.
Test system-level integrated prototype	3	23	3	13	
Demonstrate critical manufacturing processes are in statistical control	0	16	16	10	Knowledge Point 3 (informs production decisions) Of the 26 programs we surveyed that reached this knowledge point, most did not implement key knowledge practices.
Demonstrate critical processes on a pilot production line	11	5	16	10	
Test a production-representative prototype in its intended environment	9	7	16	10	

Note: DOD guidance calls for programs to demonstrate critical manufacturing processes on a pilot production line, but does not require statistical control of those processes until the full-rate production decision. Leading acquisition practices, in contrast, call for this knowledge to be in hand at production start in order to ensure manufacturing processes are repeatable, sustainable, and capable of consistently producing parts within quality standards. These practices do not apply to ships. We scored a knowledge-based practice as “NA” for a program if the particular practice was not relevant to the program, such as test of a production-representative satellite prototype in its intended environment of space. We did not score our seven one-page assessments of MDAPs that were well into production but planned to introduce new increments of capability, because the acquisition strategies these programs employed did not allow us to consistently apply our knowledge attainment metrics. In addition, we scored three programs as “information not available” for releasing 90 percent of design drawings to manufacturing. These programs either no longer tracked design drawings, implemented design changes after design review, or held separate reviews for different parts of its program.

Future MDAPs

We also surveyed four future MDAPs to assess their plans for attaining knowledge before development start.[41] Specifically, we asked whether programs conducted competitive prototyping, completed independent technical risk assessments, validated requirements, and completed preliminary design reviews. We found that these programs achieved some knowledge and plan to achieve more knowledge before starting system development—the point identified by leading practices when knowledge should be attained to confirm that resources and requirements match. Table 4 presents the number of future MDAPs that plan to meet key knowledge practices associated with the start of system development.

Table 4: Planned Implementation of Selected Knowledge-Based Acquisition Practices by Development Start among Four Future Major Defense Acquisition Programs

	Conduct competitive prototyping	Complete independent technical risk assessment	Validate requirements	Complete preliminary design review
Knowledge attained	**2**	**1**	**2**	**3**
Knowledge planned	**1**	**3**	**2**	**1**
Knowledge not planned to be attained	**1**	**—**	**—**	**—**

Source: GAO analysis of Department of Defense acquisition programs' responses to GAO questionnaire. | GAO-21-222

While the majority of future MDAPs reported plans to attain recommended knowledge, if these plans do not materialize, these programs may face the same cost and schedule risks we identified with MDAPs that do not attain sufficient knowledge before making key decisions.

Opportunities for Cost and Schedule Improvement

For the fourth consecutive year, we conducted a statistical correlation analysis to determine whether a statistically significant link exists between non-shipbuilding MDAPs' unit costs and schedule performance and their

[41]We did not assess planned knowledge attainment for the Army's Indirect Fire Protection Capability Increment 2 program because the program plans to transition to the MTA pathway, or for the Navy's Large Unmanned Surface Vehicle program because the program office stated that it had yet to determine planned dates for the associated events.

implementation of knowledge-based acquisition practices.[42] We analyzed 24 programs—an increase of three programs from our 2020 analysis—that have completed system development, held a critical design review, and started production (i.e., completed knowledge points 1 through 3).[43] For many practices, the number of programs that implemented the practices was insufficient to allow for statistically significant results. As we continue the analysis in the future, and as the number of programs completing all three knowledge points increases, it is possible our analysis will identify additional practices that have a statistically significant correlation to program outcomes.

This year we observed three knowledge practices with a statistically significant correlation to both improved program acquisition unit costs and improved schedule performance. Table 5 identifies these three practices and their statistical significance.

Table 5: Statistically Significant Knowledge-Based Acquisition Practices and Corresponding Performance Outcomes among 24 Selected Major Defense Acquisition Programs

Knowledge Practice	Net performance difference from programs that implemented the practice
Completed a preliminary design review before system development start	43.3% less unit cost growth 34.1% less schedule growth
Release at least 90 percent of design drawings by critical design review	53.3% less unit cost growth 50.3% less schedule growth
Test a system-level integrated prototype	29.1 % less unit cost growth 30.2% less schedule growth

Source: GAO analysis of Department of Defense data and acquisition programs' responses to GAO questionnaire. | GAO-21-222

Note: To ensure consistency of comparisons across MDAPs, we looked at 24 MDAPs initiated between fiscal year 2011 and fiscal year 2020 that were completed programs, or programs that passed all three knowledge points.

MTA Programs Do Not Consistently Plan to Attain Key Product Knowledge before Transition

We found that a limited number of MTA programs that intend to transition to the major capability acquisition pathway at system development or production or to an MTA rapid fielding effort plan to fully acquire

[42]Shipbuilding projects use different metrics and are therefore excluded from the statistical analysis.

[43]These 24 programs are a separate subset from the 42 programs included in our questionnaire analysis.

knowledge recommended by leading acquisition practices before entering these phases of the acquisition life cycle. MTA programs follow a streamlined acquisition process and are exempt from many of the documentation requirements and key milestones that are in place for MDAPs. However, our past work on knowledge-based acquisition practices for MDAPs suggests that gaining appropriate knowledge related to technology development, design, and production during the MTA effort will help ensure the program is well positioned to field its eventual planned capabilities and meet warfighter requirements, including timely delivery of the eventual capability.[44] For MTA programs, a knowledge deficit at the end of the current MTA effort runs the risk of having implications after the program transitions to a follow-on acquisition pathway or effort.

To understand whether MTA programs were planning to attain the recommended level of knowledge before key program decisions, we applied our knowledge-based acquisition practices to MTA programs based on the key program decisions associated with a program's specific transition plan. For example, if an MTA program planned to transition to the major capability acquisition pathway at system development, we assessed the extent to which the program planned to demonstrate knowledge that informs the decision to invest in product development by the end of the current MTA effort. Of the 17 MTA programs we reviewed, DOD expects to transition 11 for additional development or fielding through different pathways or efforts, including starting an MTA rapid fielding effort or entering the major capability acquisition pathway at system development or production start.[45]

Based on responses to our questionnaire, we found that these 11 programs had only limited plans to acquire key system development or production knowledge prior to transitioning to their planned follow-on effort. For example, none of the programs that plan to transition to the

[44]GAO-20-439.

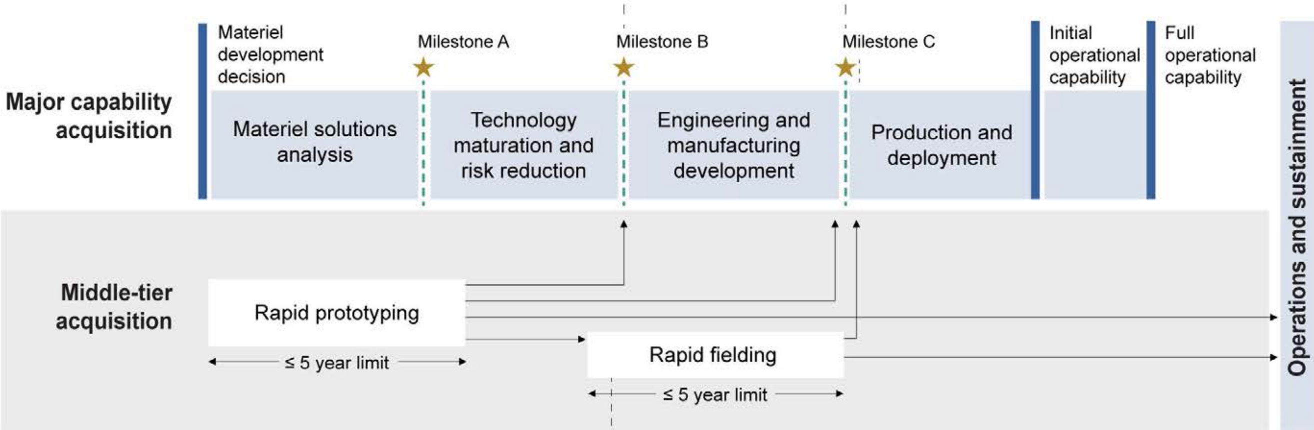
[45]Of the 11 MTA programs, three plan to transition to the major capability acquisition pathway at system development and eight plan to transition to the major capability acquisition pathway at production or to transition to an MTA rapid fielding effort. For all 11 programs, we analyzed the extent to which the programs plan to fully demonstrate critical technologies in a realistic environment and conduct a preliminary design review before starting system development, which we equate to knowledge point 1. In addition, for the eight programs that plan to transition to either rapid fielding or the major capability pathway at production, we also analyzed the extent to which the programs plan to demonstrate a stable design, which equates to knowledge point 2; and production readiness, which equates to knowledge point 3.

major capability acquisition pathway at production or to begin an MTA rapid fielding effort plan to fully demonstrate knowledge that will inform production readiness, such as demonstrating that critical manufacturing processes are in statistical control before beginning production. Figure 20 identifies the programs we reviewed and their associated planned level of knowledge attainment at the point of transitioning to another MTA effort or acquisition pathway.

Figure 20: Knowledge Attainment Plans of Middle-Tier Acquisition (MTA) Programs that Plan to Transition to another MTA Effort or Acquisition Pathway

MTA programs that plan to transition to the major capability acquisition pathway at the **development milestone:**	**Planned attainment of knowledge** Point 1
Next Generation Overhead Persistent Infared (Next Gen OPIR)	Knowledge attained or planned
Optionally Manned Fighting Vehicle Inc. 1 (OMFV Inc. 1)	N/A
Protected Tactical SATCOM (PTS)	Knowledge not planned

MTA programs that plan to transition to the major capability acquisition pathway at the **production milestone:**	**Planned attainment of knowledge**		
	Point 1	Point 2	Point 3
Extended Range Cannon Artillery (ERCA)	Knowledge attained or planned	Knowledge attained or planned	Knowledge not planned
F-15EX	Knowledge attained or planned	Knowledge attained or planned	Knowledge not planned
Mobile Protected Firepower (MPF)	Knowledge attained or planned	Knowledge attained or planned	Knowledge not planned



Programs that plan to transition to another MTA **rapid fielding effort:**	**Planned attainment of knowledge**		
	Point 1	Point 2	Point 3
Air-launched Rapid Response Weapon (ARRW)	Knowledge attained or planned	Knowledge attained or planned	Knowledge not planned
Evolved Strategic SATCOM (ESS)	Knowledge attained or planned	Knowledge not planned	N/A
Integrated Visual Augmentation System (IVAS)	Knowledge attained or planned	Knowledge not planned	Knowledge not planned
Lower Tier Air and Missile Defense Sensor (LTAMDS)	Knowledge attained or planned	Knowledge attained or planned	Knowledge not planned
Protected Tactical Enterprise Service (PTES)	Knowledge not planned	Knowledge not planned	Knowledge not planned

= Knowledge attained or planned

= Knowledge not planned

N/A = Not applicable/information not available

Source: GAO analysis of questionnaire data. I GAO-21-222

Note: Knowledge point 1 informs decisions on whether to invest in development, whereas knowledge points 2 and 3 relate to design stability and production readiness, respectively. We did not assess Optionally Manned Fighting Vehicle Increment 1 against knowledge point 1 because the program has yet to identify its critical technologies. We did not assess Evolved Strategic SATCOM against knowledge point 3 due to low planned production quantities and because satellite programs cannot test a production-representative prototype in its intended environment.

MTA programs that do not plan to achieve recommended knowledge before transitioning to another MTA effort or acquisition pathway may carry unnecessary risks into their follow-on efforts. For example, the Air Force's PTES program does not plan to demonstrate mature technologies in a realistic environment before transitioning to rapid fielding. Our past work on MDAPs has shown that programs that do not fully mature their critical technologies early in the acquisition life cycle are generally less likely to meet cost, schedule, and performance objectives as problems arise in product development. In other cases, we found that some MTA programs plan to transition to the major capability acquisition pathway without attaining recommended knowledge. For example, the Army's MPF program does not plan to attain mature manufacturing processes or demonstrate critical processes on a pilot production line before beginning low-rate initial production. Our past work on MDAPs has shown that demonstrating these practices before beginning production helps ensure that manufacturing processes are repeatable, sustainable, and capable of consistently producing parts within quality standards and that the system can be produced within the program's cost, schedule, and quality targets.

Nearly All MTA Programs with Identified Critical Technologies Plan to Mature Them during the Current MTA Effort

We found that a separate subset of 11 of the 17 MTA programs we reviewed reported having identified critical technologies, numbering between one and 18 technologies, and nearly all plan to mature those technologies during the current MTA effort.[46] These 11 programs reported current technology readiness levels (TRL) ranging from TRL 4 (which we consider immature) to a TRL 7 or higher (which we consider mature). One program reported it had yet to determine TRLs for several of its critical technologies. The other six programs reported that they did not have

[46]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.: Feb. 11, 2020). Critical technology elements are those technologies that are new or novel, or used in a new or novel way, and are needed for a system to meet its operational performance requirements within defined cost and schedule parameters.

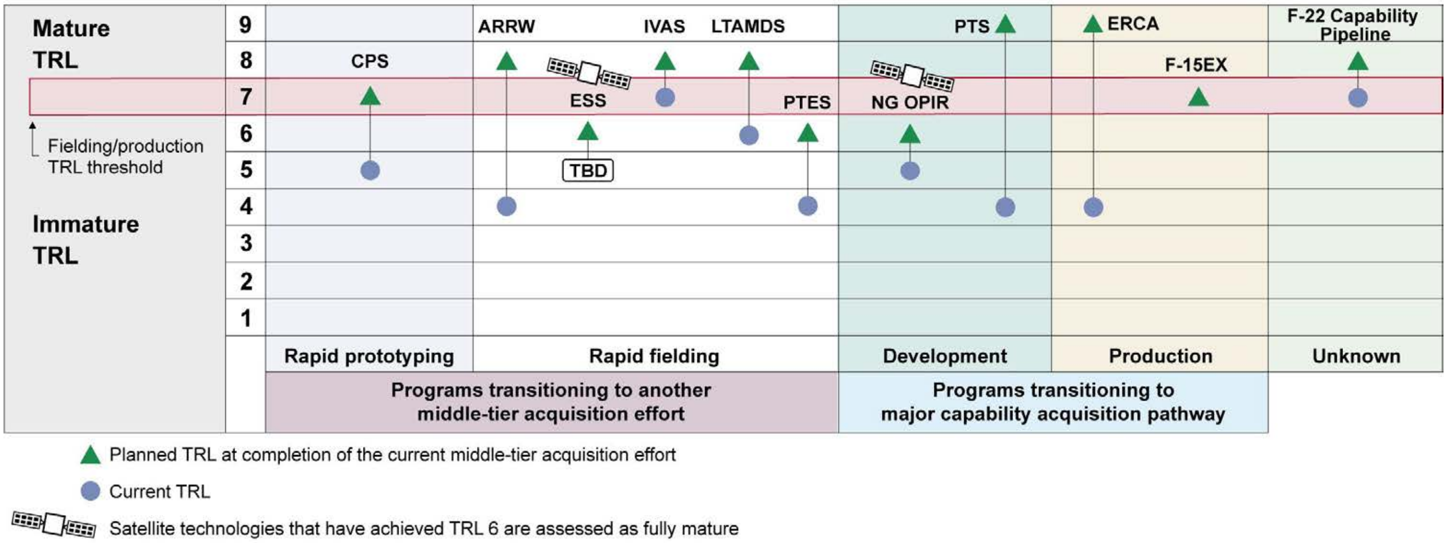
critical technologies because the program had yet to define its technologies, was software intensive, or was leveraging commercially available technologies.

While DOD guidance does not specifically require MTA programs to identify critical technologies, we found that USD(A&S) reviews MTA programs' critical technologies and associated maturity levels as a measure of program risk during program execution reviews. Additionally, our prior work found that correctly identifying critical technologies is an important step for ensuring that program officials accurately understand the technical risk facing the program.[47] Knowledge-based acquisition practices suggest that MTA programs that expect to transition to the major capability pathway at system development or production, or transition to an MTA rapid fielding effort, should plan to have matured critical technologies by the completion of the current MTA effort. Absent such information, programs lack a solid technical basis of the design and could be at risk of producing a design that is less likely to remain stable and potentially requiring costly and time-intensive rework.

We found that nearly all programs that had identified critical technologies planned to mature them by the end of the current effort. However, one program plans proceed to rapid fielding without achieving mature technologies. Figure 21 details the current TRL and planned levels at the end of the current MTA effort for MTA programs that identified critical technologies.

[47]GAO, *Columbia Class Submarine: Immature Technologies Present Risks to Achieving Cost Schedule and Performance Goals*, GAO-18-158 (Washington, D.C.: Dec. 21, 2017).

Figure 21: Current and Planned Technology Readiness Levels for Middle-Tier Acquisition Programs That Identified Critical Technologies



TRL = Technology Readiness Level
CPS = Conventional Prompt Strike
ARRW = Air-launched Rapid Response Weapon
ESS = Evolved Strategic SATCOM
IVAS = Integrated Visual Augmentation System
LTAMDS = Lower Tier Air and Missile Defense Sensor
PTES = Protected Tactical Enterprise Service
ERCA = Extended Range Cannon Artillery
F-15EX
Next Gen OPIR = Next Generation Overhead Persistent Infrared
PTS = Protected Tactical SATCOM
F-22 Capability Pipeline
TBD = To be determined

Source: GAO analysis of programs' questionnaire responses. | GAO-21-222

Note: For programs with multiple critical technologies, the figure represents the lowest current TRL and the lowest planned TRL at program completion.

At least three programs plan to significantly increase one or more TRLs during the current MTA effort to achieve mature technologies by the end of the effort. Specifically, the Air Force's ARRW and PTS programs and the Army's ERCA program plan to mature at least one of their technologies from laboratory scale testing on breadboard components to a fully demonstrated system in a final configuration within 2 to 4 years.

Our prior work on MDAPs has shown that increasing TRLs even one level can take multiple years and becomes more challenging as the technology approaches maturity.[48] We also reported in February 2020 that maturing

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

critical technologies from one TRL to the next may take varying amounts of time and effort, depending on the technology and the readiness level. The amount of time, effort, and activities needed to advance the technology to a higher TRL may not only differ largely between TRLs but also may not increase linearly between progressively higher TRLs.[49] While nearly all the MTA programs we reviewed report they are on track to mature their technologies during the current MTA effort, any challenges during prototype development and testing could lower the technologies' maturity by program transition, thereby adding design or production risk during planned follow-on efforts.

Majority of MTA Programs Continue to Move Forward Without Key Business Case Documentation

Consistent with our findings in last year's assessment, MTA programs continue to move forward with prototyping or fielding activities without having key business case documentation, such as an approved acquisition strategy, approved requirements, formal assessments of technology and schedule risk, or a cost estimate based on an independent assessment. At the time of our review, 11 of the 17 programs we reviewed lacked at least one key business case document. For example, we found that eight of these programs had yet to complete a formal assessment of schedule risk at the time of our review. Additionally, none of the six new MTA programs reviewed in this assessment had all of the key business case documents approved at program initiation. For example, we found that five of these six programs did not complete a formal schedule risk assessment at the time of initiation. While these programs made progress in completing business case documentation between initiation and the time of our review, as of January 2021, all six programs still lacked at least one business case document.

DOD Instruction 5000.80, issued in December 2019, requires MTA programs above certain cost thresholds to develop certain elements of a business case, including: approved requirements; a cost estimate; and an acquisition strategy that includes security, schedule, and technical or production risks, and also includes a test strategy or assessment of test results, and a transition plan. Moreover, DOD Instruction 5000.73, issued in March 2020, requires the Office of Cost Assessment and Program Evaluation to conduct an estimate of life-cycle costs for programs likely to

[49] GAO-20-48G.

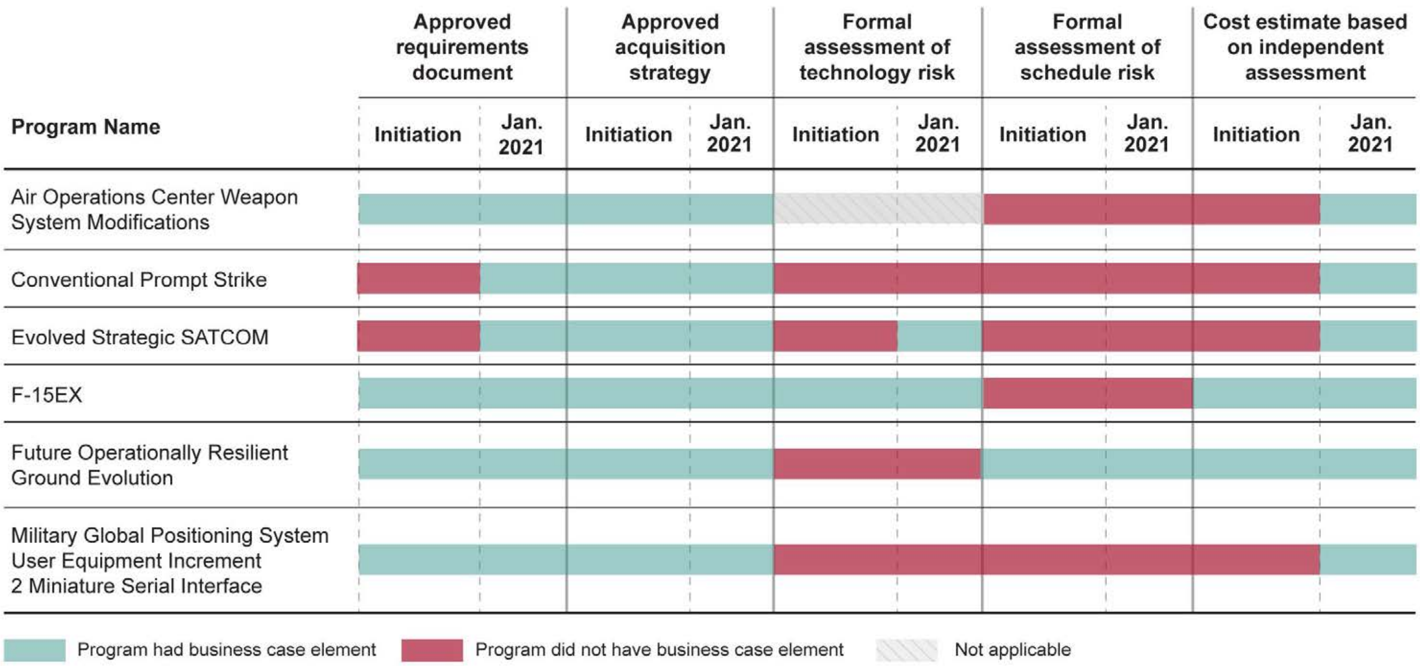
exceed the acquisition category (ACAT) I threshold using the rapid prototyping pathway, or the ACAT I or II thresholds using the rapid fielding pathway.[50] Further, our prior work shows that business case information—which typically includes documentation of the capabilities required of the weapon system, the strategy for acquiring the weapon system, sound cost estimates based on independent assessments, and a realistic assessment of technical and schedule risks—is important to help decision makers make well-informed decisions about middle-tier program initiation. Additionally, these documents can help decision makers determine whether the program is likely to meet its statute-based objectives.[51]

Figure 22 summarizes the status of key business case documents for the six new MTA programs reviewed in this assessment.

[50]For our prior work in this area, see GAO-20-439; GAO-19-439.

[51]According to section 804 of the National Defense Authorization Act for Fiscal Year 2016, the objective of a program using the rapid prototyping pathway is to field a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of the development of an approved requirement, and the objective of a program using the rapid fielding pathway is to begin production within 6 months and complete fielding within 5 years of the development of an approved requirement.

Figure 22: Completion of Key Business Case Documents for Six New Middle-Tier Acquisition Programs Reviewed in this Assessment



Source: GAO analysis of programs' questionnaire responses. I GAO-21-222

Data table for Figure 22: Completion of Key Business Case Documents for Six New Middle-Tier Acquisition Programs Reviewed in this Assessment

	Approved requirements document		Approved acquisition strategy		Formal assessment of technology risk		Formal assessment of schedule risk		Cost estimate based on independent assessment	
Program Name	**Initiation**	**Jan. 2021**	**Initiation**	**Jan. 2021**	**Initiation**	**Jan. 2021**	**Initiation**	**Jan. 2021**	**Initiation**	**Jan. 2021**
Air Operations Center Weapon System Modification[a]	Yes	Yes	Yes	Yes	N/A	N/A	No	No	No	Yes
Conventional Prompt Strike	No	Yes	Yes	Yes	No	No	No	No	No	Yes
Evolved Strategic SATCOM	No	Yes	Yes	Yes	No	Yes	No	No	No	Yes
F-15EX	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Future Operationally Resilient Ground Evolution	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes

	Approved requirements document		Approved acquisition strategy		Formal assessment of technology risk		Formal assessment of schedule risk		Cost estimate based on independent assessment	
Program Name	**Initiation**	**Jan. 2021**	**Initiation**	**Jan. 2021**	**Initiation**	**Jan. 2021**	**Initiation**	**Jan. 2021**	**Initiation**	**Jan. 2021**
Military Global Positioning System User Equipment Increment 2 Miniature Serial Interface	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes

Note: We did not assess Air Operations Center Weapon System Modifications' completion of a formal risk assessment since it is a software program that builds software applications using existing, commercially available mature technologies.

Weapon Programs Reported Inconsistent Implementation of Recommended Software and Cybersecurity Practices

Programs continued this year to identify software development factors, including meeting cybersecurity needs, as risks to efforts to develop and field capabilities to the warfighter, consistent with our findings from last year's assessment.[52] DOD made efforts to improve in these areas, such as working to update its software and cybersecurity instructions and provide guidance on Agile software development practices. However, we found that the majority of programs we surveyed continue to face challenges in executing modern software development practices and many programs we surveyed are challenged in implementing iterative and early cybersecurity assessments.[53]

Software Risk Factors Differed for MDAPs and MTA Programs

The majority of MDAP and MTA programs we surveyed identified software development as a risk. However, the MDAP programs reported different primary factors that led them to identify software as a risk than did the MTA programs. We surveyed 42 MDAPs that were either between the start of development and the early stages of production or well into production but introducing new increments of capability or significant changes; and 17 MTA programs with costs above the thresholds for designation as an MDAP. We asked programs whether software development has been identified as a risk at any point for the program, and if so, the extent to which various reasons contributed to this risk. This is the second year we asked MDAPs these questions but the first year we are assessing MTA programs' software development efforts.

[52]GAO-20-439.

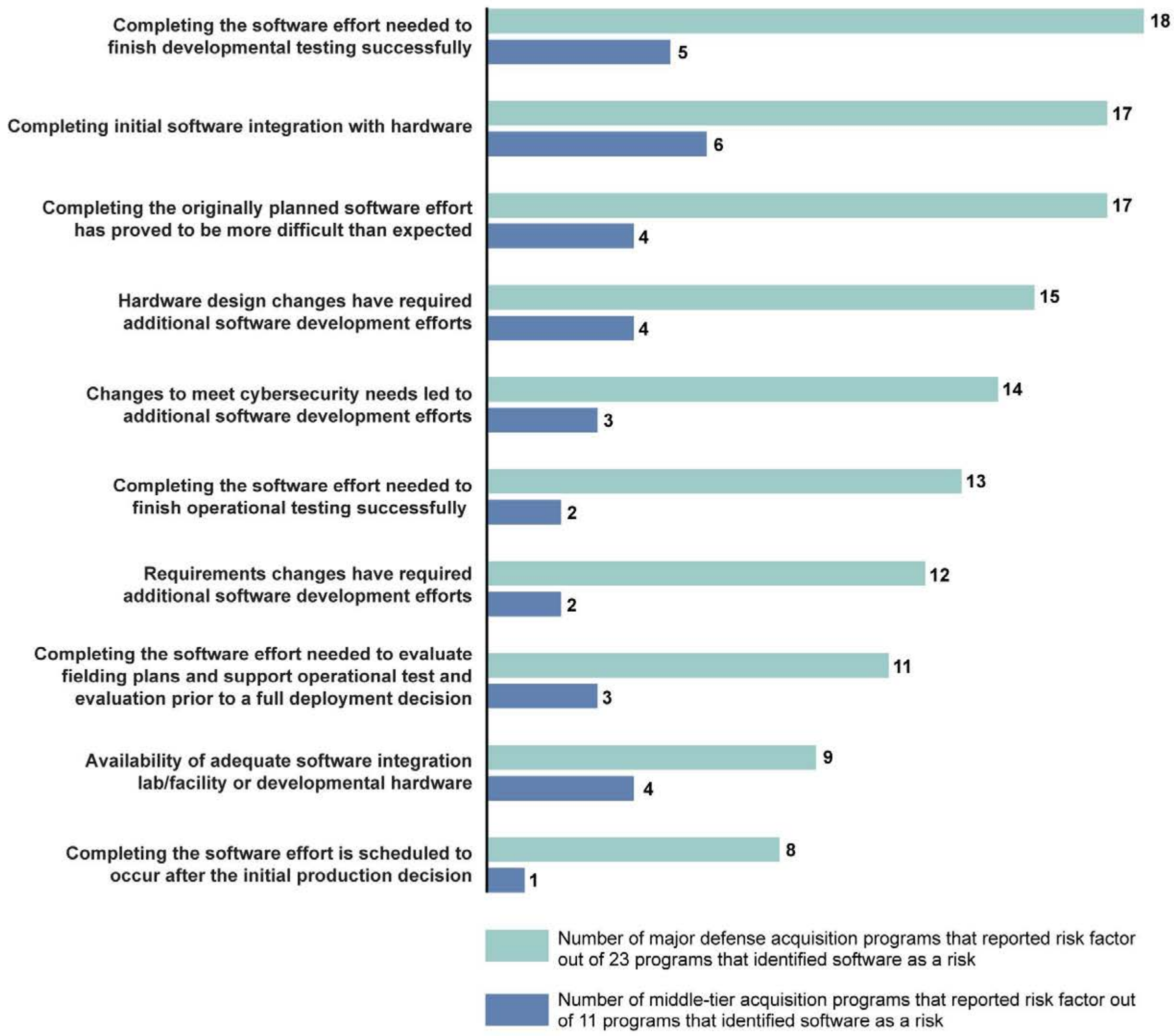
[53]The Defense Innovation Board and updated DOD instruction identify iterative software development methodologies, such as Agile, and modern tools and techniques, such as DevSecOps, as modern approaches. See Defense Innovation Board, *Software is Never Done* (May 2019); and DOD Instruction 5000.87.

Software and Cybersecurity

The largest contributing factor to software risk reported by MDAPs was completing software development in time for developmental testing. The largest contributing factor reported by MTA programs, most of which initiated their efforts within the last 2 or 3 years, was completing initial software integration with hardware. Figure 23 illustrates the various contributing factors reported by MDAPs and MTA programs.[54]

[54] Eleven MTA programs identified software as a program risk, but one program, the Air Force's Next Generation-Overhead Persistent Infrared program, did not identify contributing factors.

Figure 23: Factors that Contributed to the Identification of Software as a Program Risk by Acquisition Pathway



Source: GAO analysis of programs' questionnaire responses. I GAO-21-222

Data table for Figure 23: Factors that Contributed to the Identification of Software as a Program Risk by Acquisition Pathway

	MDAP	MTA
Completing the software effort needed to finish developmental testing successfully	18	5
Completing the originally planned software effort has proved to be more difficult than expected	17	4
Completing initial software integration with hardware	17	6

	MDAP	MTA
Hardware design changes have required additional software development efforts	15	4
Changes to meet cyber security needs led to additional software development efforts	14	3
Completing the software effort needed to finish operational testing successfully	13	2
Requirements changes have required additional software development efforts	12	2
Completing the software effort needed to evaluate fielding plans and support operational test and evaluation prior to a full deployment decision	11	3
Availability of adequate software integration lab/facility or developmental hardware	9	4
Completing the software effort is scheduled to occur after the initial production decision	8	1
Other	6	3

	Number of major defense acquisition programs that reported factor contributed to program risk
Completing the software effort is scheduled to occur after the initial production decision	8
Availability of adequate software integration lab/facility or developmental hardware	9
Completing the software effort needed to evaluate fielding plans and support operational test and evaluation prior to a full deployment decision	11
Requirements changes have required additional software development efforts	12
Completing the software effort needed to finish operational testing successfully	13
Changes to meet cyber security needs led to additional software development efforts	14
Hardware design changes have required additional software development efforts	15
Completing the originally planned software effort has proved to be more difficult than expected	17
Completing initial software integration with hardware	17
Completing the software effort needed to finish developmental testing successfully	18

Note: Programs could select more than one option.

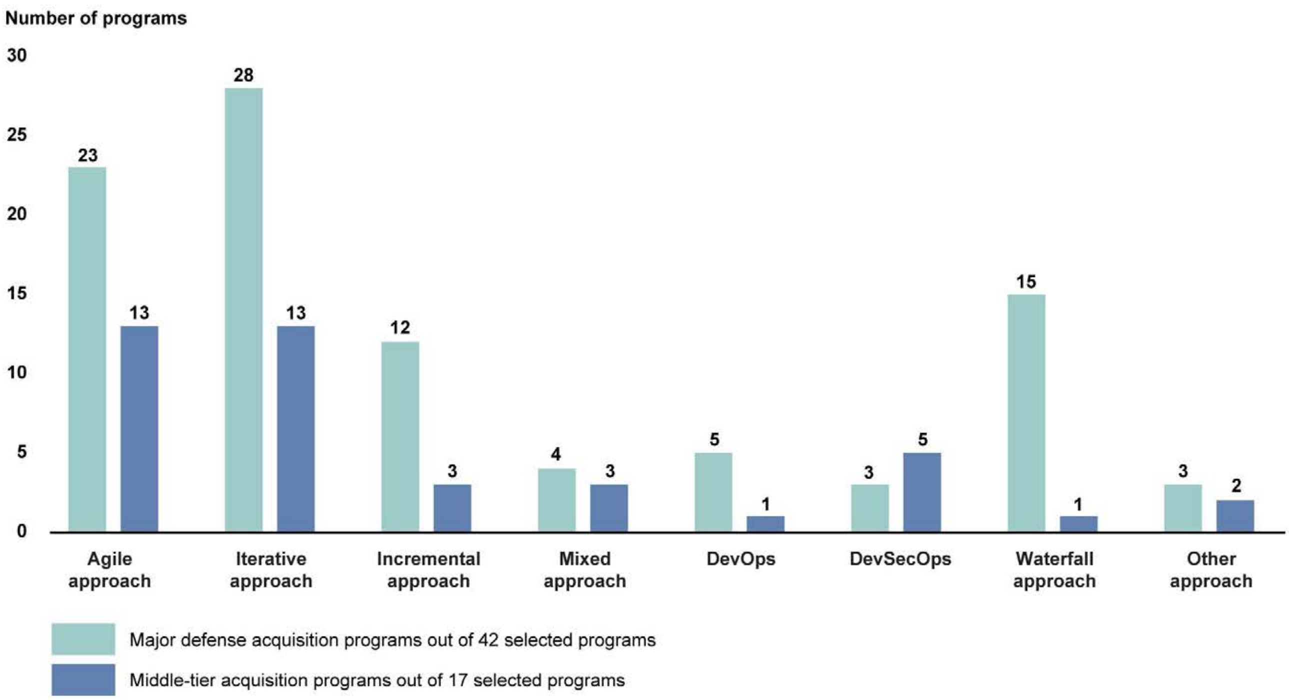
MDAPs and MTA programs also reported challenges related to their software development workforce. For example, over half of all MDAP and MTA programs reported staffing challenges, including hiring contractor and government staff in time to perform planned work and identifying contractor and government staff with expertise in software development. Programs also reported challenges with concurrency or overlap in staff needing to address cybersecurity needs and to perform testing. This is our first year reporting on MTA software development so we do not have a basis of comparison for the 17 MTA programs we reviewed. However, we did report on these challenges for MDAPs last year, and our findings for these programs are consistent with our last assessment.

Programs Increasingly Reported Using Modern Software Development Approaches but Continue To Grapple With Execution

The majority of MDAPs and MTA programs reported using Agile software development approaches, but programs were inconsistent in Agile implementation and in adopting other recommended practices. Of the 42 MDAPs that we surveyed, the number of programs that reported using modern software development approaches—such as Agile, iterative development, and DevOps or DevSecOps—increased slightly this year from our 2020 assessment.[55] In some cases, programs reported using multiple software development approaches to generate their systems' required software. For example, DevOps and DevSecOps are often based on an Agile software development approach, and some programs likewise reported using both Agile and DevSecOps or Agile and DevOps. Other programs used different software development practices for separate software efforts. Nine of the 16 programs that reported using a waterfall approach also reported using Agile. Figure 24 shows software development models employed by programs we reviewed.

[55]For example, of the 42 MDAPs in our 2020 assessment, 22 reported using Agile, three reported using DevOps, and none reported using DevSecOps. Our 2020 report did not assess MTAs on software approaches. We also surveyed future MDAPs on software approach, software type, and average length of time between software deliveries to end users. We did not include aggregate future MDAP software data in our analysis because programs reported that this information was largely unavailable, in part because specific data were pre-decisional to contract awards.

Figure 24: Software Development Approaches Employed by Acquisition Pathway



Source: GAO analysis of programs' questionnaire responses. I GAO-21-222

Data table for Figure 24: Software Development Approaches Employed by Acquisition Pathway

	Major Defense Acquisition Programs	Middle-Tier of Acquisition Programs
Agile approach	23	13
Iterative approach	28	13
Incremental approach	12	3
Mixed approach	4	3
DevOps	5	1
DevSecOps	3	5
Waterfall approach	15	1
Other approach	3	2

Note: Programs could select more than one option

Most programs stated that they have not implemented certain key practices recommended by the Defense Science Board, in 2018, to modernize DOD's approach to software acquisition. These recommendations included, among other things, that program officials receive training on modern software practices, and that programs work with end users to deliver a series of viable products, starting with a minimum viable product and followed by successive viable products.[56]

Early and continuous delivery of working software. The Defense Innovation Board and industry's Agile practices encourage the delivery of working software to users on a continuing basis—as frequently as every 2 weeks.[57] We reported in our *Agile Assessment Guide* that the value of using Agile is the emphasis on the early and continuous delivery of working software and that engaging customers early in the program limits the chance of continuing to fund a failing program or outdated technology.[58]

However, we found that of the 36 programs that reported using Agile (23 MDAPs and 13 MTA programs), only six reported delivering software to users in less than 3 months.[59] The majority of programs using Agile either responded that the question was not applicable or they did not know the frequency with which software is delivered to users; or are delivering software to users every 10 to 13 months or more, well outside the recommended range for Agile development. We previously reported that the most well-known feature of Agile software development is its emphasis on developing software in iterations that are being continuously evaluated on their functionality, and customer satisfaction.[60] Figure 25 illustrates the reported software delivery times for programs that reported using Agile development.

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

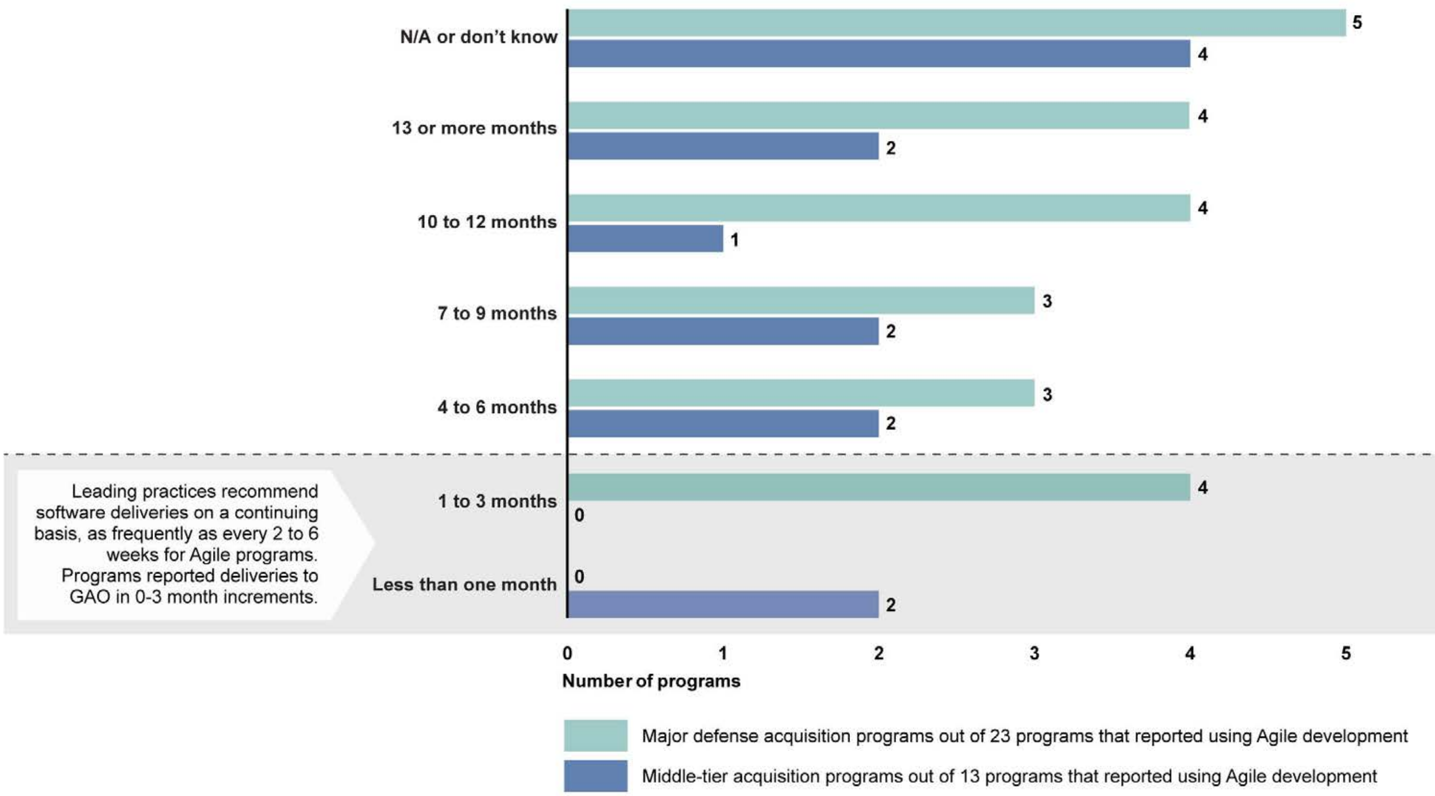
[57]The Defense Innovation Board recommends capability be delivered as frequently as every 2 weeks for many types of software. The National Defense Industrial Association, International Standards Organization, and other industry studies recommend deliveries of working software within a range of 1 to 6 weeks.

[58]GAO-20-590G.

[59]Programs reported deliveries in 0 to 3 month increments.

[60]GAO-20-590G. Agile principles also include satisfying the customer through early and continuous delivery of valuable software; welcoming changing requirements, even late in development; delivering working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter time scale; and working software as the primary measure of progress, among other things. See ©2001-2020 Agile Manifesto authors https://agilemanifesto.org.

Figure 25: Reported Software Delivery Times for Programs that Indicated Use of Agile Development



Source: GAO analysis of programs' questionnaire responses. I GAO-21-222

Data table for Figure 25: Reported Software Delivery Times for Programs that Indicated Use of Agile Development

Reported Time of Software Deliveries to Users by Programs Using Agile Development	Major Defense Acquisition Programs	Middle-Tier of Acquisition Programs
Less than one month	0	2
1 to 3 months	4	0
4 to 6 months	3	2
7 to 9 months	3	2
10 to 12 months	4	1
13 or more months	4	2
N/A or don't know	5	4

Note: Major defense acquisition programs that indicated they did not know software delivery times provided a variety of reasons, such as not having a software delivery schedule or not tracking software work elements as a separate item. For middle-tier acquisition programs that did not know software delivery times, the programs often reported that this information had yet to be determined.

DOD has recognized that Agile practices are not consistently followed by all stakeholders in the DOD acquisition system, and that this inconsistency affects delivery speed.[61] In response, USD(A&S) reported it is addressing technical and cultural challenges through a number of initiatives, including the creation of the software acquisition pathway. DOD's updated guidance on the software acquisition pathway, released in October 2020, states that software development will be done in active collaboration with end users to ensure software deliveries address their priority needs, maximize mission impact, and undergo regular assessment of software performance and risk. The guidance also emphasizes the importance of frequent user engagements.[62] We intend to monitor DOD's progress in implementing this policy. We also have ongoing work looking at DOD's execution of its software acquisition pathway in our companion product focused on major information technology (IT) programs.[63]

Implementation of Defense Science Board recommendations. We found that among the 42 MDAPs and 17 MTA programs we surveyed, the majority of MDAPs have not implemented certain practices recommended by the Defense Science Board in 2018, although proportionally more MTA programs reported they have implemented these practices. For example, we found that only 11 of the 47 programs that reported using Agile or iterative development also reported providing training for program managers and staff. We previously reported that since iterative techniques are different from those used for waterfall development, program staff should have appropriate training in iterative methods. Otherwise, programs are at risk of falling back into the traditional practices they used prior to adopting more modern practices.[64] The Defense Science Board also recommended that to support software sustainment, all documentation—including coding, application programming interfaces, design documents, and software factory framework—should be delivered to the government during production.

[61]For example, see Department of Defense, *Report to Congress on Software Development Activity Completion Section 874 of the National Defense Authorization Act for Fiscal Year 2018 (P.L. 115-91).*

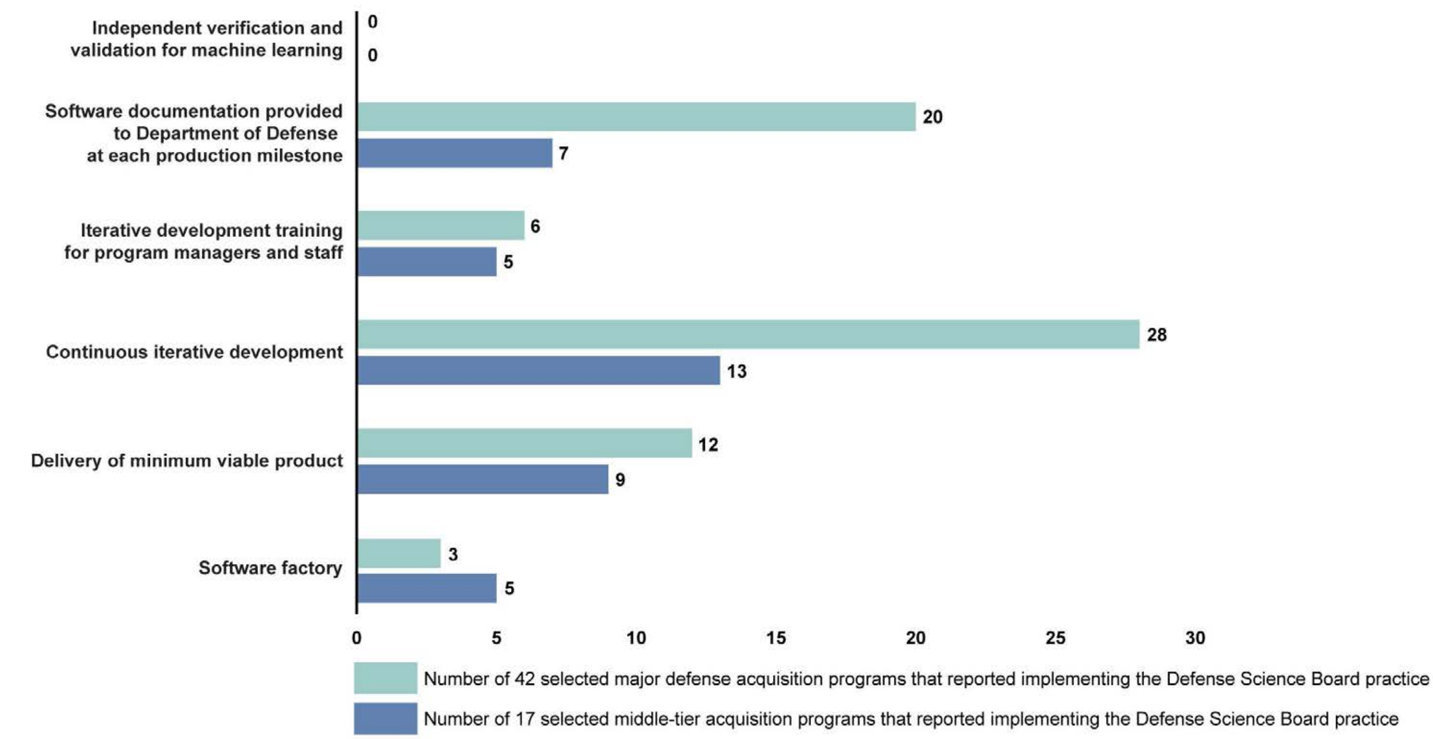
[62]DOD Instruction 5000.87.

[63]Our assessment of the performance of major IT programs is included in a separate report, which we also prepared in response to title 10, section 2229b of the United States Code.

[64]GAO-20-590G.

Figure 26 illustrates the extent to which programs reported using processes recommended by the Defense Science Board.

Figure 26: Extent to Which Programs GAO Reviewed Reported Implementing Software Practices Recommended by the Defense Science Board in 2018



Source: GAO analysis of programs' questionnaire responses. I GAO-21-222

Data table for Figure 26: Extent to Which Programs GAO Reviewed Reported Implementing Software Practices Recommended by the Defense Science Board in 2018

Defense Science Board Recommended Practice	Number of Major Defense Acquisition Programs that reported implementing the Defense Science Board practice out of 42 programs	Number of Middle-Tier of Acquisition Programs that reported implementing the Defense Science Board practice out of 17 programs
Software factory	3	5
Delivery of Minimum Viable Product	12	9
Continuous Iterative Development	28	13
Iterative Development Training for Program Managers and staff	6	5
Software documentation provided to DOD at each production milestone	20	7

Defense Science Board Recommended Practice	Number of Major Defense Acquisition Programs that reported implementing the Defense Science Board practice out of 42 programs	Number of Middle-Tier of Acquisition Programs that reported implementing the Defense Science Board practice out of 17 programs
Independent Verification and Validation for Machine Learning	0	0

Programs Continue Inconsistent Implementation of Cybersecurity Practices

We found that while MTA programs more regularly reported in questionnaire responses that they include cybersecurity in planning documents than MDAPs, about half of the MDAPs and all MTA programs have not consistently implemented cybersecurity test and evaluation processes recommended by DOD guidance.[65] This guidance notes that cybersecurity test and evaluation starts at acquisition initiation and continues throughout the entire life cycle. Accordingly, our analysis this year focused on the extent to which programs included cybersecurity in early planning, such as in cybersecurity strategies and requirements, as well as the extent to which programs assessed cybersecurity resilience and identified vulnerabilities throughout contractor development.

- **Cybersecurity planning.** DOD Instruction 5000.02 states that cybersecurity is a critical aspect of program planning that must be addressed early and continuously during the program life cycle to ensure cybersecurity risks are identified and reduced and that fielded systems are capable, effective, and resilient. Our findings this year on programs' planning for and implementation of cybersecurity practices are largely unchanged from our 2020 analysis. We found last year that the majority of MDAPs reported having an approved cybersecurity strategy but that many programs had not factored cybersecurity in key requirements documents.[66] The planning for some of these programs occurred prior to updates to guidance that specifically describes cybersecurity attributes in key performance parameters (KPP) to protect against cybersecurity

[65]DOD, *DOD Cybersecurity Test and Evaluation Guidebook* (Washington, D.C.: Feb. 10, 2020).

[66]GAO-19-136.

threats.[67] This year, we asked similar questions of 42 MDAP and 17 MTA programs regarding whether they had an approved cybersecurity strategy, and how many, if any, of the program's KPPs or key system attributes (KSA) addressed cybersecurity.

- **Cybersecurity strategies.** Thirty-seven out of 42 MDAPs and 13 out of 17 MTA programs reported having an approved cybersecurity strategy, while the remaining programs plan to have one in the future. DOD Instruction 5000.89 establishes that these plans should be based on known and postulated threats and system cybersecurity requirements. The instruction further states that the plans should describe how the authorization to operate decision—the decision to authorize use and accept the security and privacy risks to the organization's operations and assets, among other things—will be informed by cybersecurity testing.[68]
- **Cybersecurity requirements.** About half of the MDAPs we surveyed continued to report that key requirements did not address cybersecurity, while more than half of the MTA programs reported that they included cybersecurity in at least one key requirement. We previously reported that Joint Staff officials and some program officials said many current weapon systems had no high-level cybersecurity performance requirements when they began, which in turn limited emphasis on cybersecurity during weapon system design, development, and oversight.[69] We asked 42 MDAPs and 17 MTA programs about how many of their KPPs and KSAs address cybersecurity. Under the Joint Capabilities Integration and

[67]For example, in 2015, DOD updated its Joint Capabilities Integration and Development System Manual to specify that if cyber survivability is required, the program should include appropriate cyber attributes in the system survivability KPP. In 2018, the new Manual for the Operation of the Joint Capabilities Integration and Development System replaced this manual and updated the system survivability guide by adding information on cyber survivability. See Department of Defense, *Manual for the Operation of the Joint Capabilities Integration and Development System* (Aug. 31, 2018).

[68]DOD Instruction 8510.01, *Risk Management Framework (RMF) for DOD Information Technology (IT)* (Mar. 12, 2014) (Incorporating Change 3, Dec. 29, 2020) uses the NIST Special Publication 800-37 definition for authorization, which defines the authority to operate as the official management decision given by a senior federal official to authorize operation of an information system and to explicitly accept the risk to agency operations (including mission, functions, image, or reputation), organizational assets, individuals, other organizations, and the nation based on the implementation of an agreed-upon set of security and privacy controls.

[69]GAO-19-128.

Development System, KPPs are most critical to the development of an effective military capability, while KSAs are considered important to achieving a balanced solution but not critical enough to be designated a KPP.[70] Twenty-one MDAPs reported a KPP and 10 MDAPs reported a KSA that addressed cybersecurity, while 17 MDAPs reported neither KPPs nor KSAs that addressed cybersecurity. The majority of MTA programs reported at least one KPP (11 MTA programs) or KSA (six MTA programs) that addressed cybersecurity. Five MTA programs reported having neither a KPP nor a KSA that addressed cybersecurity.[71]

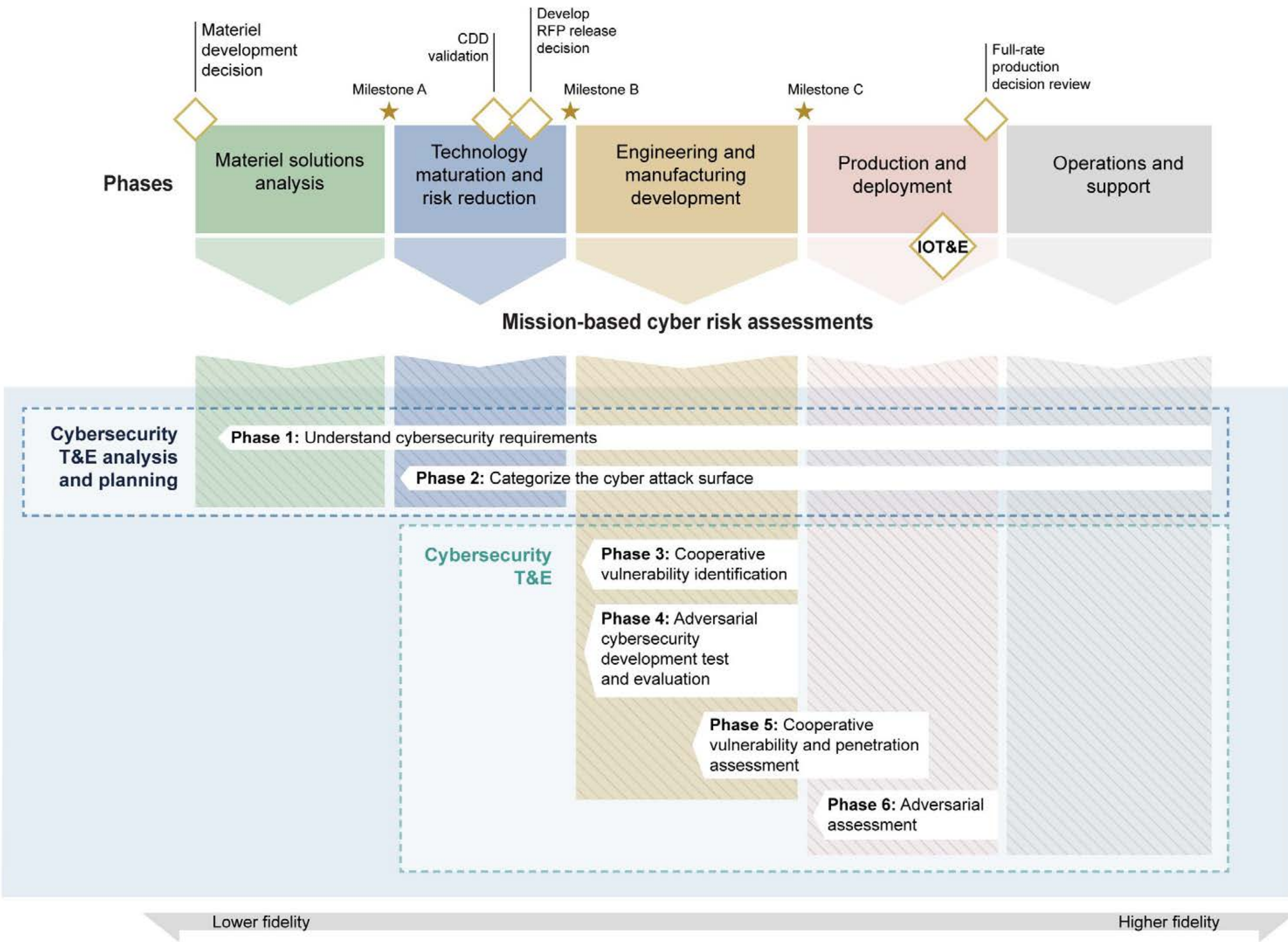
- **Cybersecurity assessments.** All DOD acquisition programs and systems, regardless of acquisition pathway, are required by DOD Instruction 5000.89 to execute cybersecurity testing and evaluation processes detailed in the *DOD Cybersecurity Test and Evaluation Guidebook* throughout the program's life cycle.[72] The guidebook provides detailed implementation guidance for program managers and test organizations during cybersecurity test and evaluation phases. Figure 27 summarizes DOD guidance on when program cybersecurity assessments should be conducted throughout the acquisition life cycle.

[70]The Joint Capabilities Integration and Development System is a process implemented in 2003 as a primary means for the Joint Requirements Oversight Council to fulfill its responsibilities, including to guide the development of capabilities across DOD, help DOD identify capability gaps, and validate the requirements of proposed capability solutions to mitigate those gaps.

[71]According to DOD Instruction 5000.80, MTA programs are not subject to the guidance in Chairman of the Joint Chiefs of Staff Instruction 5123.01H, which implements the Joint Capabilities Integration and Development System. Some MTA programs therefore may not have defined KPPs and KSAs. Two of these programs reported cybersecurity KPPs and KSAs were not applicable to their programs.

[72]Department of Defense, *Cybersecurity Test and Evaluation Guidebook* (Washington, D.C.: February 2020).

Figure 27: Department of Defense Cybersecurity Test and Evaluation Requirements 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. | GAO-21-222

We found that the surveyed programs did not consistently conduct cooperative vulnerability identification tests designed to identify vulnerabilities and plan the means to mitigate or resolve them. We asked programs whether they completed one or more cybersecurity assessments, and if so, the characteristics that described these assessments. Since MDAPs and MTA programs are in different stages of acquisition that correspond with different phases of cybersecurity test and evaluation, we report these results separately.

- **MDAPs.** The 42 MDAPs we reviewed are all either in or past phase 3, the cooperative vulnerability testing phase, which consists of identifying cybersecurity vulnerabilities, assessing mission risk associated with those vulnerabilities, and determining appropriate mitigations or countermeasures to reduce risk throughout development.[73] However, only half (21 of 42) of MDAPs we surveyed reported having conducted a cooperative vulnerability test. The majority of MDAPs characterized their cybersecurity assessments as tabletop exercises, which bring people together to talk through how they would respond to simulated scenarios.

  We also asked MDAPs whether they have conducted developmental or operational testing, and if so, whether these test events included cooperative vulnerability testing or adversarial assessments. Of the 21 programs that reported conducting developmental tests, 13 programs reported both cooperative vulnerability and adversarial assessments and an additional five programs reported only cooperative vulnerability tests. More programs had conducted these tests associated with operational testing, with 14 of 15 programs reporting cooperative vulnerability tests, and 13 of those 15 programs also reporting adversarial assessments during operational testing.

- **MTA programs**. DOD guidance states that MTA programs should have processes that keep pace with rapid acquisition and fielding timelines. In particular, the updated February 2020 DOD Cybersecurity Test and Evaluation Guidebook notes that contractor cybersecurity testing must "shift left" to include better and continuous software testing during development, among other things, to enable faster deliveries that do not sacrifice security features. We assessed the 17 MTA programs in our review based on their transition plans to identify the corresponding DOD cybersecurity test and evaluation guidance provided in the DOD Cybersecurity Test and Evaluation Guidebook that applied.

  - Five programs plan to transition to another rapid prototyping effort or to the major capability acquisition pathway at development start. Therefore, the current effort for these five programs

[73]Department of Defense, *Cybersecurity Test and Evaluation Guidebook* (Washington, D.C.: February 2020). These MDAPs have passed milestone B and have entered system development.

corresponds with cybersecurity phases focused on analysis and planning (phase 1 and phase 2). Two of these five programs reported conducting tabletop assessments.

- Eight programs plan to transition to rapid fielding or to production. Therefore, their current efforts correspond with the cooperative vulnerability testing phase (phase 3). Of these eight programs, none of the programs currently in development reported completing a cooperative vulnerability assessment.
- Four programs have yet to determine a transition pathway. Since these programs do not have transition plans, we did not assess cybersecurity test and evaluation efforts with the corresponding DOD guidance that would apply.

We will continue to evaluate DOD's implementation of its cybersecurity test and evaluation guidance as part of our ongoing work reviewing weapon system cybersecurity. DOD also continues to place additional emphasis on cybersecurity practices, including in the reissuance of its acquisition policies. For example, DOD Directive 5000.01, reissued in September 2020, directs acquisition managers to implement initiatives and processes for the continual evaluation of security requirements throughout the life cycle of the system. Further, DOD Instruction 5000.02, reissued in January 2020, states that program managers should recognize that cybersecurity is a critical aspect of program planning and must be addressed early and continuously during a program's life cycle. DOD also issued its cybersecurity instruction in December 2020, which provides responsibilities and procedures for cybersecurity threat analysis, planning, and execution in the defense acquisition system.[74]

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

DOD Has Yet to Fully Determine Its Oversight Approach for New Acquisition Guidance

DOD's Adaptive Acquisition Framework Introduced New Considerations for Program Execution and Oversight

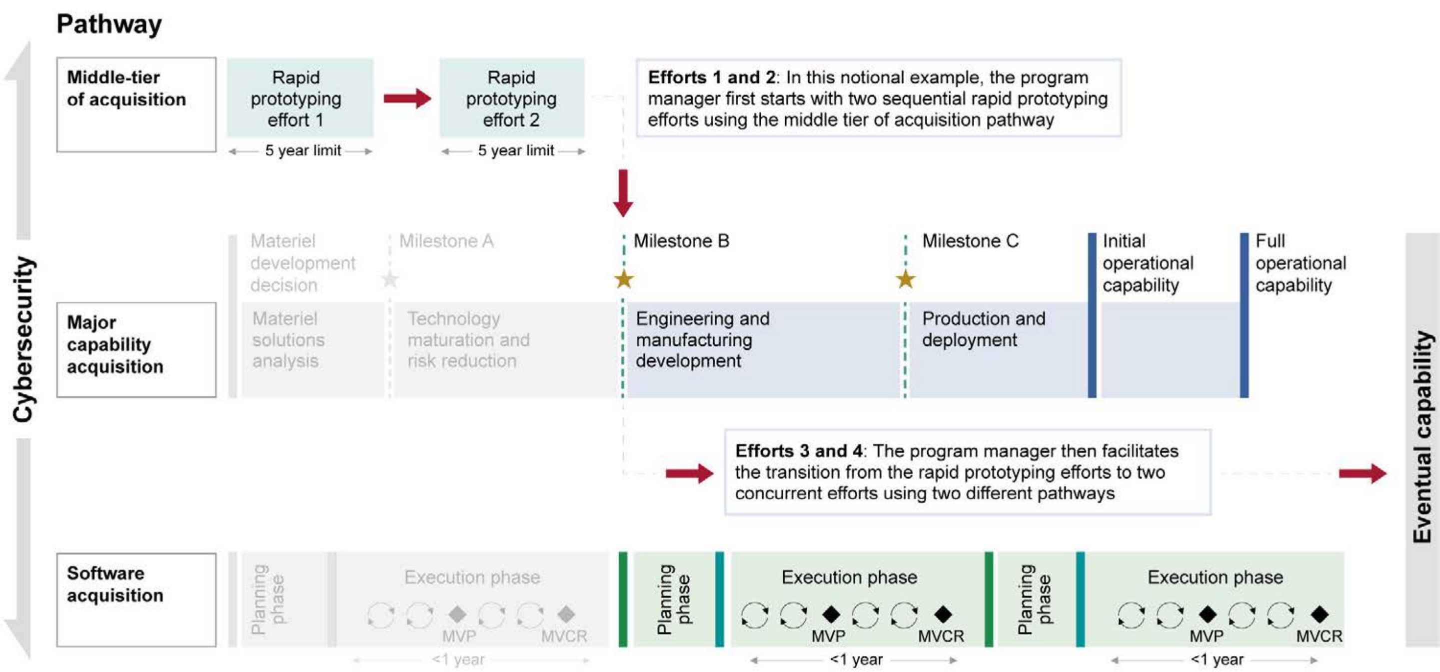
DOD established the AAF in January 2020 to support the defense acquisition system with the objective of delivering effective, suitable, survivable, sustainable, and affordable solutions to the end user in a timely manner.[75] To achieve those objectives, DOD made changes to its prior approaches to acquisition program execution. As outlined in DOD Instruction 5000.02, reissued in January 2020, milestone decision authorities, other decision authorities, and program managers have broad authority to plan and manage their programs. Rather than requiring acquisition programs to use a particular acquisition process, the Instruction identifies six pathways—each with different requirements for milestones, cost and schedule goals, and reporting. The AAF allows program managers to tailor, combine, and transition between acquisition pathways based on the characteristics and risk profile of the capability being acquired.

Under the AAF, capabilities may be developed and fielded using a single pathway or multiple pathways. In addition to using multiple pathways, a program manager can also undertake multiple distinct efforts using the same pathway, such as two or more rapid prototyping efforts using the MTA pathway or two or more software efforts using the software acquisition pathway. For example, the Air Force's procurement and installation of new engines to extend the service life of its B-52H fleet is expected to comprise at least two MTA rapid prototyping efforts and a subsequent fielding effort using a different, as yet undetermined acquisition pathway.

[75]DOD Instruction 5000.02, *Operation of the Adaptive Acquisition Framework* (Jan. 23, 2020).

In the notional example shown in Figure 28, a program manager starts with a rapid prototyping effort using the MTA pathway, then follows with another rapid prototyping effort. At the completion of the second MTA effort, the program manager then facilitates the transition from the rapid prototyping efforts to two concurrent efforts using two different pathways: the major capability pathway at system development, and the software acquisition pathway's planning phase. Once the software effort and major capability effort achieved minimum viable capability release and full operational capability, respectively, the eventual capability would be fully fielded and enter operations and sustainment.

Figure 28: Notional Example of Use of Multiple Efforts and Multiple Pathways to Develop a Capability



MVCR = Minimum viable capability release
MVP = Minimum viable product

Source: GAO analysis of Department of Defense data. I GAO-21-222

Note: An effort refers specifically to the activities undertaken using a single Adaptive Acquisition Framework pathway or any of the paths provided by an Adaptive Acquisition Framework pathway (for example, the rapid prototyping path of the middle-tier acquisition pathway).

Each pathway is governed by separate policies, and DOD's acquisition instruction requires program managers using multiple pathways to define the transition points from one pathway to another; anticipate, develop, and coordinate information requirements required at the new pathway entry point; and ensure a smooth transition between pathways.[76]

While the flexibilities associated with the different pathways allow program managers to tailor various types of acquisitions, program managers can also use multiple efforts within the same pathway and multiple pathways to develop and field a capability, which has implications for program oversight. Previously, reporting on DOD's costliest weapon programs typically encompassed the total estimated cost and schedule associated with delivery of the eventual capability once a program reached the system development milestone. Annual Selected Acquisition Reports, which facilitate oversight of individual MDAPs, would typically only have one "effort" using the single acquisition pathway. Currently, under the AAF, DOD plans to report cost, schedule, and performance information for one individual effort at a time, even if a program manager plans to use multiple efforts or pathways to develop an eventual capability. For example, an MDAP may report its costs associated with the major capability pathway in a Selected Acquisition Report but not the costs of a concurrent or planned software acquisition pathway effort. Although required to achieve the intended capability of the MDAP, the software effort is considered a separate effort that may or may not meet the cost threshold for reporting software development and enterprise resource planning information to DOD cost estimators.

[76]DOD Instruction 5000.02, *Operation of the Adaptive Acquisition Framework* (Jan. 23, 2020).

DOD Has Yet to Finalize Tracking Approach for Capabilities Being Developed Through Multiple Efforts or Pathways

DOD developed a plan to identify performance metrics and data requirements for AAF pathways and made progress on executing the plan for some pathways. However, we found that officials have yet to establish consistent practices for monitoring efforts to acquire weapon capabilities under the AAF, including finalizing metrics for all acquisition pathways, defining a “program,” and determining how to track cumulative cost, schedule, and performance data for the delivery of capabilities that leverage multiple efforts or pathways.

Developing metrics. While USD(A&S) officials stated that they worked with stakeholders to develop metrics associated with certain individual pathways, they have yet to determine how these metrics will be combined across efforts or pathways to provide insight into the overall cost and schedule for achieving a capability. In the summer of 2020, USD(A&S) developed a plan that outlined steps related to measuring the effectiveness of each of the acquisition pathways, including creating metrics, obtaining data, and conducting quarterly assessments specific to each pathway. USD(A&S) officials told us in December 2020 that they established data strategies for programs in the major capability acquisition and MTA pathways, although they have yet to document them in guidance or in policy. They stated they are continuing to work with stakeholders and program managers to identify metrics for the other four pathways. However, individual oversight metrics may not be applicable across pathways. For example, two of the initial metrics identified by USD(A&S) to measure the effectiveness of the AAF pathways were related to initial operational capability, but not all pathway guidance requires programs to identify a consistent initial operational capability date.

Defining a program. While DOD Directive 5000.01 states that “program goals” for cost, schedule, and performance will describe the program over its life cycle, DOD has yet to establish a consistent definition of a program under the AAF.[77] A DOD official told us that while programs using the major capability acquisition pathway continue to be defined as MDAPs,

[77]Under DOD Directive 5000.01, *The Defense Acquisition System* (Sept. 9, 2020), program goals for cost, schedule, and performance parameters (or alternative quantitative management controls) will describe the program over its life cycle.

USD(A&S) is still working to define a program for the other pathways and when capabilities are developed using multiple efforts within or across pathways. According to a DOD official, a program could be a single effort using one of these pathways, such as one 5-year rapid prototyping effort in the MTA pathway, or could include multiple efforts in a pathway, such as multiple rapid prototyping or fielding efforts in the MTA pathway. Defense Acquisition University guidance also describes programs as transitioning from one pathway to another as they move to a new phase of their life cycle.

Further, how DOD chooses to define a program could significantly affect how it reports on cost and schedule estimates for programs. For example, based on the Navy's fiscal year 2020 plans, the development of the Navy's Conventional Prompt Strike capability—a submarine-launched, intermediate-range, hypersonic missile capability—was expected to comprise at least two MTA rapid prototyping efforts and an MTA rapid fielding effort.[78] Program officials only reported the planned costs for the first rapid prototyping spiral, estimated to cost approximately $4 billion and be completed in March 2023. However, the cost and schedule for subsequent parts of the development, which are likely to reflect the bulk of the Navy's overall cost and schedule for the delivery of the eventual capability, would not be reflected in program reporting if the program were defined as only the current MTA effort. As a result, program reporting would not provide DOD or congressional decision makers with insight into the total investment required for the capability or when the capability is expected to be delivered to the warfighter. A USD(A&S) official told us that they are still working through how to define a program based on circumstances that are emerging as programs operate under the AAF.

Tracking cost, schedule, and performance data across pathways. DOD's plan for assessing the effectiveness of the AAF does not address how cost, schedule, and performance will be tracked for capabilities that are developed using multiple efforts within or across pathways. DOD's Acquisition and Sustainment Data and Analytics Strategic Implementation Plan identifies an objective for USD(A&S) to deploy an analytical

[78]In January 2021, the Conventional Prompt Strike program office stated that it was in the process of realigning its acquisition approach due to an expected funding reduction for fiscal year 2021.

framework for acquisition data that will help DOD understand how well it is meeting its strategic goals and objectives.[79]

However, under its current approach, DOD would collect cost and schedule data on each discrete effort but would not collect information providing insight into the cost and time to field the eventual capability to the warfighter. This approach potentially limits the utility of this data to help DOD understand how well it is meeting strategic goals and objectives, including the objective of delivering effective and affordable solutions to the end user in a timely manner. DOD officials said that currently, when a program transitions from one acquisition pathway to another, the program switches to follow the reporting requirements of the new pathway and no longer follows those associated with the previous pathway. Moreover, USD(A&S) officials have yet to identify how they will report cost and schedule information associated with previous efforts. DOD officials told us they have notional concepts for how to normalize the reported information for programs transitioning between pathways to provide more complete information but have yet to develop a formal process or guidance to do so.

DOD has also yet to establish a consistent process for how military departments should inform cost estimators or USD(A&S) when programs, including those with costs exceeding the threshold for MDAP designation, use or transition between multiple pathways, limiting DOD's insight into those efforts. DOD officials said that programs using the major capability acquisition and MTA pathways are tracked using an automated data extraction tool, Advanced Analytics (Advana). However, there is currently no database equivalent for the other four acquisition pathways, making it difficult to identify when programs transition between pathways or to track information for programs using multiple pathways. For example, USD(A&S) officials told us that, when programs intend to use the software acquisition pathway, military departments are responsible for informing USD(A&S) via email that they intend to use the pathway. DOD plans to add the capability to store information from additional pathways in Advana during fiscal year 2022.

[79]DOD, Office of Acquisition Enablers, *Acquisition and Sustainment Data and Analytics Strategic Implementation Plan* (December 2020).

Incomplete Data Collection Hinders DOD's Oversight and Congressional Reporting

DOD's lack of information on the performance of programs across pathways and efforts creates challenges for DOD with regard to assessing whether it is meeting its acquisition reform goals of building a more lethal force and speeding delivery of capability to the warfighter. In addition, the lack of information hinders DOD's ability to conduct effective internal oversight of the development of critical weapon capabilities and management of the weapon system portfolio as a whole. DOD's ability to provide quality external reporting is also constrained, which may limit information for congressional oversight of some weapon programs.

Assessing the effects of acquisition reform. The USD(A&S) stated in 2019 that the AAF was the most transformational acquisition policy change seen in decades. We have previously found that when an agency implements a reform effort that represents a significant change, the agency should measure the effect of that change.[80] Identifying cost and schedule metrics that would apply across multiple efforts or pathways would improve the department's ability to ensure that the AAF is meeting its goals. If a capability is being developed and fielded using multiple efforts under one or more pathways, measuring cost, schedule, and performance of each individual effort is an important indicator of the current performance. But these measures for individual efforts, by themselves, do not provide full insight into whether the department is achieving its overall acquisition reform goals of delivering capabilities that are affordable, timely, and meet warfighter needs.

Conducting internal oversight and portfolio management. Although milestone decision authority for most MDAPs and programs with costs greater than the threshold for MDAP designation now resides with the military departments, DOD policies establish an acquisition oversight role for multiple positions within the Office of the Secretary of Defense. For example, according to the July 2020 charter for the Under Secretary of Defense for Acquisition and Sustainment, the USD(A&S) leads acquisition and sustainment data management and provides capabilities

[80]GAO, *Agile Software Development: DHS Has Made Significant Progress in Implementing Leading Practices, but Needs to Take Additional Actions,* GAO-20-213 (Washington, D.C.: June 1, 2020); *Government Reorganization: Key Questions to Assess Agency Reform Efforts,* GAO-18-427 (Washington, D.C.: June 13, 2018); and *IT Workforce: Key Practices Help Ensure Strong Integrated Program Teams; Selected Departments Need to Assess Skill Gaps,* GAO-17-8 (Washington, D.C.: Nov. 30, 2016).

to enable DOD's reporting and data analysis, with the goal of timely access to accurate, authoritative, and reliable data supporting oversight, analysis, decision making, and improved outcomes. The USD(A&S) or other offices within the Office of the Secretary of Defense also perform oversight functions such as:

- establishing policies on developmental testing activities and advising on mission engineering,
- advising the Secretary on technology maturation,
- performing root cause analyses of problems within acquisition programs, and
- conducting or approving independent cost estimates.

However, if it does not collect data that encompasses multiple pathways, DOD will lack the information needed to perform accurate analysis and oversight of the development of weapon capabilities through their eventual fielding. For example, officials in DOD's Office of the Director of Cost Assessment and Program Evaluation told us they have yet to fully determine how they will combine cost information for programs that combine or transition between pathways. In particular, they noted that it will be difficult to piece together cost estimates for programs using multiple pathways at the same time since individual pathway guidance varies. Our cost estimation guidance states that having a realistic estimate of projected costs makes for more effective resource allocation, and reliable cost estimates are essential and necessary to establish realistic baselines from which to measure future progress.[81]

Moreover, our previous work has found that a lack of readily accessible data on acquisition programs hampered DOD officials' ability to conduct portfolio reviews and that the resulting lack of visibility into certain programs contributed to unnecessary duplication.[82] In general, portfolio management focuses on selecting the optimum mixture of programs and modifying that mixture as needed over time, based on cost and goals of an organization, rather than focusing on optimizing individual programs. Program management leading practices include assessing product investments collectively from an enterprise level, continually making

[81]GAO, *Cost Estimating and Assessment Guide,* GAO-20-195G (Washington, D.C.: March 2020).

[82]GAO, *Weapon System Acquisitions: Opportunities Exist to Improve the Department of Defense's Portfolio Management,* GAO-15-466 (Washington, D.C.: Aug. 27, 2015).

go/no-go decisions through a gated review process, and using an integrated approach to prioritize needs and allocate resources in accordance with strategic goals. Portfolio reviews, specifically, can help DOD officials ensure investments align with national security and military strategies, identify and eliminate unwarranted duplication, monitor programs to determine whether changes to the portfolio are warranted, and determine whether investments are affordable. The flexibility designed into the AAF could assist DOD officials in selecting the optimal usage of acquisition pathways to develop capabilities, but effective portfolio management first requires readily accessible and accurate data. DOD partially concurred with our 2015 recommendation related to improving portfolio management, which included identifying data needed for portfolio management and developing a plan to meet those needs. However, DOD has yet to fully address the recommendation.

Providing quality reporting to Congress. DOD has yet to determine how it will report total cost and schedule information to Congress for weapon capabilities that use multiple efforts within one or more pathways. The NDAA for Fiscal Year 2020 amended the Selected Acquisition Report requirement to include programs estimated to require eventual total costs greater than the threshold for designation as an MDAP.[83] In addition, DOD policy states that the use of multiple pathways does not affect the application of statutory thresholds otherwise applicable to the program as a whole, such as the MDAP thresholds, unless permitted by statute.[84]

[83]Congress amended the reporting requirement to include both MDAPs and any program that is estimated by the Secretary of Defense to require an eventual total expenditure for research, development, test, and evaluation of more than $300 million in fiscal year 1990 constant dollars, or an eventual total expenditure for procurement, including all planned increments or spirals, of more than $1.8 billion in fiscal year 1990 constant dollars. See National Defense Authorization Act for Fiscal Year 2020, Pub. L. No. 116-92, § 830 (2019). The explanatory statement accompanying the Consolidated Appropriations Act, 2021 also stated that the Under Secretaries of Defense for Research and Engineering and Acquisition and Sustainment and the Service Acquisition Executives should provide the congressional defense committees with the submission of the fiscal year 2022 President’s budget request, a complete list of approved acquisition programs—and programs pending approval in fiscal year 2022—utilizing prototyping or accelerated acquisition authorities, along with the rationale for each selected acquisition strategy, as well as a cost estimate and contracting strategy for each such program.

[84]DOD Instruction 5000.02. The statutory definition of an MDAP excludes programs using the MTA rapid prototyping or rapid fielding pathways. See 10 U.S.C. § 2430(a)(2)(A). Moreover, the DOD Instruction 5000.87 states that programs executing the software acquisition pathway will not be treated as MDAPs even if exceeding thresholds in 10 U.S.C. § 2430.

However, Office of the Secretary of Defense and military department officials stated that they are still determining the level of detail Congress wants, including whether a program is required to submit acquisition data only based on the cost of the current effort, or on the total estimated life-cycle cost of the eventual capability. Further, while DOD continues to provide Congress with Selected Acquisition Reports for MDAPs and in 2020 submitted similar reporting to Congress for MTA programs, Office of the Secretary of Defense officials told us they are defining reporting approaches for other pathways.

DOD's implementation plan for its acquisition and sustainment data and analytics identifies an objective for USD(A&S) to deploy an analytical framework to report on the performance of the defense acquisition system using quantitative data analysis to measure cost, schedule, and technical performance of DOD acquisitions.[85] However, DOD's current approach to reporting on individual efforts or pathways without also reporting on the planned cost and schedule required to deliver the eventual capability potentially undermines Congress's oversight of the performance of individual programs and limits insight into the full cost and schedule needed to deliver final capability. For example, Unified Platform initiated as an MTA program in August 2018 and provided an MTA acquisition report in February 2020. When the program transitioned from an MTA pathway to the software acquisition pathway in August 2020, according to USD(A&S) officials, it was no longer required to provide congressionally mandated acquisition reports as it had under the MTA pathway.

The NDAA for Fiscal Year 2020 required DOD to submit to the congressional defense committees a proposal for an alternative methodology for reporting on all acquisition programs. DOD's proposal, submitted in November 2020, states that each pathway will have unique data strategies for reporting to Congress, but does not address how reporting will be handled for programs that use more than one effort or pathway. We have ongoing work addressing DOD's proposed changes to its congressional reporting requirements, including proposed metrics for program performance. For that reason, we are not making recommendations that address these areas at this time but will continue to monitor DOD's progress.

[85]DOD, Office of Acquisition Enablers, *Acquisition and Sustainment Data and Analytics Strategic Implementation Plan* (December 2020).

Conclusions

Unless DOD takes appropriate action, its decision makers and Congress will lack needed insight into some of the department's most complex and costliest weapon systems. DOD currently lacks an overarching data collection and reporting strategy for programs transitioning between acquisition pathways or conducting multiple efforts using the same pathway to deliver the intended capability. In addition to limiting insight, the absence of such a strategy hinders the quality of DOD's reporting to Congress, and makes the full cost and schedule of the eventual weapon system more difficult to ascertain.

Given that program execution is well underway for several programs planning to use multiple pathways or efforts within a pathway, addressing the gap with regard to reporting on eventual capabilities quickly is essential while DOD works on a longer term effort to finalize metrics and define programs under the new AAF.

Recommendation for Executive Action

The Secretary of Defense should direct the Office of the Under Secretary of Defense for Acquisition and Sustainment to ensure that internal and external reporting for capabilities developed using multiple efforts or pathways provides information on each individual effort, as well as the overall planned cost and schedule required to deliver the eventual capability. (Recommendation 1)

Agency Comments and Our Evaluation

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

We are sending copies of this report to the appropriate congressional committees and offices; the Secretary of Defense; the Secretary of the Army and Acting Secretaries of the Navy and Air Force; and the Acting 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 VI.

Shelby S. Oakley
Director, Contracting and National Security Acquisitions

List of Committees

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

The Honorable Jon Tester
Chairman
The Honorable Richard Shelby
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

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

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

Appendix I: Individual Assessments

Assessments of Individual Programs

This section contains (1) 64 assessments of individual weapon programs, and (2) three summary analyses—each segmented by the three military departments. Each assessment presents data on the extent to which programs are following a knowledge-based acquisition approach to product development.[86] Each military department's summary analysis page presents aggregated information about selected programs' acquisition phases, current estimated funding needs, cost and schedule performance, knowledge attainment, and software and cybersecurity characteristics.

For 34 MDAPs, we produced two-page assessments discussing the technology, design, and manufacturing knowledge obtained, software and cybersecurity efforts, as well as other program issues. Each of these two-page assessments also contains a comparison of total acquisition cost from the first full estimate for the program to the current estimate. The first full estimate is generally the cost estimate established at development start; however, for a couple of programs that did not have such an estimate, we used the estimate at production start. For shipbuilding programs, we used their planning estimates if those estimates were available. For programs that began as non-MDAPs, we used the first full estimate available. The 34 MDAPs for which we developed two-page assessments are primarily in development or early production. See figure 29 for an illustration of the layout of each two-page assessment.

[86]The assessments also contain basic information about the program, including the prime contractor(s) 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 incentive (FPI), and indefinite delivery/indefinite quantity (IDIQ). We did not distinguish between the different forms of FPI contracts.

Figure 29: Illustration of Two-Page Major Defense Acquisition Program Assessment

- **A** Illustration or photo of system
- **B** Program description
- **C** Schedule timeline identifying key dates for the program including, the start of development, major decision reviews, production decision, and planned operational capability
- **D** **Program Essentials** Programmatic information, including milestone decision authority, program office location, prime contractor, and contract type
- **E** **Program Performance** Cost, quantity and schedule baseline estimates and the latest estimate provided
- **F** **Estimated Cost and Quantities** Development and production funding and production quantity requirements to date and from fiscal year 2021 through completion
- **G** **Software Development** Software approach and metrics, including average delivery time, percentage of total program cost, and different types of software used
- **H** **Attainment of Product Knowledge** Depiction of selected knowledge-based practices and the program's progress in attaining that knowledge
- **I** Assessment of program's technology, design and production maturity, as well as software, cybersecurity, and other program issues
- **J** **Program Office Comments** General comments provided by the cognizant program office

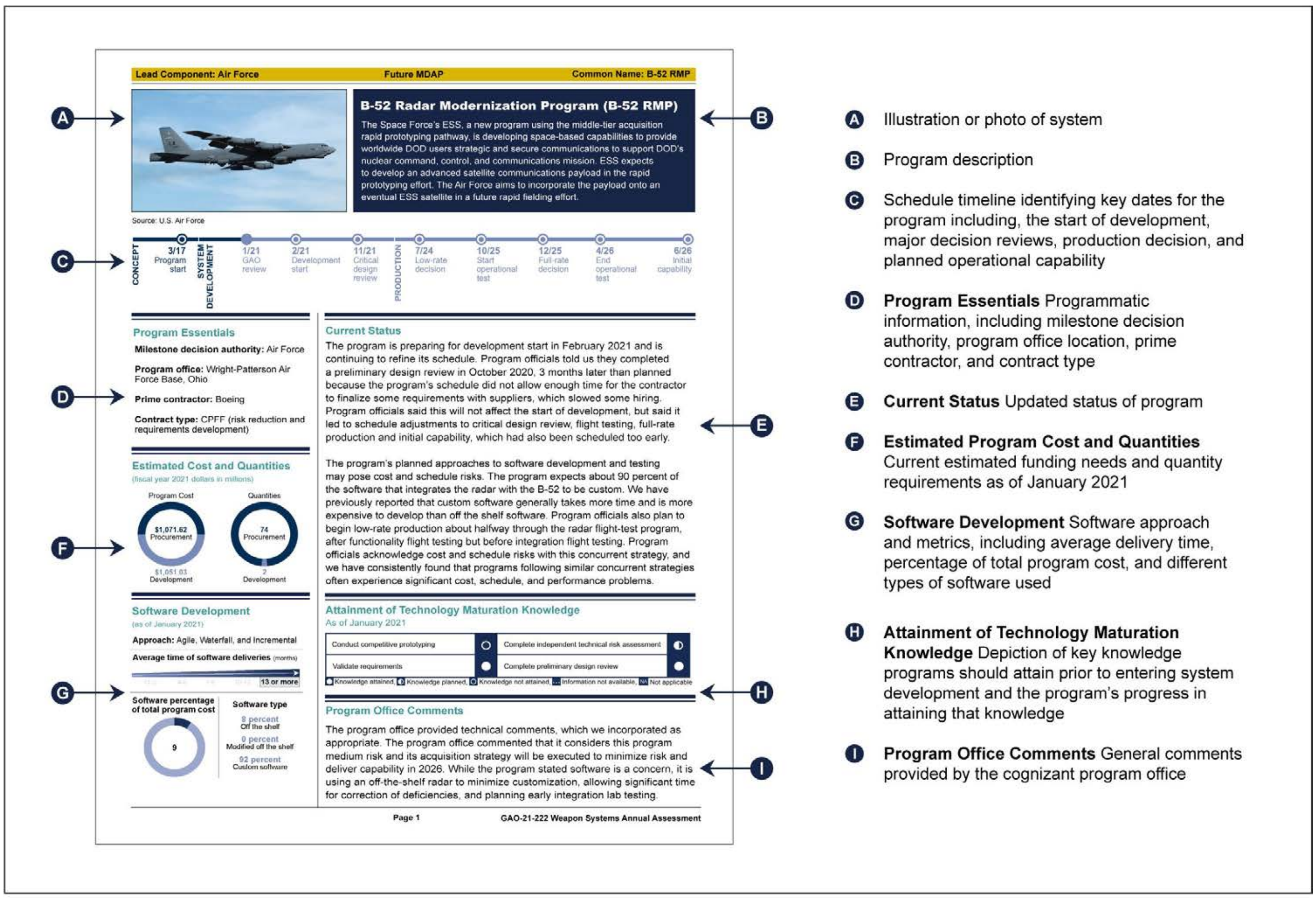
Source: GAO. | GAO-21-222

In addition, we produced one-page assessments on the current status of 13 programs:

- six future MDAPs and,
- seven MDAPs that were well into production, but planned to introduce new increments of capability.

See figure 30 for an illustration of the layout of each one-page assessment.

Figure 30: Illustration of One-Page Future or Current Major Defense Acquisition Program Assessment



Source: GAO. | GAO-21-222

For 17 programs using the MTA pathway, we produced two-page assessments discussing program background and transition plans, technology issues, completion of or updates to key elements of a business case, planned attainment of applicable product knowledge during the current MTA effort, and software and cybersecurity issues.

Each two-page assessment also provides estimated total program cost and quantities, and software development approach—including software percentage of total program cost and software type. See Figure 31 for an illustration of the layout of each two-page middle-tier acquisition program assessment.

Figure 31: Illustration of Two-Page Middle-Tier Acquisition Program Assessment

Lead Component: Air Force | MTA | Common Name: ESS

Evolved Strategic SATCOM (ESS)

The Space Force's ESS, a new program using the middle-tier acquisition rapid prototyping pathway, is developing space-based capabilities to provide worldwide DOD users strategic and secure communications to support DOD's nuclear command, control, and communications mission. ESS expects to develop an advanced satellite communications payload in the rapid prototyping effort. The Air Force aims to incorporate the payload onto an eventual ESS satellite in a future rapid fielding effort.

Source: U.S. Air Force

8/19 MTA initiation; 9/20 MTA funds obligated; 9-11/20 Contract award; 1/21 GAO review; 12/23 Preliminary design review; 9/25 Operational demonstration/ 5 years since MTA funds obligated/ Expected MTA completion

Program Essentials

Decision authority: Air Force

Program office: Los Angeles Air Force Base, CA

Contractors: Boeing, Lockheed Martin, Northrop Grumman

MTA pathway: Rapid Prototyping

Contract type: FFP (development)

Program Background and Transition Plan

The Air Force initiated ESS as a middle-tier acquisition effort in August 2019. The program stated that in September through November 2020 it competitively awarded contracts to three contractors, each to develop an advanced satellite communications payload prototype. At the end of the rapid prototyping phase, the program expects to hold a competition for the planned rapid fielding phase to select one or more contractors to deliver the fielded system.

Transition Plan: Transition to a new middle-tier rapid fielding effort.

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2021 dollars in millions)

$229.50 | $1,159.73

Quantity 1

Funded to date

To complete

Attainment of Technology Maturation Knowledge

As of January 2021

Key Elements of a Business Case	Status at Initiation	Current status
Approved requirements document	○	●
Approved middle-tier 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

Software Development

(as of January 2021)

Approach: Mixed

Average time of software deliveries (months)

Information not available

Software percentage of total program cost: 10-11

Software type: Information not available

The program has yet to identify the software type that will be used and does not track software releases to end users.

Planned Knowledge by MTA Transition

Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	◐	Demonstrate all critical technologies in form, fit, and function within a realistic environment	NA
Complete system-level preliminary design review	◐	Release at least 90 percent of design drawings	⊗
Test a system-level integrated prototype	◐	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, ... Information not available, NA Not applicable

We did not assess ESS planned knowledge by MTA transition for: demonstration of critical technologies in a realistic environment or test of a production-representative prototype in its intended environment because the program will not demonstrate the prototype in space; or demonstration of manufacturing readiness levels and critical processes on a pilot production line because the program office said it had limited insight into manufacturing due to the program's early stage.

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Lead Component: Air Force | MTA | Common Name: ESS

ESS Program

Key Elements of Program Business Case

The ESS program did not have several key business case documents approved at initiation—including an approved requirements document, formal technology and schedule risk assessments, and a cost estimate based on independent assessment. Our prior work shows that these assessments help to inform decisions about middle-tier program initiation, including whether the program is likely to meet the statute-based objective of fielding a prototype within 5 years of the development of an approved requirement.

The program has since completed most of its business case documents. In May 2020, the Air Force conducted an independent cost estimate and completed an independent technical risk assessment on the range of available technologies considered for use on ESS. The program also has an approved acquisition strategy and validated requirements, both completed in 2019. Program officials said they manage schedule risks through risk management processes, but do not plan to complete a formal schedule risk assessment.

Technology

The program identified eight critical technologies, four of which are fully mature and one of which is approaching maturity. The remaining three are reported at various levels based on the three contractors' varying proposals. The program reported contractors might also identify additional critical technologies to counter emerging threats as they mature their designs. The program expects the contractors to mature all technologies by September 2025, the planned end of the rapid prototyping phase. Consequently, the program's technology risk level is not fully known.

Software Development and Cybersecurity

ESS officials stated that the contractors will likely use an Agile software development approach, but how and in what ways it will be used will become clear as contractors move to execution. Officials said the three contractors are responsible for the combination of software development approaches, potentially including a combination of custom software development and existing commercial and government products.

The Air Force approved the program's cybersecurity strategy in April 2020. The strategy is limited to specific areas including the payloads under development. Program officials noted they have not incorporated possible vulnerabilities associated with connecting to the ground system in their cybersecurity strategy, but they will consider such risks as the ground acquisition strategy is developed.

Transition Plan

The program is planning to transition to rapid fielding at the end of rapid prototyping. Concurrent with the end of rapid prototyping, the program will test and demonstrate critical payload capabilities for each contractor's payload. The rapid prototyping phase is scheduled to be completed following preliminary design review, with further testing occurring in the follow-on fielding phase. The program does not expect to demonstrate production maturity before transitioning to rapid fielding, because, according to the program, the three contractor ground prototypes will not be full production articles. The program also plans to release 90 percent of its design drawings 3 months after its planned transition date. In addition, as is typical for space programs, ESS will demonstrate its prototypes in a representative laboratory environment rather than in the intended environment, because it is not possible to demonstrate prototypes in space.

Other Program Issues

The program expects each contractor to deliver prototype payloads and associated capabilities by the end of rapid prototyping. Because the contractors will not deliver full satellites, a substantial amount of work will remain under the rapid fielding phase to build and launch the first satellite. For example, the program will assess the results of the prototype operational testing to competitively select one or more contractors for fielding, conduct additional integration of the payload with a compatible satellite, and carry out integrated testing before launch. The program identified integration of the technical components as a significant risk, and it has yet to determine who will be responsible for the integration—the government, the payload provider, or a third party contractor. The program stated that it is designing a fielding phase strategy with an approach that minimizes integration 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. According to the program office, ESS continues the strategic SATCOM mission by providing worldwide secure communications for DOD assets in all operational environments. The program stated that its acquisition approach energizes the industrial base to drive innovation, reduce risk, and maximize demonstrated prototype capability within budget and schedule constraints. The program noted that its strategy uses lessons learned from other programs to target the highest technical risks, focused predominantly on payload development. The program also stated that ESS will leverage a modular open system approach that enables incremental technology insertion. The program stated that it is developing an overall integration strategy to drive innovation through competition, deliver enterprise capabilities, and avoid costs traditionally associated with using a single vendor in the follow-on fielding phase.

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A Illustration or photo of system

B Program description

C Schedule timeline identifying key dates for the program including MTA initiation, funds obligated date, major decision reviews, and MTA completion or transition date

D **Program Essentials** Programmatic information, including decision authority, program office location, prime contractor, MTA pathway, and contract type

E **Program Background and Transition Plan**

F **Estimated Middle-Tier Program Cost and Quantities** Estimated cost and quantity requirements as of January 2021

G **Software Development** Software approach and metrics, including average delivery time, percentage of total program cost, and different types of software used

H **Key Elements of a Business Case** Depiction of key elements of a business case and the program's progress in completing those elements

I **Planned Knowledge by MTA Transition** Depiction of selected knowledge program plans to attain by MTA transition

J Assessment of a program's business case elements, technology, software and cybersecurity, transition plan, and other program issues

K **Program Office Comments** General comments provided by the cognizant program office

Source: GAO. | GAO-21-222

For 57 of our 64 assessments, we used scorecards to depict the extent of knowledge that a program has gained or plans to gain.[87] These scorecards display key knowledge-based practices that should be implemented by certain points in the acquisition process. In our prior and current work, we found that the more knowledge a program has attained by these key points, the more likely the weapon system will be delivered within its estimated cost and schedule. For MDAPs, future MDAPs, and MTA programs, we assessed different key points in the acquisition cycle and applicable knowledge-based practices based on differences in characteristics for these three program types. Additionally, within our assessments of MDAPs, we assessed different knowledge-based practices for shipbuilding programs at the point a design contract was awarded and at the point ship fabrication starts. These shipbuilding key points and practices were informed by our prior work.[88]

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. For future MDAPs and MTA programs, we used a partially closed circle to denote a knowledge-based practice that the program reported it plans to implement. For MTA programs, we also used an “x” within a circle to indicate that a program did not plan to obtain select knowledge by transition.
- **A dashed line** to denote that the program did not provide us with enough information to make a determination.
- **NA** to denote any scorecard field that corresponded with a practice that was not applicable to the program. A practice may be marked “NA” for a program if it has not yet reached the point in the acquisition cycle when the practice should be implemented, or if the particular practice is not relevant to the program.

We included notes beneath the figures as appropriate to explain information not available or NA scores, as well as other explanatory notations for the scorecards where appropriate. Appendix I provides

[87]We did not use scorecards in our seven one-page assessments of MDAPs that were well into production but planned to introduce new increments of capability, because our metrics on knowledge attainment were incongruent with the acquisition strategies these programs employed.

[88]GAO-09-322.

additional detail on our scorecard methodology. Figures 32, 33, and 34 provide examples of the knowledge scorecards we used in our assessments.

Figure 32: Examples of Knowledge Scorecards on Two-Page Major Defense Acquisition Program Assessments

Program in production

Attainment of Product Knowledge (as of January 2021)

	Status at	Current status
Resources and requirements match	Development start	
Demonstrate all critical technologies are very close to final form, fit and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit and function within 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 Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA	NA
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

Shipbuilding program

Attainment of Product Knowledge (as of January 2021)

	Status at	Current status
Resources and requirements match	Detail Design Contract Award	
Demonstrate all critical technologies are very close to final form, fit and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit and function within a realistic environment	○	○
Complete a system-level preliminary design review	○	●
	Fabrication start	
Complete basic and functional design to include 100 percent of 3D product modeling	●	●

● Knowledge attained, ○ Knowledge not attained, ··· Information not available, NA Not applicable

Source: GAO analysis of DOD data. I GAO-21-222

Figure 33: Example of Knowledge Scorecard on One-Page Future Major Defense Acquisition Program Assessments

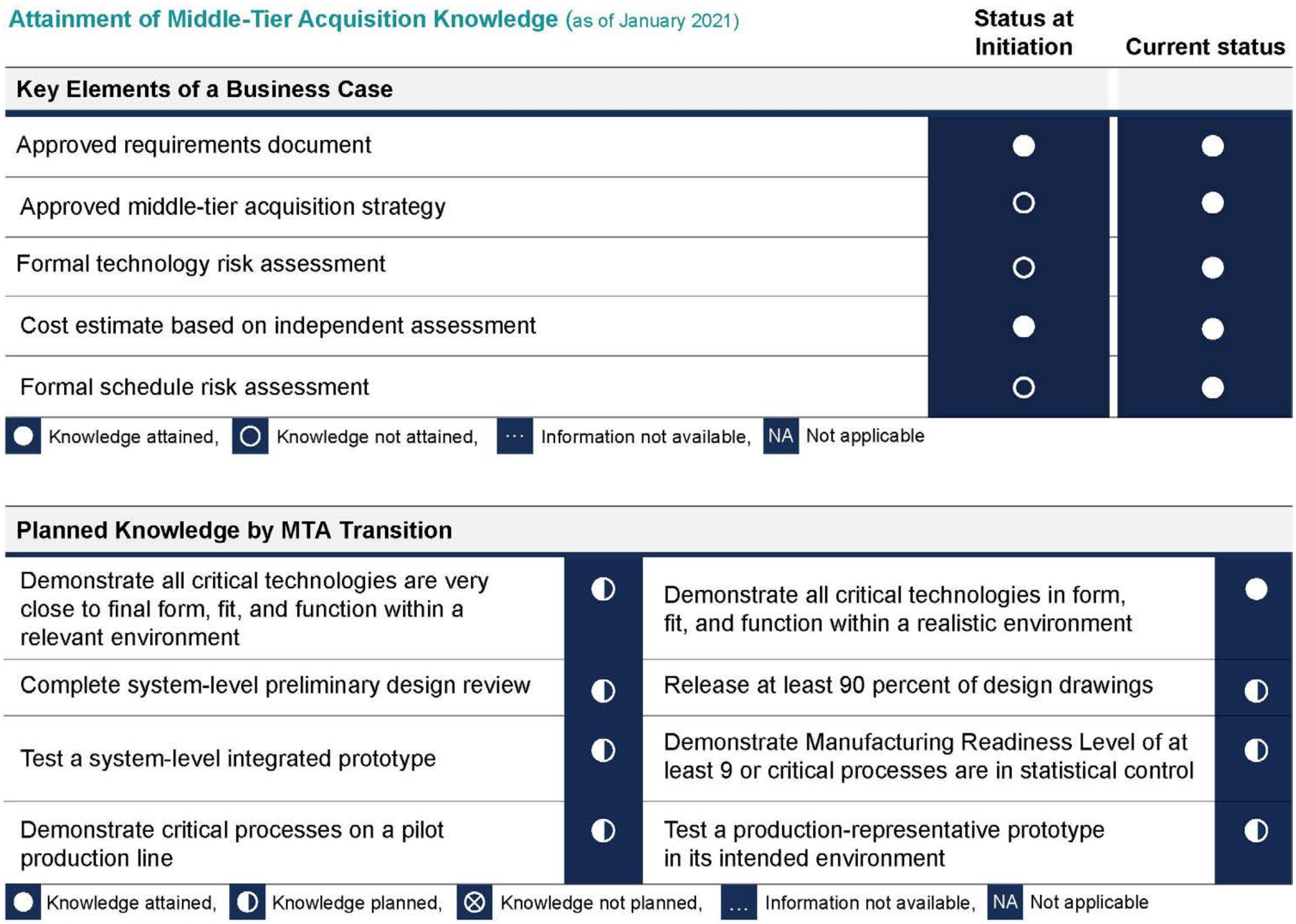
Attainment of Technology Maturation Knowledge (as of January 2021)

Conduct competitive prototyping	◐	Complete independent technical risk assessment	●
Validate requirements	◐	Complete preliminary design review	◐

● Knowledge attained, ◐ Knowledge planned, ○ Knowledge not attained, ··· Information not available, NA Not applicable

Source: GAO analysis of DOD data. | GAO-21-222

Figure 34: Example of Knowledge Scorecards on MTA Program Assessments

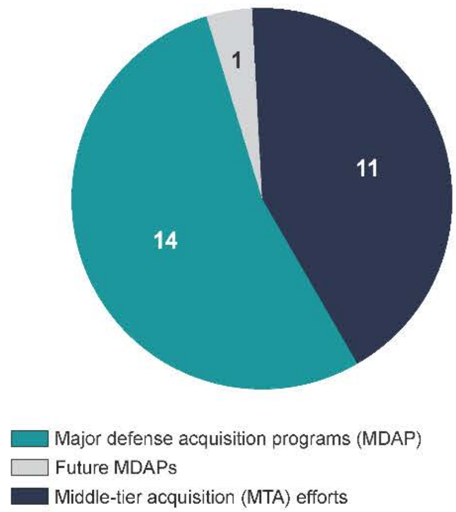


Source: GAO analysis of DOD data. | GAO-21-222

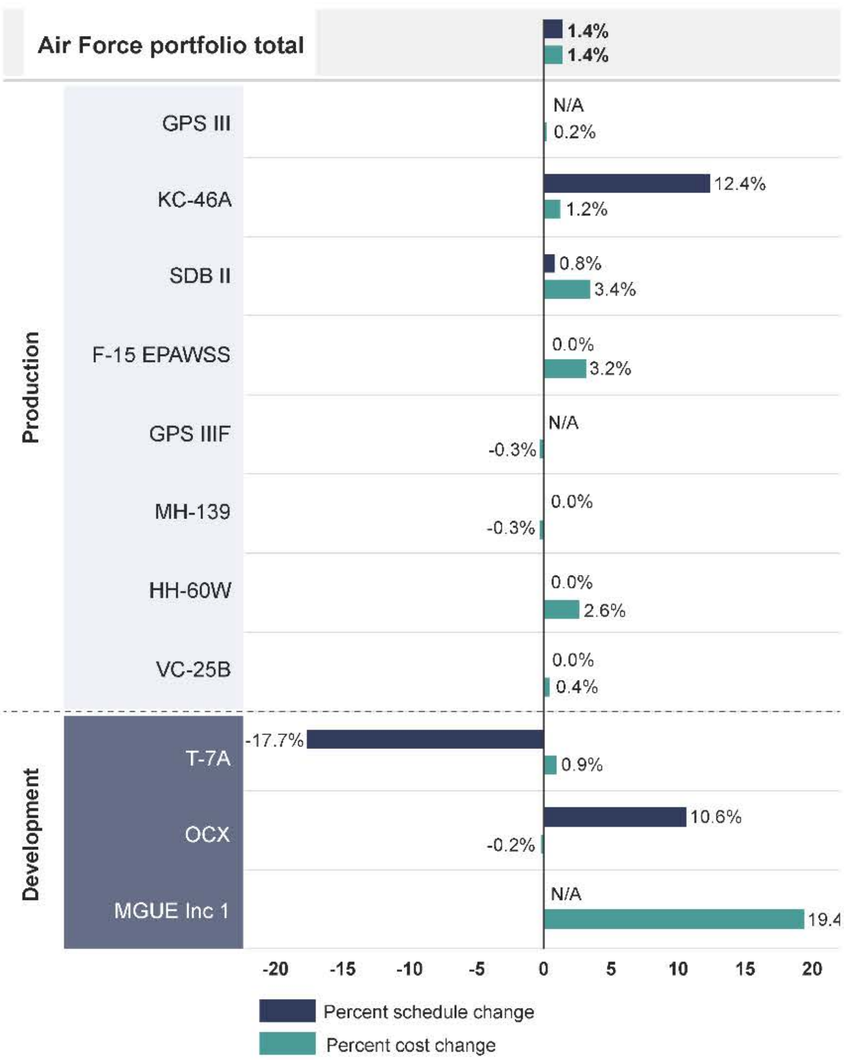
AIR FORCE AND SPACE FORCE PROGRAM ASSESSMENTS

Source: Lockheed Martin Corporation. | GAO-21-222

GAO Assessed 26 Air Force Weapon Programs

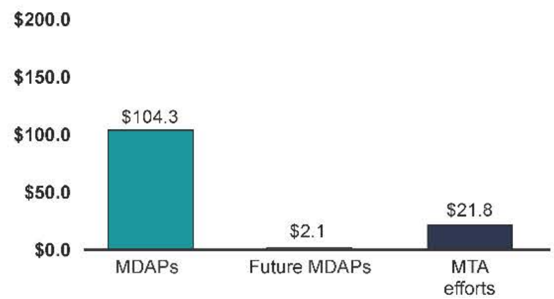


Most Air Force MDAPs Had At Least Some Cost Growth, Schedule Delays, or Both Since 2020



Air Force Programs Reported a Combined Acquisition Cost of $128.2 Billion

(Fiscal Year 2021 dollars in billions)



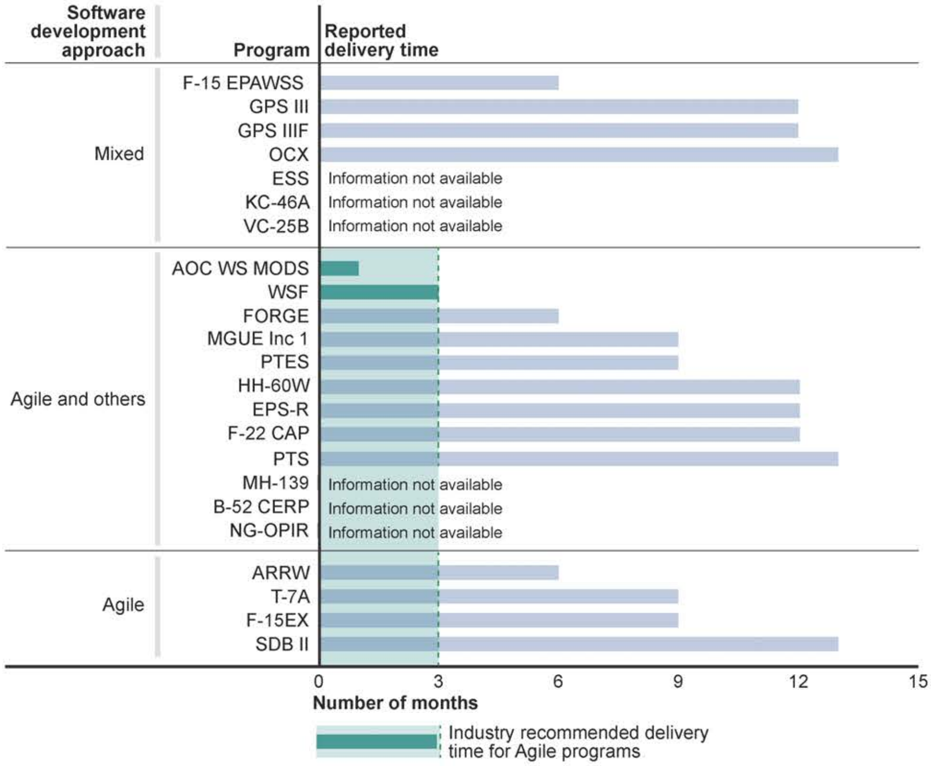
- Note: Acquisition costs for MTA programs reflect estimates for current efforts only. Additionally, cost estimates for future MDAPs may not reflect full costs since programs may still be defining them.

- The term "programs," when used alone in figure titles, refers to all MDAP, future MDAPs, and MTA programs that GAO assessed.
- Cost and schedule analyses are primarily based on estimates from DOD's Defense Acquisition Executive Summary reports. This information may differ from information reported in the Program Performance table and Funding and Quantities figures in individual assessments, which in some cases are based on more recent program estimates. See appendix I for details.

All data in figures are based on GAO analysis of DOD data and program office questionnaire responses. | GAO-21-222

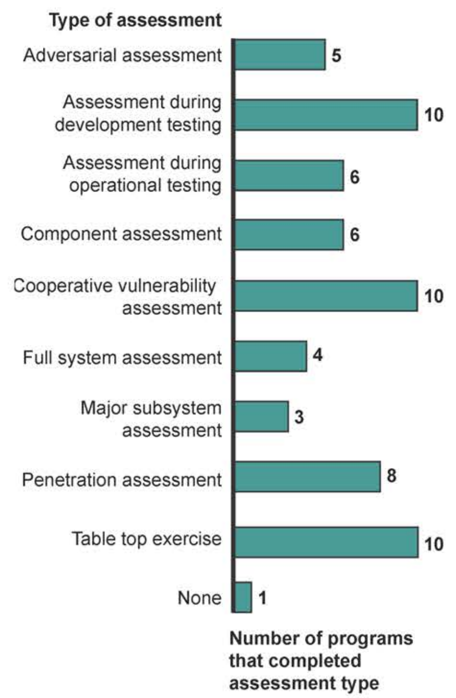
AIR FORCE AND SPACE FORCE PROGRAM ASSESSMENTS

Air Force Programs Often Reported Software Delivery Times Greater than Recommended by Leading Practices

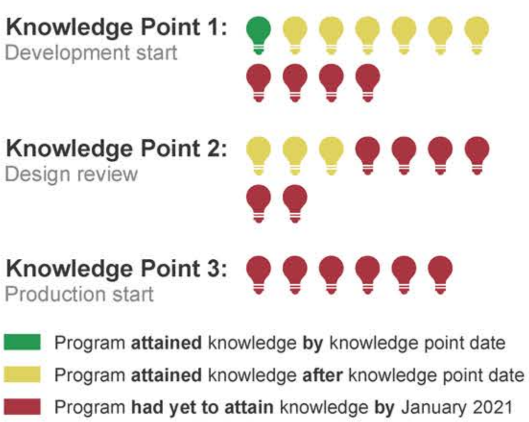


- Industry recommends deliveries on a continuing basis, as frequently as every 2 to 6 weeks for Agile programs. Programs reported deliveries to GAO in 0-3 month ranges and this figure represents the high end of those ranges. Mixed indicates more than one approach, not including Agile.
- Software development approach was not available for the MGUE Inc. 2 and NSSL programs.

Most Air Force Programs Completed At Least One Cybersecurity Assessment

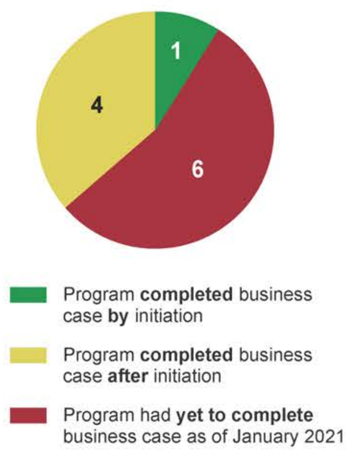


Air Force MDAPs Generally Did Not Attain Knowledge at Key Points on Time



- Note: For each knowledge point, GAO assessed the MDAPs that had reached that point as of January 2021. GAO excluded programs for which it determined that the practice was not applicable.

Most Air Force MTA Programs Did Not Have a Completed Business Case at Initiation, But Some Completed It Later



Only One of the Air Force MTA Programs Plans to Attain Key Knowledge by Transition

Plan to Attain Knowledge by Transition

- Note: GAO assessed programs planning to transition to the major capability acquisition pathway or to a rapid fielding effort, and excluded programs planning to transition to another rapid prototyping effort or that had yet to determine transition plans.

All data in figures are based on GAO analysis of DOD data and program office questionnaire responses. | GAO-21-222

Source: U.S. Air Force.

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

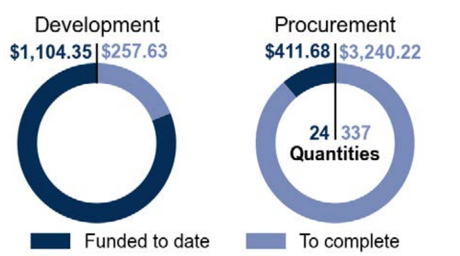
The Air Force's F-15 EPAWSS program plans to modernize the F-15 electronic warfare (EW) system used to detect and identify threat radar signals, employ countermeasures, and jam enemy radars. The program plans to reconfigure hardware and software from other military aircraft to address current EW threats. 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 Essentials

Milestone decision authority: Air Force
Program office: Wright-Patterson Air Force Base, OH
Prime Contractor: Boeing
Contract type: CPIF/CPFF/FFP (development); CPFF/FFP/FPI (low-rate initial production)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



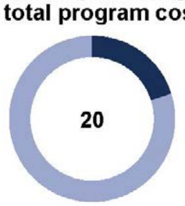
Software Development

(as of January 2021)

Approach: Mixed

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Off the shelf
79 percent Modified off the shelf
21 percent Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (11/2016)	Latest (10/2020)	Percentage change
Development	$965.84	$1,361.98	+41.0%
Procurement	$3,719.01	$3,651.90	-1.8%
Unit cost	$11.34	$13.81	+21.8%
Acquisition cycle time (months)	83	116	+39.8%
Total quantities	413	363	-12.1%

The latest total quantity includes two F-15C development units, 217 F-15E, and 144 F-15EX production units. Six of the F-15E production units will start out as development units before they are refurbished into production units.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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 and Design Stability

Since our last assessment, the EPAWSS program matured its remaining two critical technologies, with the last one demonstrated just before the October 2020 production start decision, but almost 4 years after development start. While the program always planned to fully mature these technologies after development start, this approach falls short of leading practices and resulted in product changes after the critical design review. In combination with test article production issues, this lack of maturity led to cost growth and test article hardware delivery delays, which then delayed the completion of testing needed to support the production decision by more than a year. While technology maturity is now achieved and no significant design changes were reported during the past year, EPAWSS will continue to face design risks until all system testing is completed. As of January 2021, the program needs to complete eight more ground-based test events and about 50 percent of the developmental flight testing.

Production Readiness

The Air Force approved the start of production for EPAWSS in October 2020 with a separate approval needed in May 2022 to install the procured hardware on fielded aircraft. EPAWSS demonstrated production line manufacturing processes and tested a production-representative prototype in support of this production decision, but has not demonstrated manufacturing readiness to an industry best practice high level. This introduces risk in stabilizing and controlling all manufacturing processes. The program deferred other preproduction activities a year or more to the planned May 2022 fielding decision, including some hardware qualification testing and demonstration of full EPAWSS performance in-flight, among other things.

These delays increase concurrency between system testing and production, which in turn increases the potential risk for costly retrofits and cost and schedule growth to achieve the required operational capabilities. While no retrofits are currently planned, the program intends to request funding for all low-rate initial production (LRIP) quantities before the December 2022 completion of developmental flight testing. While the Defense Contract Management Agency (DCMA) reported quality issues with the installation of EPAWSS on the test aircraft in 2019, it no longer considers the quality of installation work to be a high risk issue as corrective actions have resolved the quality issues.

Software and Cybersecurity

The program is developing custom software in a series of 13 incremental releases building up to the required operational capability. As of January 2021, the contractor will have issued seven releases, with about 82 percent of the software capability delivered for testing. According to DCMA, program officials are actively tracking and managing software development as a risk in recognition of the importance of delivering the remaining software on time to finish all flight testing successfully. The program updated its cybersecurity strategy in support of the production decision and plans to complete some cybersecurity testing after production start. Program officials stated that EPAWSS has had a cybersecurity strategy since program start in 2015, which outlines the completion of cybersecurity testing both before and after the start of production.

Other Program Issues

Due to earlier cost and schedule overruns, the program reported completing a restructure of the EPAWSS development contract in August 2020, converting the majority of remaining work from cost-reimbursable to firm-fixed-price. According to the program, this shifted the cost risk to the prime contractor for the remaining work—approximately $196 million in future development costs or about 26 percent of the contract's value. The program's total cost includes procuring EPAWSS for both the F-15E and the new F-15EX—a replacement for some older model F-15s. The program includes several years of LRIP, with the contractor to supply up to 45 EPAWSS units for upgrading fielded F-15Es and 32 or more for use on the F-15EX before EPAWSS enters full-rate production. As a result, both the F-15E and F-15EX could be subject to retrofits if changes need to be made to this LRIP hardware.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. In reply, the program office provided technical comments, which we incorporated where appropriate. The program office also stated that it made significant progress in 2020, with EPAWSS now installed on seven test aircraft and the eighth and last installation planned for completion in the summer of 2021. According to the program, design verification testing is complete, demonstrating the hardware meets basic functionality requirements and is ready to enter production. It noted that all other design testing is 90 percent complete and stated it considers what remains to be low risk and unlikely to reveal issues that necessitate redesigns or retrofits. The program reported that EPAWSS performed well through 12 ground-based tests and 20 months of flight testing. It added that the EPAWSS supplier made several investments to support the start of production and is producing similar systems for several other programs. The program office stated it is taking risks it believes to be prudent and accelerating the production decision to acquire EPAWSS as quickly as possible, in an effort to enable the program to deliver a critical capability to the warfighter.

Source: U.S. Air Force.

Global Positioning System III (GPS III)

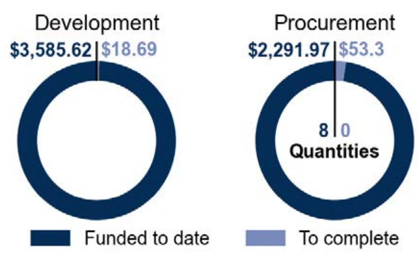
The Space Force's GPS III program is building and fielding a new generation of satellites to supplement and eventually replace GPS satellites currently in use. GPS III will provide a stronger military navigation signal, referred to as M-code, to improve jamming resistance, and a new civilian signal that will be interoperable with foreign satellite navigation systems. Other programs are developing the related ground system and user equipment.

Program Essentials

Milestone decision authority: Air Force
Program office: El Segundo, CA
Prime Contractor: Lockheed Martin
Contract type: CPIF/CPAF (procurement)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



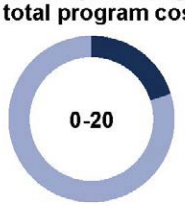
Software Development

(as of January 2021)

Approach: Waterfall and Incremental

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Off the shelf
0 percent Modified off the shelf
100 percent Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (5/2008)	Latest (9/2020)	Percentage change
Development	$2,963.91	$3,604.32	+21.6%
Procurement	$1,664.1	$2,345.27	+40.9%
Unit cost	$578.50	$594.96	+2.8%
Acquisition cycle time (months)	N/A	N/A	N/A
Total quantities	8	10	+25.0%

We could not calculate GPS III cycle times because the initial capability depends on the availability of complementary systems. Total quantities comprise two development quantities and eight procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	●
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 GPS III critical technologies in a realistic environment or test of a production representative prototype in its intended environment due to the difficulty of conducting tests in a realistic or intended environment—space.

GPS III Program

Technology Maturity, Design Stability, and Production Readiness

The program office reported that GPS III's eight critical technologies are mature and the design is stable. Lockheed Martin delivered five of the 10 GPS III satellites to the now-Space Force, with the remaining five in various production stages. The first four GPS III satellites launched and are now operational, and the fifth is scheduled to launch in July 2021.

While the GPS III program has reported improvements in contractor manufacturing processes over the past few years, the sixth GPS III satellite encountered failures in multiple assemblies during testing, which delayed the satellite's projected delivery by 8 months to April 2021. Consequently, Lockheed Martin conducted rework on various assemblies, such as the onboard computer and one of the satellite's atomic clocks. Due to the level of rework, the program carried out an additional thermal vacuum test of the satellite following reassembly. Program officials reported the satellite successfully completed this testing in October 2020.

Additionally, the progam identified schedule risks to the delivery of the eighth GPS III satellite in December 2021 and the 10th in May 2023. Assembly delivery delays and rework requirements for the program's prior satellites indicate these satellites may face similar delays. Of particular concern is the potential for rework to the satellite's remote interface units—components that serve as "routers" between the various assemblies within the satellite—given that four earlier GPS III satellites already required similar rework. Program officials stated that Lockheed Martin and its subcontactors have been working to address this risk through efforts in both the production and inspection of these components.

Software and Cybersecurity

The GPS III program pursued software development efforts specific to various satellite components, such as the satellite's mission data unit and the onboard computer. During an integrated GPS test event in August 2019, the Air Force reported one software-related deficiency pertaining to GPS III, which was subsequently addressed to permit the first GPS III satellite's January 2020 operational acceptance.

The GPS III program has an approved cybersecurity strategy, and cybersecurity testing for the program has been integrated with testing for related systems. Specifically, according to program officials, the Air Force incorporated cybersecurity testing for GPS III into a test and evaluation plan at the GPS enterprise-level, incorporating both ground control and satellite segments. The plan is structured to test system cybersecurity objectives to support major decisions, such as the readiness to launch. The Air Force found no GPS III cybersecurity deficiencies in the late 2019 integrated GPS test event that operationally assessed the first on-orbit GPS III satellite.

Other Program Issues

Program officials stated that the planned launch of the fifth GPS III satellite has been delayed 7 months to July 2021 due to additional pre-launch activities in preparation of the launch vehicle's use of a previously-flown first stage booster—the first such use for a national security mission.

Because of delays to the Next Generation Operational Control System (OCX) program—needed to enable the full range of GPS III capabilities—the GPS III program expects to accept delivery of all 10 GPS III satellites before beginning operational testing with OCX Block 1. Air Force plans establish that these tests, scheduled to begin in 2023 when OCX Block 1 transitions to operations, will confirm GPS III's modernized signal capabilities. However, this sequencing introduces the possibility that testers might discover deficiencies to already-produced or launched satellites—thereby constraining the Space Force's corrective options—and carries risk to overall GPS III cost, schedule, and performance.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that satellite production, launch, and mission operations continue to be the program's main focus. The program highlighted its accomplishments of 2020, including launch of the third GPS III satellite in June and the fourth in November. Additionally, the program office stated that the Space Force operationally accepted the first four GPS III satellites into the GPS constellation in 2020. The program office also noted that in 2021, it expects to accept three more GPS III satellites from Lockheed Martin, while continuing production efforts on the two remaining satellites of the GPS III series. Also in 2021, the program office plans to launch the fifth GPS III satellite and incorporate it into the GPS constellation, while preparing for a planned 2022 launch of the sixth satellite. The program office added that on-orbit data have confirmed the GPS III satellites meet or exceed all technical performance mission requirements.

Source: Lockheed Martin Corporation.

Global Positioning System III Follow-On (GPS IIIF)

The Space Force's GPS IIIF program will build upon the efforts of the GPS III program to develop and field next generation GPS 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 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.

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

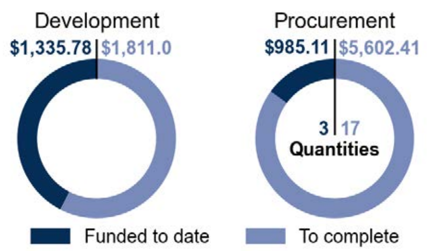
- 9/18 Development start
- 3/20 Critical design review
- 7/20 Production decision
- 1/21 GAO review
- 2/26 First satellite available for launch
- TBD Start operational test
- TBD End operational test

Program Essentials

Milestone decision authority: Air Force
Program office: El Segundo, CA
Prime Contractor: Lockheed Martin Corporation
Contract type: FPI (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

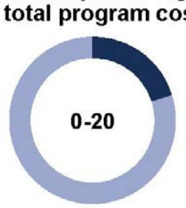
(as of January 2021)

Approach: Waterfall and Incremental

Average time of software deliveries (months)

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

Software percentage of total program cost



Software type

90 percent Off the shelf
0 percent Modified off the shelf
10 percent Custom software

According to program officials, approximately 90 percent of GPS IIIF software is expected to be reused from the GPS III program.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (9/2018)	Latest (9/2020)	Percentage change
Development	$3,351.15	$3,146.78	-6.1%
Procurement	$6,481.13	$6,587.52	+1.6%
Unit cost	$446.92	$442.47	-1.0%
Acquisition cycle time (months)	N/A	N/A	N/A
Total quantities	22	22	+0.0%

We could not calculate cycle time because initial capability depends on the availability of complementary systems. Total quantities comprise two development quantities and 20 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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 GPS IIIF critical technologies in a realistic environment or test of a production representative prototype in its intended environment due to the difficulty of conducting tests in a realistic or intended environment—space. We have updated this graphic to reflect that the program did not conduct a preliminary design review prior to development start. The Air Force waived the requirement for the review for this program.

GPS IIIF Program

Technology Maturity and Design Stability

The GPS IIIF program's two critical technologies—a linearized traveling wave tube amplifier and a digital waveform generator—are mature to the level generally required to begin development. The program completed its critical design review in March 2020, which included both components. While new to GPS satellites, the traveling wave tube amplifier draws from Lockheed Martin designs used on other space programs. The digital waveform generator is a new module that is part of the satellite's mission data unit (MDU), described as the brain of the satellite's navigation mission.

In May 2020, the Air Force conducted an independent technical risk assessment, which identified schedule risk related to the MDU. In 2021, the program plans to take delivery of five engineering development MDUs for use in various applications. However, the program will start building the MDU to qualify the flight design for the GPS IIIF satellite before testing is completed on the engineering development units. Consequently, the risk assessment warned that if flaws are uncovered in the development unit testing, any resulting MDU design changes could drive schedule delays to the flight qualification MDU, which could require re-work to incorporate any changes. While the GPS IIIF MDU design has remaining fabrication, integration, and test work to complete, 74 percent of its design draws directly from the GPS III MDU, limiting risk to areas where GPS IIIF incorporates new design to the MDU.

Prior to integrating and testing the first GPS IIIF satellite, the program plans to test a nonflight, system-level integrated prototype that includes all key subsystems and components, but with less redundancy than the final configuration. This prototype, projected for a November 2023 completion, will help the program gain fabrication, integration, and testing knowledge.

Production Readiness

In July 2020, the Air Force approved the program's production decision, and 3 months later modified the contract to exercise options to build the third and fourth GPS IIIF satellites. The program has yet to ensure that all GPS IIIF-specific manufacturing processes are in statistical control, as recommended by leading acquisition practices. However, program officials told us they expect to mitigate the majority of technical risk in the building and testing of the first two satellites. Specifically, they expect assembly and developmental and operational test and evaluation efforts for these two satellites will help ensure that new elements of the satellite design meet program requirements.

Software and Cybersecurity

The GPS IIIF leverages software from the GPS III program, and only 22 percent of the MDU software and 26 percent of the on board computer software is new or modified content. The GPS IIIF program utilizes both waterfall and incremental approaches to develop custom software for satellite control, command and control, and other domains. The Air Force's independent technical risk assessment assessed the program's software development risk as low.

The GPS IIIF program has an approved cybersecurity strategy but has yet to set a date for completing a cybersecurity assessment. Not addressing cybersecurity issues early in development may increase risk to the program since it becomes more difficult to fix at a later point. The independent technical risk assessment noted that, relative to the GPS III program, the GPS IIIF program plans include improvements in cybersecurity processes for threat analysis and security verification. However, the assessment noted that the program had not yet approved or budgeted for adequate testing for assessing system survivability and cybersecurity resiliency in a contested operational environment. The assessment noted the program's efforts to incorporate such testing into the next test plan revision.

Other Program Issues

The independent technical risk assessment noted risk from potential delays in the planned OCX Block 3F program, a separate program that aims to modify the ground control segment to launch and control the GPS IIIF satellites. The assessment highlighted delays with OCX's Blocks 1 and 2 and noted the likelihood that OCX Block 3F will not be ready in time to support GPS IIIF training and test preparation activities planned for fiscal years 2024 and 2025. Such delays would, in turn, delay the operational use of GPS IIIF satellites.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that it has been working closely with the contractor to ensure that schedule milestones are met and that no schedule growth occurs. The program office stated that the program completed its critical design review in March 2020, and the Air Force approved the program's production decision in July 2020. The program office noted that as part of that production decision, an updated program cost and schedule baseline was approved and a summary report of the production decision was provided to Congress. According to the program office, development efforts for the first two GPS IIIF satellites are proceeding as planned. It added that two additional satellites were placed under contract in October 2020, while three more satellites are planned to be placed under contract in fiscal year 2022.

Source: Sikorsky Aircraft Co.

HH-60W Jolly Green II

The Air Force's HH-60W Jolly Green II (formerly known as the Combat Rescue Helicopter or CRH) program will replace the Air Force’s aging HH-60G Pave Hawk rescue helicopter fleet. It will provide 113 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, among other things.

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

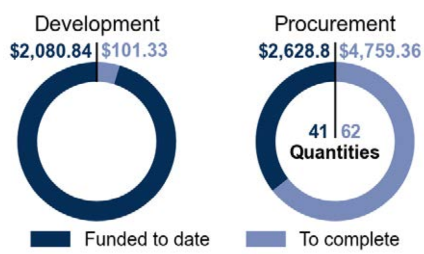
- 6/14 Development start
- 5/17 Critical design review
- 9/19 Low-rate decision
- 1/21 GAO review
- 7/21 Start operational test
- 1/22 End operational test
- 4/22 Initial capability
- 5/22 Full-rate decision

Program Essentials

Milestone decision authority: Air Force
Program office: Wright-Patterson Air Force Base, OH
Prime Contractor: Sikorsky Aircraft Co.
Contract type: FPI/FFP/CPFF (Development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



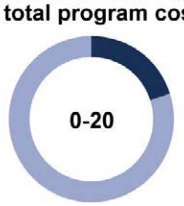
Software Development

(as of January 2021)

Approach: Agile, Waterfall, and Incremental

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Off the shelf
99 percent Modified off the shelf
1 percent Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (6/2014)	Latest (9/2020)	Percentage change
Development	$2,208.34	$2,182.17	-1.2%
Procurement	$6,886.58	$7,388.16	+7.3%
Unit cost	$81.44	$85.15	+4.6%
Acquisition cycle time (months)	82	94	+14.6%
Total quantities	112	113	+0.9%

Total quantities comprise 10 development quantities and 103 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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 current status of HH-60W design drawing stability because program officials said that they no longer track design drawings.

HH-60W Jolly Green II Program

Technology Maturity and Design Stability

As of October 2020, the program has yet to fully demonstrate its one critical technology—the radar warning receiver—in a realistic environment. Program officials report the technology is not fully mature in advance of realistic testing planned for 2021 and 2022. Program officials stated they have tested in the most realistic and stressing environments available. Program officials concur with the review previously conducted by Office of the Under Secretary of Defense for Research and Engineering (OUSD (R&E)) officials. This review assessed that the radar warning receiver was only nearing maturity until flight tests occurred, which contradicted the program's earlier maturity determination. Program officials told us they have high confidence in their original assessment and believe the technology is most likely to achieve maturity based on about 900 hours of developmental flight testing, which included 75 hours of radar warning receiver testing.

Program officials report a stable design, although an OUSD (R&E) review found moderate technical risk associated with the helicopter's weight. They stated they identified no deficiencies that would result in significant weight growth and budgeted for helicopter upgrades in future fiscal years, including new capability integration. If equipment needed for future capabilities cannot be integrated within maximum weight limits, then some redesign or requirements trade-offs may be necessary. Program officials also stated the program is no longer tracking design drawing metrics, precluding assessment of changes in design stability based upon these metrics since the time of last year's assessment.

Production Readiness

More than a year after entering production, the program has yet to demonstrate two of the three leading practices that our prior work has shown help ensure mature manufacturing processes. Program officials reported they demonstrated pilot production line capability and that the production line is common to that of a mature helicopter system with only minor differences. They stated that the differences have been shown to be readily incorporated through initial helicopter builds. However, they have not collected statistical process control data on their production processes and did not test a production-representative prototype in its intended environment before beginning production, limiting both our assessment and the program's understanding of its production readiness.

These officials noted the program experienced parts shortages and was affected by COVID-19 pandemic-driven absenteeism, resulting in a 1-month delay in initial deliveries for the first production lot. The officials told us that pandemic-related delays in developmental testing and in the validation and verification of training manuals delayed routine helicopter availability for aircrew and maintenance qualification from the September 2020 contractual date until December 2020.

Software and Cybersecurity

The program's software development approach continues to differ from leading commercial practices. The program is using a combination of approaches, including Agile, but plans only a single software delivery to the end user for initial operational testing and evaluation. This approach stands in contrast to industry's Agile practices, which encourage working software to be delivered to users as frequently as every 2 weeks so issues can be found and addressed quickly. The program office stated that it has been using Agile for test software development, but that due to the need to adhere to airworthiness and safety standards, it is time-consuming to provide multiple software deliveries to users. It noted that it uses alternative methods to obtain user feedback during development.

Program officials reported moderate risk associated with development for the heads-down tactical situational awareness system software, which will undergo developmental testing in June 2021. The software will then be assessed during initial operational testing. The program office noted that its development timelines for this software have exceeded customer expectations.

Program officials stated they previously addressed related recommendations from the Director, Operational Test and Evaluation. These recommendations called for creating and executing a plan to address situational awareness system issues and providing cybersecurity operational test teams with early access to systems on newly produced helicopters.

Other Program Issues

Program officials stated that increases in planned capability upgrades approved by the Air Force last year continue to drive cost growth. The program also stated more recent cost increases since last year were caused by the acceleration of production over the next several years and related spare parts 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 reported that it is performing to its baseline schedule. It stated that it has conducted developmental testing and completed over 75 flight hours in a representative operational environment. However, it also noted that the radar warning receiver has yet to demonstrate all technical requirements and further testing is scheduled for February 2021. The program office added that it plans to continue using an incremental test approach. According to the program, it is on track to achieve full-rate production in May 2022 and subsequently plans to award the first full-rate production contract.

Source: © 2016 Boeing Company - Photo by Paul Weatherman.

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

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 refueling capacity, efficiency, cargo, and aeromedical capabilities over the KC-135.

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

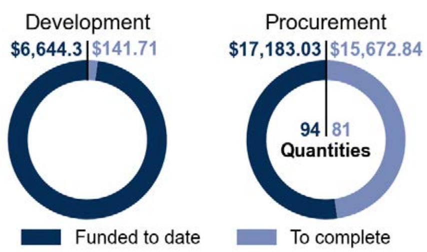
- 2/11 Development start
- 7/13 Critical design review
- 9/15 KC-46 first flight
- 8/16 Low-rate decision
- 10/19 Start operational test
- 1/21 GAO review
- 9/21 Required assets available
- Fiscal year 2024 End operational test
- 7-9/24 Full-rate decision

Program Essentials

Milestone decision authority: Air Force
Program office: Fairborn, OH
Prime Contractor: Boeing
Contract type: FPI (development), FFP (procurement)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Waterfall and Incremental

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Information not available

Software type

0 percent Off the shelf
64 percent Modified off the shelf
36 percent Custom software

The program does not have a software delivery schedule or track software work elements for current software efforts.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (2/2011)	Latest (7/2020)	Percentage change
Development	$8,045.64	$6,786.01	-15.7%
Procurement	$39,063.96	$32,855.87	-15.9%
Unit cost	$287.45	$237.40	-17.4%
Acquisition cycle time (months)	78	127	+62.8%
Total quantities	179	179	+0.0%

Total quantities comprise four development quantities and 175 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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 office 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

The KC-46A's three critical technologies are fully mature, but the program continues to experience design instability. As of October 2020, the aircraft has six critical deficiencies discovered during developmental and operational testing that require design changes.

- The two most recent deficiencies, identified over the past year, relate to fuel manifold leaks and auxiliary power unit drain mast cracks, which have resulted in increased maintenance, limiting aircraft availability.
- Another deficiency relates to auxiliary power unit duct clamps detaching, which could pose personnel safety risks.
- Two other deficiencies relate to shortcomings with the remote vision system cameras and their display (one of the program's critical technologies) that can cause the operator to scratch stealth aircraft with the boom during refueling due to poor visual acuity and inadequate depth perception.
- Another deficiency relates to the boom being too stiff during refueling attempts with lighter receiver aircraft, which could cause it to strike and damage the receiver aircraft.

Program officials stated Boeing will address five of the six deficiencies without cost to the government, while the Air Force will be responsible for the cost of the boom stiffness deficiency. Program officials estimate that all of the deficiencies will be corrected by 2023, with additional time required to retrofit delivered aircraft.

The program delayed operational testing completion and the full-rate production decision by at least 3 years due to the remote vision system and boom deficiencies. Additionally, while Boeing completed nearly all planned developmental testing as of August 2020, a small amount of testing remains related to the wing aerial refueling pods. Until this testing is complete, Boeing may find additional deficiencies that could require further design changes, adding risk of cost growth and schedule delays.

The program is continuing to use a combination of manufacturing readiness assessments and the Federal Aviation Administration (FAA) certification process to assess KC-46A production readiness, program officials said. They added that Boeing is behind schedule in demonstrating manufacturing readiness for production and installation of wing aerial refueling pods due to FAA certification related testing, but program officials expect the FAA to certify by June 2021.

The Air Force began accepting aircraft in January 2019. As of December 2020, Boeing delivered 42 low-rate production aircraft and is producing 29 more, program officials noted. Program officials stated all delivered aircraft will be retrofitted with a redesigned boom and remote vision system when available. The program expects Boeing to deliver the first nine sets of wing aerial refueling pods by September 2021.

Software and Cybersecurity

Current software activities continue to be directed at fixing critical deficiencies and delivering capability for the wing aerial refueling pods, which program officials estimate could be completed in 2021. The program is currently using waterfall and incremental software development approaches, and program officials noted that they are considering Agile development for the program's modernization and sustainment phase.

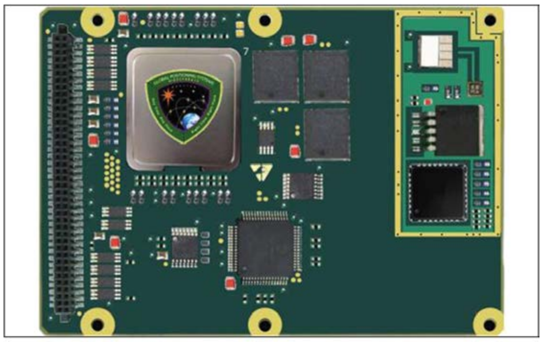
Although the program's key performance requirements do not specifically address cybersecurity, the program conducted cooperative vulnerability and penetration assessments during both developmental and operational testing.

Other Program Issues

Program officials stated that Boeing now plans to deliver the refueling pods in September 2021, 49 months later than initially planned. While the Air Force was withholding 20 percent of each aircraft's payment at delivery until critical deficiencies were fixed, according to program officials, the Air Force provided Boeing with the withheld amount in early 2020 to assist the company with COVID-19-related supply issues. The KC-46A can conduct some aspects of its mission, but it is currently restricted on refueling certain aircraft due to the identified deficiencies.

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: U.S. Air Force.

Military Global Positioning System (GPS) User Equipment (MGUE) Increment 1

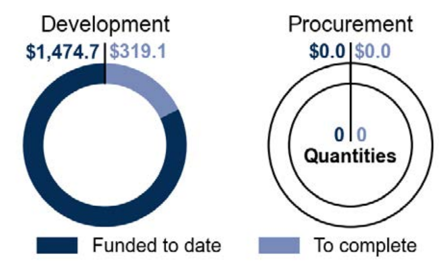
The Air Force's MGUE program is developing GPS receivers compatible with the military code (M-code) signal. The receiver cards will provide enhanced position, navigation, and timing capabilities and improved resistance to threats. Increment 1, assessed here, is developing two types of receiver cards for testing—one for aviation and maritime applications, and one for ground applications. The military services will make procurement decisions.

Program Essentials

Milestone decision authority: Air Force
Program office: El Segundo, CA
Prime Contractor: L3Harris, Raytheon Technologies, BAE Systems
Contract type: CPIF/CPFF/FFP (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)

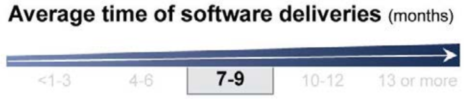


Software Development

(as of January 2021)

Approach: Agile and Incremental

Average time of software deliveries (months)



Software percentage of total program cost

Software type

0 percent
Off the shelf

0 percent
Modified off the shelf

100 percent
Custom software

According to program officials, they do not track software cost elements separately.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (1/2017)	Latest (1/2021)	Percentage change
Development	$1,631.49	$1,793.8	+9.9%
Procurement	$0.0	$0.0	N/A
Unit cost	N/A	N/A	N/A
Acquisition cycle time (months)	N/A	N/A	N/A
Total quantities	0	0	N/A

We did not assess procurement, unit cost, or acquisition cycle time because the program does not intend to procure cards beyond test articles, which are not reported as development or procurement quantities, and the program will end with operational testing.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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 military services may decide to procure.

MGUE Increment 1 Program

Technology Maturity

Consistent with last year, the program assessed four of its five critical technologies as fully mature. The remaining critical technology—anti-spoof software designed to prevent tracking false GPS signals—is nearing maturity. During a May 2020 test, the program determined additional fixes to the ground card would be required. Further software updates and testing on the card are planned for early 2021. Program officials said this software testing is also needed for the aviation/maritime card with a date to be determined. The program office forecasts this software will be mature once testing is complete on the first lead platform for both card types.

Design Stability

In our prior assessment, we reported that the design was stable, according to program officials, but the program faced related challenges over the past 2 years. Early 2019 developmental testing uncovered problems with the ground card's ability to detect problems with the external antenna, requiring modification of the card's hardware. A program official told us that the contractor for the first requirements-compliant ground card provided updated hardware in September 2020, which addressed the antenna deficiency, among others. However, separate software deficiencies in the aviation/maritime card prevented the program from completing verification of technical requirements for that card—its first schedule milestone—as planned. The program also reported that it would miss milestones for certification of readiness to begin final testing on the B-2 aircraft and DDG 51 class destroyer. In addition, program officials consider late discovery of aviation/maritime card hardware deficiencies a moderate risk, and if future integration and testing for this card reveal unexpected issues, those issues could disrupt the design stability achieved thus far.

Production Readiness

Although program officials said the ground card is on track to begin final testing by May 2021, the program is developing a new schedule to complete the aviation/maritime card. We previously reported that completion of final testing of that card was delayed from April 2021 to March 2022. However, a program official indicated further delays are likely to be reflected in the new schedule expected to be finalized in January 2021, possibly delaying MGUE procurement decisions across DOD.

Software and Cybersecurity

The MGUE Increment 1 program uses a mix of Agile and incremental software development to provide software deliveries intended to check requirements, design, internal testing, and production representative testing. However, the program is behind schedule delivering aviation/maritime software due to multiple problems. Program officials said they conducted in-depth analysis of more than 300 problem reports in late 2019, with some deficiencies addressed by the contractor and some undergoing root-cause analysis, and they expect resolution of deficiencies in 2021.

Program officials said MGUE contractors continue to experience challenges hiring software development staff. They also reported challenges in finding government staff with required expertise, including cybersecurity, and noted that addressing cybersecurity controls resulted in cost and schedule growth.

Other Program Issues

Delays and associated costs and updated contractor market strategies led the Air Force to revise the criteria for completing the program and reduce program scope in August 2020. Some contractors no longer plan to produce some cards that they were initially developing under the program, so the program scope is now focused on only MGUE cards that have a production plan. Specifically, the Air Force reduced the number of cards requiring technical requirements verification from all five initially developed to just two—the first available ground and aviation/maritime cards. The Air Force cited costs associated with delays and engineering changes, among other issues. The Air Force also removed the requirement to complete manufacturing readiness assessments for contractors that do not plan to produce cards they developed under the 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. The program office stated it made significant progress in 2020, such as integrating the ground card into lead platforms, conducting developmental testing, and completing certification of the first ground card. The program office also stated that it resolved a ground card performance deficiency identified in May 2020 testing and made progress addressing technical challenges to the aviation/maritime card. According to the program office, it converted the remaining development of the aviation/maritime card to a firm-fixed-price contract in December 2020. The program office stated that it is scheduled to deliver the aviation/maritime card before the end of 2021. It added that the program began working to a new acquisition program baseline in January 2021 and expects to complete the final lead platform field test in July 2024.

Source: U.S. Air Force.

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

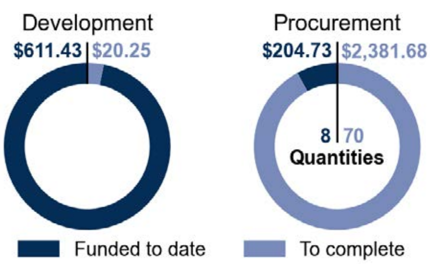
The MH-139A program will replace the Air Force's fleet of 63 UH-1N utility helicopters. The MH-139A helicopter's missions include securing intercontinental ballistic missile sites and convoys and transporting senior government officials in the National Capital Region. The MH-139A program is acquiring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

Program Essentials

Milestone decision authority: Air Force
Program office: Wright-Patterson Air Force Base, OH
Prime Contractor: Boeing
Contract type: FFP (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Agile and Waterfall

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Software type

99.6 percent Off the shelf
0.4 percent Modified off the shelf
0 percent Custom software

The program said it does not track estimated software costs.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (9/2018)	Latest (7/2020)	Percentage change
Development	$603.69	$631.68	+4.6%
Procurement	$2,568.38	$2,586.41	+0.7%
Unit cost	$41.76	$41.27	-1.2%
Acquisition cycle time (months)	60	60	+0.0%
Total quantities	84	84	+0.0%

Total quantities comprise six development quantities and 78 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	NA
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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 said it does not have any, or preliminary design review or some design stability knowledge metrics because the program said these were not applicable. We also did not assess manufacturing maturity because the system has yet to reach production; however, the program stated that it had tested a production-representative prototype in the system's intended environment.

MH-139A Program

Technology Maturity and Design Stability

The MH-139A does not have any critical technologies and program officials said a preliminary design review was not applicable since the Air Force initiated the program at preproduction, rather than development start.

Over the past year, program officials reported more than a 700 percent increase in its total number of expected drawings–from 507 last year to 4,119 this year. Based on this increase, we determined the program had only 12 percent of drawings releasable to manufacturing at its critical design review and 35 percent as of July 2020, well below the 90 percent recommended by leading acquisition practices. Program officials said the increase is due to issues identified during manufacturing and testing. They stated that many of the drawing changes were insignificant because MH-139 is based on a commercial aircraft, and they expect design instability to decrease once they are able to demonstrate compliance with Federal Aviation Administration (FAA) requirements.

Additionally, in September 2020, Air Force officials told us that they had yet to determine the aircraft's final weight despite aiming to do so by December 2019. Air Force officials told us they rated the weight risk as medium, stating they have four aircraft with known weight flying for test, and that they have determined the aircraft has 65 pounds of margin. However, if design changes that may be required to address issues identified during manufacturing and testing result in a final aircraft weight that exceeds design parameters, the MH-139A may not meet speed and range requirements.

Production Readiness

The program plans to start low-rate initial production in September 2021. In September 2020, Air Force officials stated that the program completed all six manufacturing readiness assessments intended to support this milestone. The program is pursuing a manufacturing readiness level that according to DOD guidance approaches maturity and corresponds with demonstrating a pilot production line. The officials also stated that four aircraft had been produced as of February 2021, and two more were in production. Program officials noted they believe the completed assessments mitigate risks and they are comfortable accepting a risk that manufacturing issues may disrupt production because the aircraft is based on an existing commercial aircraft.

Software and Cybersecurity

Program officials said the MH-139A program has two software development efforts—Honeywell's air vehicle software and Boeing's training system software—developed using waterfall and Agile approaches, respectively. While the air vehicle software is almost entirely commercially-derived, the training system software is customized for the program. However, the program does not track software cost, so we cannot assess the extent to which software costs are contributing to the program's overall cost estimate.

Program officials said they identified some cybersecurity vulnerabilities through two assessments and plan to conduct additional testing on production aircraft. Program officials said they will work with Boeing to schedule an additional assessment within the next 6 months. However, program officials said that the helicopter is not required to meet all of DOD's requirements because the helicopter's cybersecurity requirements were agreed upon before DOD had established its requirements.

Other Program Issues

Program officials said that the Air Force withheld payments to the contractor in February 2020 due to late and poor quality deliverables, and in September 2020, program officials told us that they saw no significant improvements in deliverables. Program officials cited Boeing's challenge in obtaining civil certification from the FAA as the primary cause of late deliverables. The program continues to work with the FAA to determine whether Boeing will need to conduct additional engine-power testing before the FAA will certify the helicopter's airworthiness. Program officials said the FAA is considering allowing Boeing to submit existing performance data in lieu of additional testing, but has yet to make a decision.

According to program officials, although Boeing's performance has not improved, in April 2020, the Air Force released withheld payments in response to the COVID-19 pandemic. They said Boeing has yet to complete its assessment of COVID-19-related effects and has not committed to a timeline to submit its assessment to the program office. Program officials told us that COVID-19-related effects to date have been minimal, involving minor schedule delays due to travel restrictions and temporary shutdowns at Boeing.

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 MH-139A is a commercial derivative aircraft that leverages a firm engineering software and hardware foundation to provide military capabilities. It noted that Boeing faced challenges achieving certification with the FAA. To help mitigate delays, the program revised its test strategy, using four available test aircraft to supplement Air Force and FAA flight testing, with military utility testing to follow, according to the program office. The program said it continues to work toward a successful production decision and reports that assessments determined that manufacturing was mature enough to proceed to low-rate initial production.

Source: U.S. Air Force.

Next Generation Operational Control System (OCX)

The Space Force is developing software to replace the existing Global Positioning System (GPS) ground control system. The Space Force intends for OCX to help ensure reliable, secure delivery of position, navigation, and timing information to military and civilian users. The Space Force is developing OCX in blocks that provide upgrades as they become available. We assessed the first three blocks: Block 0 for launch and limited testing of new satellites; Block 1 for satellite control and basic military signals; and Block 2 for modernized military and additional navigation signals.

CONCEPT
- **2/10** Development contract award

SYSTEM DEVELOPMENT
- **11/12** Development start
- **10/17** Initial capability-Block 0
- **9/18** Development restart
- **1/21** GAO review

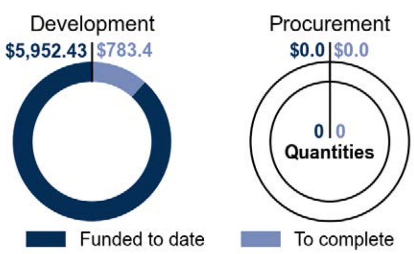
PRODUCTION
- **4/22** Blocks 1/2 delivery
- **4/23** Initial capability-Blocks 1/2
- **5-7/23** Operational test

Program Essentials

Milestone decision authority: Under Secretary of Defense, Acquisition and Sustainment
Program office: El Segundo, CA
Prime Contractor: Raytheon
Contract type: CPIF/CPAF (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



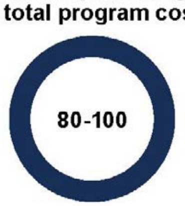
Software Development

(as of January 2021)

Approach: Mixed

Average time of software deliveries (months)

Software percentage of total program cost



Software type

37 percent Off the shelf
21 percent Modified off the shelf
42 percent Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (11/2012)	Latest (9/2020)	Percentage change
Development	$3,887.57	$6,735.83	+73.3%
Procurement	$0.0	$0.0	N/A
Unit cost	$3,887.57	$6,735.83	+73.3%
Acquisition cycle time (months)	55	125	+127.3%
Total quantities	1	1	+0.0%

We calculated acquisition cycle time using the program's initial capability date for Block 2. Total quantities comprise one development quantity and zero procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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 could not assess OCX design stability metrics because the program does not track the metrics we use to measure design stability, and we could not assess manufacturing maturity metrics because the system has yet to reach production.

OCX Program

Technology Maturity and Design Stability

Over the past year, the OCX program finished maturing the program's critical technologies. It delivered nine of the 14 technologies when it delivered Block 0 in September 2017. This year, the program reported that the remaining five critical technologies, to be delivered as part of Block 1, have been successfully demonstrated in a realistic environment. OCX is primarily a software development effort. As a result, the program does not track metrics used for this assessment to measure design stability, such as the number of releasable design drawings.

Additionally, the OCX program commenced its software qualification testing in 2020. Of note, the program successfully completed testing on its GPS satellite simulator, which is needed to test the OCX satellite control software. Program officials noted, however, that much of the OCX software qualification testing will need to be run again after the program acquires new hardware in 2021 to replace OCX's IBM server hardware.

Software and Cybersecurity

IBM sold the server product line used by the program to Lenovo, a Chinese corporation, creating a cybersecurity risk. Consequently, in March 2020, the OCX program modified an existing contract with Raytheon to replace IBM hardware, which would no longer be supported after August 2022. According to program documentation, this $359 million contract modification added 10 months to the development schedule, delaying the contractor's delivery of OCX Blocks 1 and 2 from June 2021 to April 2022.

According to program officals, the contract modification resulted in changes to the OCX program's approach to software development, with the program now employing mixed software development approaches for two distinct efforts. For the program's current software qualifying efforts leading up to a planned April 2021 certification, the program continues to apply a mix of Agile, incremental, and waterfall methods. For subsequent work, the program will employ an Agile approach embedded within a master waterfall schedule.

In last year's assessment, we reported that the program's incorporation of automation processes facilitated faster software testing and earlier software defect discovery. However, the Defense Contract Management Agency notes that the program's backlog of software deficiencies remaining to be addressed is high, creating cost and schedule risk.

Other Program Issues

Due to travel restrictions resulting from the COVID-19 pandemic, the OCX program's global deployment of modernized GPS signal monitoring stations has been delayed. In December 2019, the program anticipated deployment of all 17 stations by the end of July 2020. However, as of October 2020, it had installed the equipment at only six of these stations. If these deployment delays extend beyond April 2021, they could result in delays to Raytheon's planned delivery of OCX Blocks 1 and 2. Program officials stated that they expect the monitoring station upgrade deployments to be complete by March 2021.

The program office reported that the Space Force plans to award a sole source contract in April 2021 to Raytheon for the OCX Block 3F program that will enable launch and operational control of the GPS IIIF satellites currently in development. The preliminary timeline for the planned program projects a 2025 contractor delivery of Block 3F. An Air Force GPS IIIF independent technical risk analysis highlighted the potential for Block 3F delays. However, OCX program officials expressed confidence that Block 3F could be delivered in time to support the first GPS IIIF mission readiness testing and launch. The program officials noted that the satellite launch and checkout test capability are expected to be delivered in advance of capabilities to control the satellite GPS navigational payload, as was done for the current OCX program. Space Force plans indicate that the Block 3F launch and checkout capability is required to support launch rehearsal exercises in 2024 for the first GPS IIIF satellite.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that the OCX program is on track to be completed within the program's current cost and schedule baseline. It also stated that it estimates OCX Blocks 1 and 2 will transition to operations in November 2022. However, the program office indicated the COVID-19 pandemic has slowed some progress and remains a risk that the program is tracking. The program office stated that OCX Block 0 has launched and conducted checkout testing on four GPS III satellites. The program also noted that—through risk reduction work using a simulator—they have demonstrated OCX's ability to interoperate with GPS satellites for all signal types. The program office added that 12 of the 17 modernized monitoring stations have been deployed, with the remainder to be installed in the first half of 2021. Lastly, regarding the IBM hardware replacement, the program stated that it has completed initial assembly efforts.

Source: © 2009 Raytheon Company.

Small Diameter Bomb Increment II (SDB II)

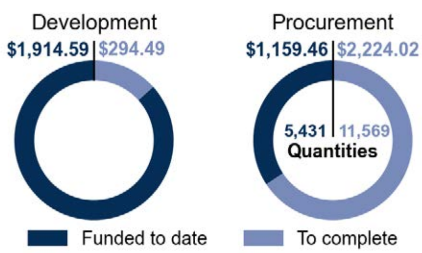
The Air Force's Small Diameter Bomb Increment II, StormBreaker, is a joint program with the Navy and is designed to provide attack capability against mobile targets in adverse weather from extended range. It combines radar, infrared, and semiactive laser sensors to acquire, track, and engage targets.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

Program Essentials

Milestone decision authority: Air Force
Program office: Eglin Air Force Base, FL
Prime Contractor: Raytheon Missile Systems
Contract type: FFI/FFP (procurement)

Estimated Cost and Quantities

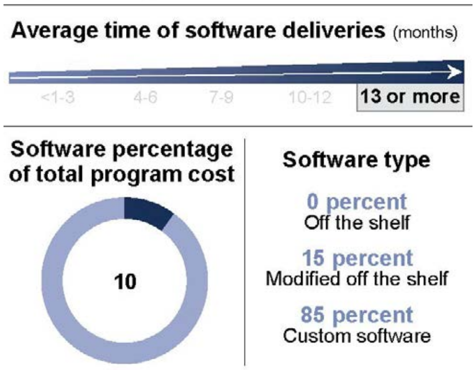
(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Agile



Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (10/2010)	Latest (8/2020)	Percentage change
Development	$1,931.02	$2,209.08	+14.4%
Procurement	$3,589.36	$3,383.47	-5.7%
Unit cost	$0.32	$0.33	+1.3%
Acquisition cycle time (months)	72	122	+69.4%
Total quantities	17,163	17,163	+0.0%

Total quantities comprise 163 development quantities and 17,000 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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 how these changes affected the design stability previously reported at its design review.

SDB II Program

Technology Maturity, Design Stability, and Production Readiness

The SDB II program has mature critical technologies and a stable design, although ongoing redesigns to certain components after test failures could affect its design stability.

In September 2020, SDB II reached initial operational capability, defined as fielding the weapon on the F-15. According to program officials, the program is currently conducting testing to integrate SDB II on the F-18. Initial F-18 operational capability was planned for fall 2020. However, the program experienced delays due in part to inclement weather and travel restrictions associated with COVID-19. As a result, program officials indicated they expect this event to be delayed to early 2021.

The program is continuing to address issues that we reported last year, including with the clip holding the bomb's fins. Specifically:

- We previously reported that due to safety deficiencies related to the fin clip, the program partially halted production in 2019 on lot 3. Testing revealed that excess vibration could cause the clip to fail, deploying the fins before launch. Over the past year, the contractor developed a component to reduce vibration and successfully introduced it into production. Program officials said they expect to begin the retrofit process for lots 1-3 and lot 4 units that are already completed in March 2021. The component will be included during production for some lot 4 units.
- Since our last assessment, the program found through environmental testing that the clip holding the fins is susceptible to corrosion. The component to address the previously identified issue of excess vibration also mitigates the potential for corrosion and is being addressed for lots 1-4 through the retrofit. However, to address these issues in the long term, the contractor redesigned the fin clip with an alternate material. The contractor plans to introduce it to the production line no later than lot 5 in fiscal year 2021.

Additionally, the program is still addressing an issue with the guidance component. Specifically, the guidance component for weapons acquired after the first production lot is susceptible to shock, due to lot 2 configuration changes. According to program officials, the contractor has proposed a number of options to solve this issue. They added that the program office, in coordination with the contractor, is monitoring the issue through ongoing flight tests but is not planning any retrofits at this time.

Program officials stated that the contractor completed lot 3 deliveries and lot 4 deliveries for Navy units in November 2020. They also stated the contractor is continuing production for remaining lot 4 units with an expected delivery completion of April 2021.

Software and Cybersecurity

Since completing operational testing in May 2019, the program resumed a planned schedule of operational software deliveries using Agile software development to include one update per year for the next 3 years and then one update biennially for the program's life. This approach differs from industry's Agile practices, which encourage the delivery of working software to users as frequently as every 2 weeks. However, the program reported delivering software for testing in simulations at the recommended rate, and noted that providing software to the end user requires a rigorous process of flight clearance, testing, and safety analysis for each instance. The program completed its first cybersecurity test in September 2019, but it is unsure when cybersecurity testing will be completed since it is dependent on the F-35's schedule.

Other Program Issues

The program reported that it experienced a delay in definitizing the contract award for lot 6 units—the contract was awarded as an undefinitized contract action in April, and was definitized in October 2020. According to the program, this contract is the program's first noncompetitive contract, as they awarded the first five lots competitively, and those negotiations added to the delay. Additionally, program officials attributed cost growth since our last assessment to a revised program cost estimate based on lot 1-2 actual costs and addressing obsolescence issues, among other reasons. They stated that issues with the guidance component and the fin clip have not contributed to cost growth.

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 the SDB II program reached a significant milestone this year, authorization to field the weapon on the F-15. The program office added that weapon inventory has reached 941 units. The program office also stated it continues to pursue affordability efforts.

The program office stated that the fin clip component to reduce vibration mitigates fatigue for lot 1-4 weapons and a redesigned fin clip is expected for lot 5 units and beyond. The program office added that its investigation into guidance component failures in two lot 2 weapons found a correlation between the lot 2 configuration changes and increased deployment shock but stated that performance continues to meet the current reliability requirement.

Source: Boeing, St Louis.

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 (GBTS). The T-7A program addresses the Air Force's advanced fighter pilot training needs and seeks to close training gaps that the T-38C cannot fully address.

Program Essentials

Milestone decision authority: Air Force

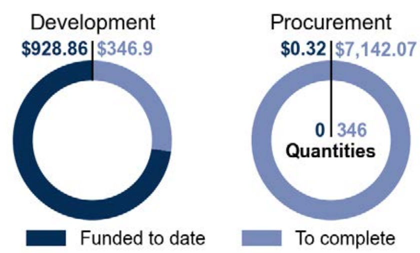
Program office: Wright-Patterson Air Force Base, OH

Prime Contractor: Boeing

Contract type: FPI/FFP (Development)

Estimated Cost and Quantities

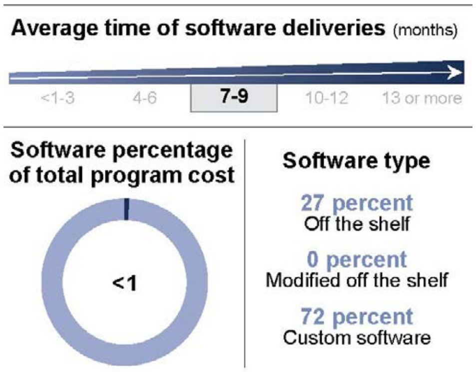
(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Agile



Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (9/2018)	Latest (7/2020)	Percentage change
Development	$1,311.92	$1,275.76	-2.8%
Procurement	$7,070.61	$7,142.39	+1.0%
Unit cost	$24.39	$24.57	+0.7%
Acquisition cycle time (months)	85	70	-17.6%
Total quantities	351	351	+0.0%

Total quantities comprise five development quantities and 346 procurement quantities. Cycle time is calculated using the required assets available date. This date was labeled initial capability in our prior year's assessment (GAO-20-439), but updated to the required assets available date at the program office's request.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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

Although the T-7A program did not report critical technologies to GAO in prior years, this year it reported two critical technologies approaching maturity: the air vehicle emergency escape system's Canopy Fracturing System and the ground based training system's projector. Program officials stated they tracked the critical technologies in past years but erred in not reporting them. Our Attainment of Product Knowledge table reflects this change.

In August 2020, the progam completed its critical design review with 90 percent of design drawings released to manufacturing, consistent with leading acquistion practices. However, in contrast with these practices, the program did not test a system-level integrated prototype prior to design review. Program officials stated two developmental aircraft demonstrated key performance requirements prior to source selection, but they do not anticipate the first live test of integrated aircraft and GBTS simulation capability until 2022. Our prior work shows that testing an integrated prototype before design review reduces the risk of costly design changes and rework.

T-7A program officials noted two primary schedule risks: qualification of the emergency escape system and the integration of the GBTS's visual display projector. According to program officials, the emergency escape system's risk is driven by the Canopy Fracturing System and ejection seat qualification, including the certification of the seat's ability to safely accommodate the pilots' various physical attributes upon ejection, along with increased safety requirements. The program is executing a qualification test plan to confirm the seat design satisfies requirements.

Officials explained the projector specifications replicate pilots' abilities to identify small items over 5,000 feet away, but the projector the program planned to use did not successfully meet visual acuity requirements during developmental testing. Therefore, program officials stated they transitioned to the backup projector, which necessitates additional development to meet requirements. Given the additional development needs and that only one company produces the state-of-the art projector, program officials identified projector integration as a major technical risk. They told us they hold weekly working group meetings with the contractor and manufacturer to mitigate the risk.

Software and Cybersecurity

The Air Force approved the software development plans for the air vehicle and GBTS in August and October 2019, respectively. The program uses an Agile framework to develop new software and combines it with modified commercial off-the-shelf software. Problems with the software latency required three additional software deliveries over the last 2 years. These unscheduled deliveries resulted in delays, postponing some capabilities to a later development phase.

T-7A officials stated the program's cybersecurity strategy is approved and in compliance with National Institute for Standards and Technology cybersecurity controls. They noted the program identified cybersecurity requirements early and built them into the systems engineering process. The program also explained that the program reviews confirmed requirements were properly met and cost and schedule effects were mitigated.

Other Program Issues

Since our last assessment, the program revised its schedule estimates to reflect an accelerated production decision schedule (7 months earlier for low-rate initial production and 1 month earlier for the full-rate production decision) and the date that required assets will be available (15 months earlier). According to program officials, the revised dates reflect the current schedule identified at the program's integrated baseline review. The aggressive schedule poses a risk, given that the projector and ejection seat still need to meet their respective 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.

Source: Boeing.

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 Essentials

Milestone decision authority: Under Secretary of Defense, Acquisition and Sustainment

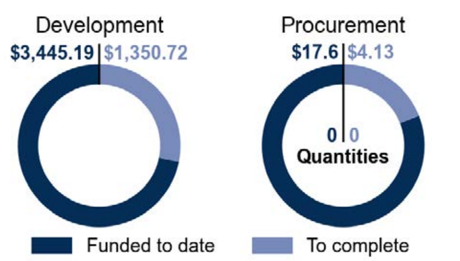
Program office: Wright-Patterson Air Force Base, OH

Prime Contractor: Boeing

Contract type: FFP (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



VC-25B quantities include two development quantities.

Software Development

(as of January 2021)

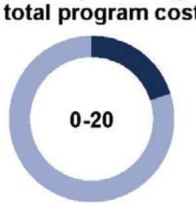
Approach: Mixed

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Software type



33 percent
Off the shelf

59 percent
Modified off the shelf

7 percent
Custom software

The program reported it does not track software deliveries and costs as it is managed under the firm fixed price development contract.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (12/2018)	Latest (8/2020)	Percentage change
Development	$4,831.96	$4,795.91	-0.7%
Procurement	$54.07	$21.73	-59.8%
Unit cost	$2,657.97	$2,622.30	-1.3%
Acquisition cycle time (months)	136	145	+6.6%
Total quantities	2	2	+0.0%

Total quantities comprise two development quantities and zero procurement quantities. Procurement cost reductions are due to the realignment of procurement costs associated with outfitting of the VC-25B Hangar Complex to acquisition operations and maintenance.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	NA
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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 said it does not have any. We did not assess manufacturing maturity because the program stated these metrics are not applicable due to its plan to modify fully mature commercial aircraft.

VC-25B Program

Technology Maturity and Design Stability

The VC-25B program plans to integrate other platforms' technology into existing commercial aircraft. In March 2020, the program completed a system-level critical design review. The review was delayed nearly 7 months due to the system's complexity and late subcontract awards. Program officials stated Boeing discovered that the number of interfaces between subsystems and the aircraft were more than double the amount originally anticipated due to differences in the structure of various sections of the aircraft. They explained that this requires the program to strengthen certain sections to accommodate lower entry/exit doors, internal stairwells, and equipment racks that differ from a standard 747-8 passenger compartment layout.

As of December 2020, the program had released 90 percent of design drawings. However, the program did not meet the leading practice to test a system-level integrated prototype before design review. VC-25B program officials stated that the total system will not come together until aircraft testing starts in the fourth quarter of 2021 and explained that the VC-25B acquisition strategy does not call for a separate system-level integrated prototype. The program reported that the VC-25B leverages the integration of mature capabilities and technologies and that Boeing is using modeling and simulation, mock ups, and integration labs to reduce integration risks for multiple major subsystems. GAO previously found a correlation between programs that tested a system-level integrated prototype by design review and decreased schedule growth. We have updated our Attainment of Product Knowledge table to reflect these changes in the status of design activities from our previous assessment.

Production Readiness

The VC-25B program does not involve the production of aircraft but modifies two existing aircraft. Boeing started modification work on the first aircraft in February 2020 and the second aircraft in June 2020. Program officials stated that they now track progress by monitoring when modification work is completed rather than the previous approach of monitoring if planned start dates are met. Boeing added design and manufacturing engineers to the VC-25B effort, as well as a second shift, to accelerate output of engineering and design drawings. Also, Boeing leveraged internal capacity to accelerate fabrication of VC-25B parts. However, Boeing already experienced some slight delays, which program officials told us they attributed to first time activities. For example, the program expected completion of the first aircraft's structural modifications in October 2020, but completion is now anticipated to occur in February 2021, according to VC-25B officials. They also said that despite the delays, the program remains within the schedule margin to deliver the first aircraft.

VC-25B officials stated that the program office and Boeing meet monthly to discuss ways to identify, track and mitigate program level risks and opportunities, including those for wiring, interior design, and certification, among others. They noted that Boeing also started work in its system integration laboratories to reduce risk with the mission communication system, flight avionics, and electrical power distribution. In parallel, the VC-25B test team—comprised of officials from the program office, Boeing, the developmental and operational test communities, the Defense Contract Management Agency, and the Federal Aviation Administration—signed a test operations plan in July 2020 to mitigate risk and ensure resources will be available for the test program, which is scheduled to start in December 2021. According to program officials, these organizations are already hiring and putting personnel resources in place.

Software and Cybersecurity

Program officials reported that supplier software development—which consists of signal processing and communications software—is valued at less than $20 million. The program also reported there are no significant software-related issues at this time.

Program officials stated that they are updating test plans to clarify some specific details related to cybersecurity boundaries within the system. They explained that these activities include identifying approving officials and ensuring alignment of requirements. The VC-25B will undergo cybersecurity testing as part of the overall test 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. In April 2021, a program official stated that the VC-25B program is working on an updated integrated master schedule but was unable to provide additional details until it is completed.

Source: U.S. Air Force.

Weather System Follow-On (WSF)

The Air 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 is being developed to conduct remote sensing of weather conditions, such as wind speed and direction at the ocean's surface, and provide real-time data to be used in weapon system planning and weather forecasting models. The family of SBEM systems replaces the Defense Meteorological Satellite Program.

Program Essentials

Milestone decision authority: Air Force

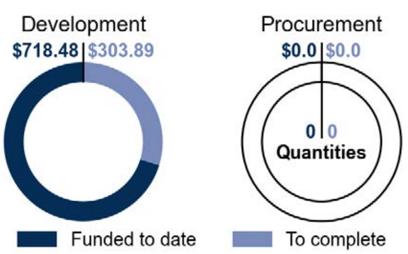
Program office: El Segundo, CA

Prime contractor: Ball Aerospace and Technologies Corporation

Contract type: FFP (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



WSF quantities include 2 development quantities.

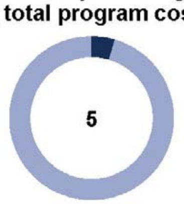
Software Development

(as of January 2021)

Approach: Agile, Waterfall, and DevOps

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent
Off the shelf

95 percent
Modified off the shelf

5 percent
Custom software

Percentages above reflect ground operations software. Software for the flight vehicle testbed, payload, spacecraft bus, and mission data processing are 100 percent custom.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (6/2020)	Latest (6/2020)	Percentage change
Development	$1,022.37	$1,022.37	+0.0%
Procurement	$0.0	$0.0	N/A
Unit cost	$511.18	$511.18	+0.0%
Acquisition cycle time (months)	46	46	+0.0%
Total quantities	2	2	+0.0%

We previously assessed cycle time based on program start to initial capability. The program has since started development, so cycle time now reflects development to initial capability. Quantities comprise two development quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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 WSF critical technologies in a realistic environment because satellite technologies demonstrated in a relevant environment are assessed as fully mature; design stability because the program said the metrics were not applicable; and manufacturing metrics because the program does not have a production milestone.

WSF Program

Technology Maturity

The WSF program's eight critical technologies are mature, based on an updated December 2019 independent technical risk assessment (ITRA). Last year, the program anticipated development start in October 2019, but the Joint Requirements Oversight Council did not approve requirements until February 2020, and the Assistant Secretary of the Air Force approved development start in May 2020. We have updated our timeline to reflect this change.

Design Stability

The program office considers the WSF design complete but does not track design drawings to monitor design progress. According to program officials, the computer-aided design systems it uses generate hundreds of thousands of drawings, and counting those would not provide useful information. Instead, program officials told us they considered the design complete when models were finished, purchase and build orders were ready for manufacturing, and a critical design review was completed, which occurred in April 2020.

The program plans to conduct prelaunch testing of compatibility between the space, ground, and launch segments over several years, beginning as early as fiscal year 2021. The program office said testing a system-level integrated prototype does not apply to WSF because it is impossible to test certain functions until the satellite is in orbit, so functional testing will not begin until after launch. While this increases the risk of potentially unfixable issues, the program office said that there is no singular test event capable of addressing all test and integration concerns. The first satellite is planned to be ready for launch by September 2023. According to the program office, one critical path supplier was shut down for 1 day and multiple suppliers have been slowed as a result of COVID-19-related delays. The program office noted that the program manager is actively monitoring related schedule and cost impacts.

Software and Cybersecurity

Program officials report that software development is in early design and testing, and all planned deliveries to the user are on time thus far. The WSF software development plan was approved in June 2020. The program is taking a mixed approach that includes Agile, waterfall, and DevOps. The program said it does not track software development costs separately, in part because its use of firm-fixed-price contracts limits insight into separate costs. It also said tracking costs is not useful because nearly all of WSF's software is reused. Approximately 95 percent of WSF's ground operations software is government-developed software with no modifications, while software items for the flight vehicle testbed, imaging payload, spacecraft bus, and mission data processing are custom software.

WSF has an approved cybersecurity strategy and completed a tabletop assessment to evaluate potential vulnerabilities in October 2019. The results are classified, but the program office said it expects to address all identified system gaps as required.

Other Program Issues

A May 2019 ITRA deemed mission capability as high risk because Satellite Control Network (SCN) officials project the network—which the WSF program intends to use—will exceed up to 90 percent of its capacity on other projects and be unable to fully support WSF's data download needs. As of November 2020, Space Force officials said they were evaluating and preparing for alternatives, including supplementing SCN capacity with civil agency and commercial networks in the near term and upgrades to increase SCN capacity in the long term. While commercial networks are capable of performing the same tasks as SCN according to program officials, Space Force officials said commercial networks do present additional cybersecurity risks, which the program would need to assess before use.

Maintaining the program schedule continues to be important for the Air Force to mitigate potential capability gaps. Currently, there is no operating platform that fully meets the Air Force's needs for ocean surface vector wind data, which WSF will provide once operational.

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: U.S. Air Force.

Enhanced Polar System – Recapitalization (EPS-R)

The Space Force's EPS-R—a continuation of the EPS program that provides protected communications over the North Polar Region—plans to develop an additional two satellite payloads and update the EPS ground segment to prevent a coverage gap in protected polar satellite communications. The Space Force is collaborating with Norway to host the two payloads on two Space Norway-procured satellites. The updates to the ground system will provide command, control, and mission planning for the payloads.

Program Essentials

Milestone decision authority: Air Force

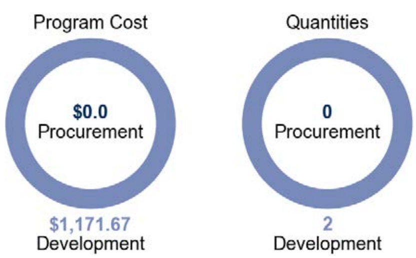
Program office: El Segundo, CA

Prime contractor: Northrop Grumman Aerospace Systems

Contract type: CPIF/CPFF (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Cost and quantities only reflect the EPS-R increment of work.

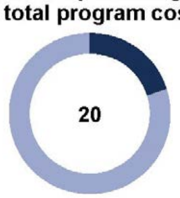
Software Development

(as of January 2021)

Approach: Agile, Waterfall, DevOps, and DevSecOps

Average time of software deliveries (months)

Software percentage of total program cost



Software type

26 percent Off the shelf

24 percent Modified off the shelf

50 percent Custom software

Current Status

The EPS-R program held final design reviews of the payload and ground system in October 2019 and June 2020, and the program office participated in the design review of the Space Norway satellite in August 2020. The program is tracking risks associated with the concurrent development of the payload with the host satellite. Specifically, as the satellite matures, any performance issues or changes to requirements could affect the delivery of the payloads for integration, which as of August 2020 had only 6 days of margin. Though originally planned with 27 days of margin, recent supplier delivery delays, COVID-19 staffing challenges, facility shutdowns, and resource constraints such as backlogs in material inspections required the use of 21 days of payload margin. Program officials indicated that the program remains on schedule and that they are working with the payload developer to implement mitigation strategies and prioritize activities critical to meeting the Space Norway launch date of December 2022. The Space Force plans an integrated test of payload, satellite, and ground system engineering models in October 2021, after the planned shipment of the first payload. This event was originally deemed necessary to burn down risk prior to payload shipment. Officials have since concluded that any issues identified during testing can be addressed on the ground system or incorporated at the Norway host facility.

The EPS program is currently developing an updated cybersecurity strategy and test strategy for EPS-R but has yet to have these approved. Officials said they continue to work with the test community to reach conceptual agreement on cybersecurity and test approaches that will include focus on the changes between EPS and EPS-R, and that the effort is on track to meet the program schedule. The program is also in the process of working with security officials to update and revalidate the current EPS criticality analysis, to include the assessment of critical EPS-R payload and ground system information. The updated criticality analysis is expected to be completed by the end of fiscal year 2021.

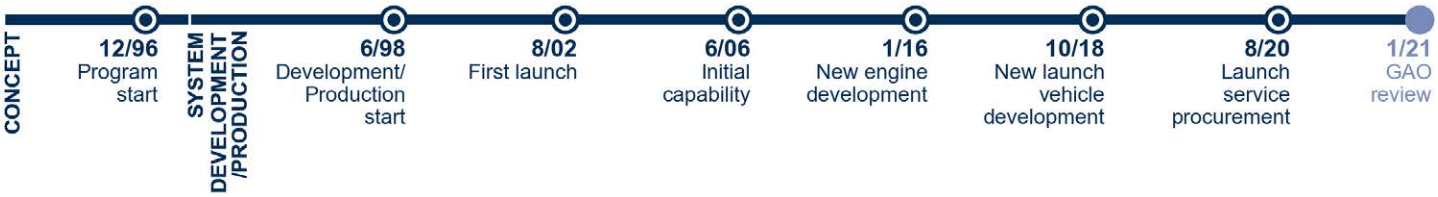
Program Office Comments

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: SpaceX and United Launch Alliance.

National Security Space Launch (NSSL)

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), supporting 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 investments in new launch systems from U.S. launch providers.

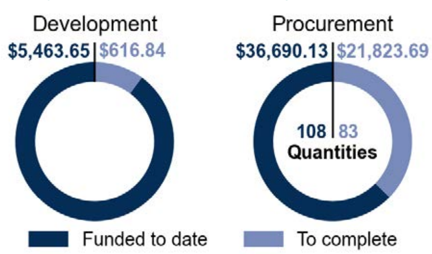


Program Essentials

Milestone decision authority: Under Secretary of Defense, Acquisition and Sustainment
Program office: El Segundo, CA
Prime contractors: Space Exploration Technologies; United Launch Alliance
Contract type: Other Transaction (engines and launch vehicle prototypes); FFP (launch services)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



The cost figure represents costs for the total program and is not specific to NSSL's investment in new launch systems.

Software Development

(as of January 2021)

Approach: Information not available

Average time of software deliveries (months)

Information not available

Software percentage of total program cost	Software type
Information not available	Information not available

The program office stated that software used to provide launch services is procured from launch service contractors.

Current Status

In August 2020, the program told us it competitively awarded 5-year launch service contracts to ULA and SpaceX for approximately 34 launches beginning in 2022 and planned to continue through 2027.

NSSL faces technical challenges to meeting its goal of ending reliance on rocket engines manufactured in the Russian Federation by the end of 2021. The Carl Levin and Howard P. "Buck" McKeon National Defense Authorization Act for Fiscal Year 2015, as amended, prohibited, with certain exceptions, the award or renewal of a contract for the procurement of property or services for National Security Space launch activities under the NSSL—then-Evolved Expendable Launch Vehicle—program if such contract carries out such activities using rocket engines designed or manufactured in the Russian Federation. A subsequent amendment to the statute provided an exception for contracts awarded through 2022 for such procurements that include the use of a total of 18 rocket engines designed or manufactured in the Russian Federation. A U.S. produced rocket engine under development for ULA's Vulcan launch vehicle is experiencing technical challenges related to the igniter and booster capabilities required and may not be qualified in time to support first launches beginning in 2021. A joint program office and ULA team is tracking these challenges, and NSSL officials told us Vulcan remains on track to support first launches and certification in 2021. However, if ULA cannot complete engine qualification before the 2021 flight certification, the program might continue to rely on ULA's Atlas V—which uses engines manufactured in the Russian Federation—to support ULA's 2022 launches, despite a nearly $2.9 billion investment in new launch system development. SpaceX's Falcon 9 and Falcon Heavy vehicles are certified to conduct national security launches. The Falcon Heavy is undergoing some modifications to fully meet launch requirements and is on track to support its first mission in May 2021.

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. The program office stated that it has been extremely successful and efficient with unprecedented mission success and a $22 billion reduction to life-cycle costs, representing a 28 percent unit cost decrease since 2013. It added that the Phase 2 Launch Service Procurement contract provides assured access manifest flexibility, and incorporates industry innovation.

Source: U.S. Air Force.

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

The Air Force's B-52 RMP is planned to replace the current APQ-166 radar on all 76 B-52H aircraft to improve functionality and reliability. This modernization is expected to support B-52H missions employing an array of nuclear and conventional weapons while also allowing for mission-essential aircraft navigation and weather avoidance. The Air Force plans for continued B-52H operations through the year 2050.

Program Essentials

Milestone decision authority: Air Force

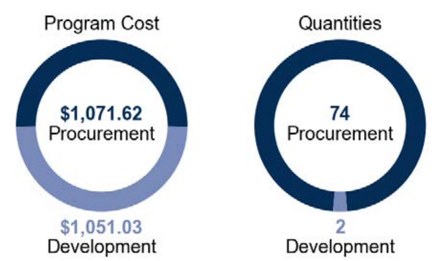
Program office: Wright-Patterson Air Force Base, OH

Prime contractor: Boeing

Contract type: CPFF (risk reduction and requirements development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



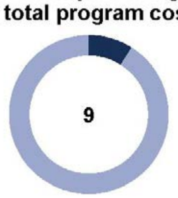
Software Development

(as of January 2021)

Approach: Agile, Waterfall, and Incremental

Average time of software deliveries (months)

Software percentage of total program cost



Software type

8 percent
Off the shelf

0 percent
Modified off the shelf

92 percent
Custom software

Current Status

The program is preparing for development start in February 2021 and is continuing to refine its schedule. Program officials told us they completed a preliminary design review in October 2020, 3 months later than planned because the program's schedule did not allow enough time for the contractor to finalize some requirements with suppliers, which slowed some hiring. Program officials said this will not affect the start of development, but said it led to schedule adjustments to critical design review, flight testing, full-rate production, and initial capability, which had also been scheduled too early.

The program's planned approaches to software development and testing may pose cost and schedule risks. The program expects about 90 percent of the software that integrates the radar with the B-52 to be custom. We have previously reported that custom software generally takes more time and is more expensive to develop than off the shelf software. Program officials also plan to begin low-rate production about halfway through the radar flight-test program, after functionality flight testing but before integration flight testing. Program officials acknowledge cost and schedule risks with this concurrent strategy, and we have consistently found that programs following similar concurrent strategies often experience significant cost, schedule, and performance problems.

Attainment of Technology Maturation Knowledge (as of January 2021)

Conduct competitive prototyping	○	Complete independent technical risk assessment	◐
Validate requirements	●	Complete preliminary design review	●

● Knowledge attained, ◐ Knowledge planned, ○ Knowledge not attained, … Information not available, NA Not applicable

Program Office Comments

The program office provided technical comments, which we incorporated as appropriate. The program office commented that it considers this program medium risk and its acquisition strategy will be executed to minimize risk and deliver capability in 2026. While the program stated software is a concern, it is using an off-the-shelf radar to minimize customization, allowing significant time for correction of deficiencies, and planning early integration lab testing.

Source: U.S. Air Force.

Air Operations Center Weapon System Modifications (AOC WS Mods)

The Air Force's AOC WS Mods consist of six parallel middle-tier acquisition, rapid fielding efforts to develop new software needed to modernize existing command and control capabilities for theater air operations. These efforts aim to ensure that the legacy AOC WS remains interoperable, certified, supportable, and able to provide new capabilities that support the entire spectrum of joint air, space, and cyberspace operations, at strategic and tactical levels.

7/19 MTA initiation/ MTA funds obligated

1/21 GAO review

6/24 Expected MTA completion

7/24 5 years since MTA funds obligated

Program Essentials

Decision authority: Air Force

Program office: Hanscom Air Force Base, MA

Prime contractor: Various

MTA pathway: Rapid fielding

Contract type: CPFF, Time & Materials

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2021 dollars in millions)

Software Development

(as of January 2021)

Approach: Agile and DevSecOps

Average time of software deliveries (months)

Software percentage of total program cost

Software type

0 percent Off the shelf

9 percent Modified off the shelf

91 percent Custom software

Program Background and Transition Plan

The Air Force initiated AOC WS Mods as six rapid fielding efforts in July 2019. According to program officials, it delivers new command and control software capabilities directly into operational use approximately every 11 hours. The program centers on continuous development and operation activities rather than prototypes. The program made progress in its six rapid fielding efforts, each of which delivers capabilities in a different mission area, such as intelligence collection or targeting. For example, one effort developed a tool that allows the collection of operational mission data to inform intelligence analysis and future mission planning.

Transition Plan: Transition pathway yet to be determined.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

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

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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	Demonstrate all critical technologies in form, fit, and function within a realistic environment	NA
Complete system-level preliminary design review	NA	Release at least 90 percent of design drawings	NA
Test a system-level integrated prototype	NA	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned,
… Information not available, NA Not applicable

We did not assess AOC WS Modifications' formal technology risk assessment because the program stated that this knowledge metric was not applicable due to its plan to develop software with commercially-available technologies; or planned knowledge by MTA transition because the program has yet to decide the transition pathway.

AOC WS Mods Program

Key Elements of Program Business Case

While AOC WS Mods had an approved requirement and acquisition strategy at program initiation in July 2019, it did not have a cost estimate based on an independent assessment. Our prior work shows such an estimate is important to help decision makers make well-informed program initiation choices. In April 2020, the Air Force Cost Analysis Agency conducted an independent cost estimate and estimated the cost—including costs beyond the six middle-tier acquisition efforts—at $1.1 billion for fiscal years 2018 through 2026.

The program did not complete technology or schedule risk assessments at initiation and does not plan to complete them. Program officials stated that they have not assessed these risks because, as a program focused on Agile software development, they are not developing any new technologies and do not have a detailed master schedule that could be assessed for risk. However, our prior work on Agile development has found that all programs need to establish a schedule to be accountable for delivering a value-based outcome.

Technology

AOC WS Mods uses existing, commercially available technologies to develop and deliver new software capabilities and does not have any critical technologies, program officials reported.

The program has also planned an upcoming operational assessment. This assessment is intended to demonstrate the effectiveness of all six rapid fielding efforts' capabilities and allow a program office decision to retire the AOC WS Mods' current infrastructure.

Software Development and Cybersecurity

AOC WS Mods uses Agile and DevSecOps software development principles to deliver mostly custom software. AOC WS Mods staff—both U.S. government and industry personnel—develop and test software iteratively so that software is delivered weekly to operations. The software capability maturation relies on a continuous delivery approach, where the program conducts concurrent development, deployment, training, testing, and operations and maintenance. The entire development process takes about 4 to 5 months for a mission capability to be started and adopted, program officials reported.

AOC WS Mods encountered difficulty finding and hiring government staff with required expertise to develop software, according to program officials. Specifically, they cited challenges competing with the private sector for talent and long timelines to hire civilians, discouraging some highly qualified candidates. To address these issues, the program is filling positions with contractors and reported using expedited and direct hiring authorities.

The program has a cybersecurity strategy in place to identify cybersecurity requirements and threats and to manage risk. The strategy is in accordance with DOD's Risk Management Framework, according to the strategy. Over the past year, AOC WS Mods completed a comprehensive review of cybersecurity hardening across its software development activities. The review addressed security of its enterprise service capabilities (i.e., software development), knowledge management documentation, and leading practices on the development of well-architected secure applications.

Transition Plan

Program documentation shows the program plans to develop and deliver software beyond the current MTA efforts' completion time frame. However, the program has yet to determine a transition pathway following the rapid fielding efforts. The program and its Program Executive Officer are evaluating which pathway to take after completion of the 5-year rapid fielding efforts and may transition ongoing development efforts to the software acquisiton pathway.

Other Program Issues

The program slowed its fiscal year 2021 planned delivery pace due to funding constraints. Specifically, amid ongoing efforts to migrate capabilities from legacy systems and tools to its new system, the program delayed its planned retirement date for the legacy system by approximately 20 months. The delay was due to two program decisions to slow development activities in fiscal years 2020 and 2021 to mitigate funding shortfalls and to prioritize cybersecurity activities.

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 also concurred with the contents of this assessment.

Source: U.S. Air Force.

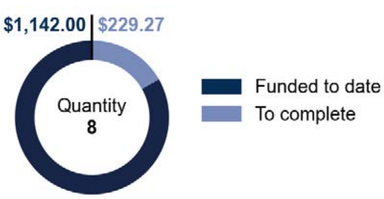
Air-launched Rapid Response Weapon (ARRW)

The Air Force's ARRW, a program using the rapid prototyping middle-tier acquisition pathway, is developing a conventional, long-range, air-launched hypersonic missile that can be carried on the wing of a B-52H bomber aircraft. The program leveraged the Defense Advanced Research Projects Agency's ongoing tactical boost glide effort to develop the missile's hypersonic-speed glider component.

Program Essentials

Decision authority: Air Force
Program office: Eglin Air Force Base, FL
Prime contractor: Lockheed Martin
MTA pathway: Rapid prototyping
Contract type: CPFF (development)

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2021 dollars in millions)

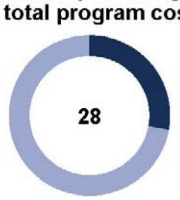


Software Development
(as of January 2021)

Approach: Agile

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent
Off the shelf

0 percent
Modified off the shelf

100 percent
Custom software

Program Background and Transition Plan

The Air Force initiated ARRW as a middle-tier acquisition in May 2018 with an objective to complete prototyping by September 2022. In August 2018, the program awarded a contract to Lockheed Martin for design, development, and demonstration work. According to program officials, the program will produce eight missiles—four for testing and four spares. Since last year, the ARRW program conducted numerous ground tests on missile components, completed its critical design review, and flight tested the missile on a B-52H that program officials said ensured the missile and aircraft interfaced and communications worked. The program plans for three booster tests in fiscal year 2021 and its first flight test in early fiscal year 2022.

Transition Plan: Transition either to a new middle-tier acquisition rapid fielding effort or to the major capability acquisition pathway for production

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	◐	Demonstrate all critical technologies in form, fit, and function within a realistic environment	◐
Complete system-level preliminary design review	●	Release at least 90 percent of design drawings	●
Test a system-level integrated prototype	◐	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	⊗
Demonstrate critical processes on a pilot production line	◐	Test a production-representative prototype in its intended environment	◐

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned,
… Information not available, NA Not applicable

ARRW Program

Updates to Program Performance and Program Business Case

Over the last year, ARRW program officials updated business case documents. For example, the Air Force approved the program's requirements in March 2018 but updated them in June 2020, which predominantly removed some requirements. We reported last year, based on information the program provided, that ARRW had an approved acquisition strategy prior to program initiation. However, program officials subsequently told us that final acquisition strategy approval occurred several months after initiation. Consequently, we updated our attainment of acquisition knowledge figure.

In March 2020, the Air Force Cost Analysis Agency completed an updated independent cost assessment that showed a cost estimate increase of approximately $128 million—over 10 percent—driven by supplier costs and changing the contractor fee structure, among other things. Since March 2018, ARRW's cost estimate has grown approximately 46 percent. To help offset some of this cost growth, program officials said they received approximately $182 million in additional funding, reprogrammed from the Hypersonic Conventional Strike Weapon program, which was cancelled in 2020.

Technology

The program identified two critical technologies that help the missile survive extreme temperatures at hypersonic speed. One of the two technologies is currently immature, while the other is approaching maturity. The program indicated both technologies will meet the criteria for maturity by the rapid prototyping effort's end. However, since last year, the program reduced the expected maturity level at the rapid prototyping effort's completion by one level for both technologies. According to program officials, the original predicted maturity levels—which showed levels proven in mission operations through operational testing—overestimated the final maturity level at program completion for both. The program changed the levels to match tits plan to qualify the missile through testing in expected operational conditions. Program officials said they plan to conduct four joint developmental/operational flight test missions—the first scheduled for the fall of 2021—to collect data and identify operational issues and involve operational testers. Program officials said operational testers will produce the equivalent of an operational test report, but the Air Force's independent test organization will not conduct the testing. The reduced requirements, lower level of technology maturation, and lack of full operational testing raise the risk that issues could emerge that require costly and time-intensive fixes, and limit ARRW's operating conditions. These issues also limit the Air Force's ability to make fully informed procurement decisions since program officials said only two of the four flight tests will be completed before the Air Force plans to award a production contract.

Software Development and Cybersecurity

The ARRW program office considers a portion of its software development as high risk, in part due to the prime contractor realizing that some critical safety software required additional maturation based on results from simulations. The ARRW program uses an Agile software development approach to deliver custom software, delivering software every 4 to 6 months and, according to the program office, in advance of major flight test events. However, this approach differs from industry's Agile practices as reported by the Defense Innovation Board, which encourage the delivery of working software to users on a continuing basis—as frequently as every 2 weeks—so that feedback can focus on efforts to deploy greater capability. The ARRW program has received three of nine software increments. Its final software delivery is scheduled for July 2022 to support the final flight test. The program's cybersecurity strategy was approved in March 2019.

Transition Plan

ARRW program officials said they plan to transition to production either using a major capability acquisition pathway or as a middle-tier acquisition rapid fielding effort, pending Air Force approval. The program plans to mature its critical technologies, demonstrate production processes on a pilot production line, and have a stable design before this time. However, it does not expect to demonstrate that manufacturing processes are stable, adequately controlled, and capable prior to ARRW's transition point. Our prior work shows that programs beginning production without this type of knowledge face increased risk of missing cost, schedule, and quality targets.

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 program has maintained its schedule to the first flight test and is on track to attain an early operational capability by the end of fiscal year 2022, despite numerous challenges and delays resulting from COVID-19. In addition, the program office stated ARRW will undergo intensive flight testing over the next 2 years, including three booster tests and four flight tests to demonstrate full-system capability. It also stated that close coordination with the prime contractor is expected to result in a manufacturing readiness level of 8 at the end of development. The program office added that it expects ARRW will provide the Air Force opportunities for production, further development, and incorporation of additional capabilities in the future.

Source: U.S. Air Force.

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

The Air Force's B-52 CERP, a rapid prototyping middle-tier acquisition, plans to develop, integrate, and test military-configured commercial engines and associated equipment on two B-52H aircraft through two rapid prototyping efforts or "spirals." We evaluated Spiral 1, which will deliver a virtual system prototype to reduce risk and inform a second spiral. We provide information on Spiral 2, which is expected to deliver physical prototypes to inform the Air Force's longer-term effort to extend the life of the B-52H fleet beyond 2030.

Program Essentials

Decision authority: Air Force

Program office: Tinker Air Force Base, OK

Prime contractor: Boeing

MTA pathway: Rapid Prototyping

Contract type: CPIF

Estimated Middle-Tier Program Cost and Quantities

(fiscal year 2021 dollars in millions)

Software Development

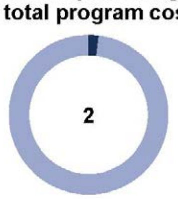
(as of January 2021)

Approach: Agile and Incremental

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

0 percent Off the shelf

0 percent Modified off the shelf

100 percent Custom software

The program reported that software development is concurrent with hardware development and the program will deliver software when hardware is fielded.

Program Background and Transition Plan

Following middle-tier initiation in September 2018, the program noted that they placed an order for Boeing to begin risk reduction requirements studies. In November 2019, program officials stated Boeing delivered virtual engine power pod prototypes—computer-modeled engine component integration—for each candidate engine. In February 2020, the program placed an order for Boeing to incorporate these prototypes into a virtual system prototype and complete the system's preliminary design. According to program officials, Boeing is working with multiple engine vendors until a single engine supplier is selected. Virtual system prototype development is to occur incrementally, with initial capability planned for delivery in October 2021 (Spiral 1 Increment 1) and full capability expected in April 2022 (Spiral 1 Increment 2).

Transition Plan: Transition to a follow-on middle-tier acquisition rapid prototyping effort.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	Demonstrate all critical technologies in form, fit, and function within a realistic environment	NA
Complete system-level preliminary design review	NA	Release at least 90 percent of design drawings	NA
Test a system-level integrated prototype	NA	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, … Information not available, NA Not applicable

We did not assess B-52 CERP RVP's planned knowledge by MTA transition because the program plans to transition to a follow-on middle-tier rapid prototyping program.

B-52 CERP RVP Program

Updates to Program Performance and Program Business Case

Over the last year, program officials updated some original business case elements to reflect shifts in design work from Spiral 2 to Spiral 1. Program officials told us that prior to the February 2020 order for the Spiral 1 virtual system prototype, the acquisition strategy was updated to reflect delays in awarding the other transaction agreement for the virtual power pod prototypes and additional time for the preliminary design review, which will take place under Spiral 2. While more time was needed for system preliminary design, officials believe detailed design work of many subsystems without engine dependencies can continue. As a result, the updated strategy shifted the detailed design work for these subsystems from Spiral 2 into Spiral 1, increasing the timeline for Spiral 1 efforts by approximately 9 months. Finally, the updated strategy now calls for incremental delivery of the virtual system prototype with the first increment delivered in October 2021, and a fully capable second increment delivered in January 2022.

Given these changes, the Air Force Cost Analysis Agency reassessed Spiral 1 costs at more than $525 million, an increase of more than $240 million since 2018. Program officials largely attributed this cost increase to the movement of work from Spiral 2 to Spiral 1.

Technology

In July 2020, the program reviewed 19 technologies as part of its technology readiness assessment for both spirals, and the program did not identify any critical technologies for either effort. According to officials, Spiral 1 is a computer-modeled virtual system prototype and is not a technology-intensive effort. In addition, officials stated they did not identify any critical technologies because the program is integrating commercial components onto existing aircraft.

Software Development and Cybersecurity

According to program officials, while Spiral 1 is virtual, some of the models used for design have not been validated. Without a validated model, the program may not be able to ensure its virtual system prototype is representative of the operating environment. Officials stated all models would be validated and Boeing is expected to deliver its Modeling and Simulation Verification and Validation plan in March 2022 to support Spiral 2. They also stated that system software deliveries and software data reporting will not begin until hardware deliveries begin in Spiral 2. For Spiral 2, program officials noted they plan to use an Agile development approach to incrementally develop and deliver software. The program approved the cybersecurity strategy in January 2020.

Transition Plan

At the time of Spiral 1 completion full capability delivery, expected in January 2022, the Air Force plans to transition to a follow-on rapid prototyping effort for Spiral 2 to deliver a physical prototype. Once installed on the two B-52 aircraft, the Air Force will complete ground, flight safety, and flight testing of the physical prototypes. The Air Force considers the completion of this testing to be the end of the two rapid prototyping spirals. If prototyping is successful, the Air Force expects to procure 592 new engines to modify the 74 remaining B-52H aircraft. Officials have yet to determine the acquisition pathway for procuring the 592 engines.

Other Program Issues

The Air Force's plan to transition to Spiral 2 before modified technologies are proven may pose cost or schedule risk for the longer-term engine replacement effort. For example, while officials stated they considered all 19 technologies for Spiral 2 mature because they are based on commercially-proven components, some of these technologies will require modification of their current form, fit, or function for proper integration. These modifications would degrade technology readiness and could present future cost and schedule risk. While officials plan to complete these technology modifications by the conclusion of Spiral 2 development, if the modified technologies do not mature as planned, the Air Force's broader effort to modify engines for the B-52H fleet could potentially cost more or take longer than expected.

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 the prototyping phase reduces design, development, and integration risks associated with replacing B-52 engines with commercially available engines. It also noted that virtual power-pod prototypes were delivered, which it said demonstrated integration of the pods onto the B-52. It stated that virtual system-level prototyping is now underway, emphasized that this will add virtual B-52 flight and cockpit subsystems to the power pod prototypes, and added that a final physical prototyping phase (Spiral 2) will integrate eight physical engines each onto two physical aircraft to reduce overall integration risk.

The program office also noted that digital engineering tools are giving better insights early in the design process and reducing component integration risk prior to Spiral 2 transition. It stated that model-based systems engineering and virtual system prototypes are allowing rapid design exploration and yielding integrated solutions. Lastly, it noted that while the current technologies are mature, it will continue to assess technology readiness as the program progresses.

Source: U.S. Air Force.

Evolved Strategic SATCOM (ESS)

The Space Force's ESS, a new program using the middle-tier acquisition rapid prototyping pathway, is developing space-based capabilities to provide worldwide DOD users strategic and secure communications to support DOD's nuclear command, control, and communications mission. ESS expects to develop an advanced satellite communications (SATCOM) payload in the rapid prototyping effort. The Air Force aims to incorporate the payload onto an eventual ESS satellite in a future rapid fielding effort.

8/19 MTA initiation | **9/20** MTA funds obligated | **9-11/20** Contract award | **1/21** GAO review | **12/23** Preliminary design review | **9/25** Operational demonstration/ 5 years since MTA funds obligated/ Expected MTA completion

Program Essentials

Decision authority: Air Force

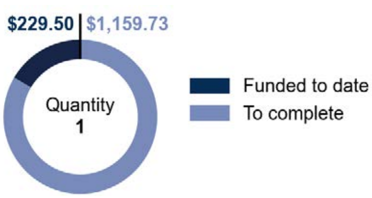
Program office: Los Angeles Air Force Base, CA

Contractors: Boeing; Lockheed Martin; Northrop Grumman

MTA pathway: Rapid Prototyping

Contract type: FFP (development)

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2021 dollars in millions)



Software Development

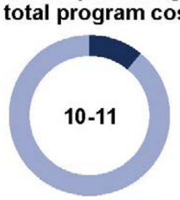
(as of January 2021)

Approach: Mixed

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

Information not available

The program has yet to identify the software type that will be used and does not track software releases to end users.

Program Background and Transition Plan

The Air Force initiated ESS as a middle-tier acquisition effort in August 2019. The program stated that from September through November 2020 it competitively awarded contracts to three contractors, each to develop an advanced satellite communications payload prototype. At the end of the rapid prototyping phase, the program expects to hold a competition for the planned rapid fielding phase to select one or more contractors to deliver the fielded system.

Transition Plan: Transition to a new middle-tier rapid fielding effort.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	○	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	◐	Demonstrate all critical technologies in form, fit, and function within a realistic environment	NA
Complete system-level preliminary design review	◐	Release at least 90 percent of design drawings	⊗
Test a system-level integrated prototype	◐	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned,
… Information not available, NA Not applicable

We did not assess ESS planned knowledge by MTA transition for: demonstration of critical technologies in a realistic environment or test of a production-representative prototype in its intended environment because the program will not demonstrate the prototype in space; or demonstration of manufacturing readiness levels and critical processes on a pilot production line because the program office said it had limited insight into manufacturing due to the program's early stage.

ESS Program

Key Elements of Program Business Case

The ESS program did not have several key business case documents approved at initiation—including an approved requirements document, formal technology and schedule risk assessments, and a cost estimate based on independent assessment. Our prior work shows that these assessments help to inform decisions about middle-tier program initiation, including whether the program is likely to meet the statute-based objective of fielding a prototype within 5 years of the development of an approved requirement.

The program has since completed most of its business case documents. The Air Force conducted an independent cost estimate In May 2020 and completed an independent technical risk assessment in June 2020 on the range of available technologies considered for use on ESS. The program also has an approved acquisition strategy and validated requirements, both completed in 2019. Program officials said they manage schedule risks through risk management processes, but do not plan to complete a formal schedule risk assessment.

Technology

The program identified eight critical technologies, four of which are fully mature and one of which is approaching maturity. The remaining three are reported at various levels based on the three contractors' varying proposals. The program reported that contractors might also identify additional critical technologies to counter emerging threats as they mature their designs. The program expects the contractors to mature all technologies by September 2025, the planned end of the rapid prototyping phase. Consequently, the program's technology risk level is not fully known.

Software Development and Cybersecurity

ESS officials stated that the contractors will likely use an Agile software development approach, but how and in what ways it will be used will become clear as contractors move to execution. Officials said the three contractors are responsible for the combination of software development approaches, potentially including a combination of custom software development and existing commercial and government products.

The Air Force approved the program's cybersecurity strategy in April 2020. The strategy is limited to specific areas including the payloads under development. Program officials noted they have not incorporated possible vulnerabilities associated with connecting to the ground system in their cybersecurity strategy, but they will consider such risks as the ground acquisition strategy is developed.

Transition Plan

The program is planning to transition to rapid fielding at the end of rapid prototyping. Concurrent with the end of rapid prototyping, the program will test and demonstrate critical payload capabilities for each contractor's payload, with further testing occurring in the follow-on fielding phase. The program does not expect to demonstrate production maturity before transitioning to rapid fielding, because, according to the program, the three contractor ground prototypes will not be full production articles. The program also plans to release 90 percent of its design drawings 3 months after its planned transition date. In addition, as is typical for space programs, ESS will demonstrate its prototypes in a representative laboratory environment rather than in the intended environment, because it is not possible to demonstrate prototypes in space.

Other Program Issues

The program expects each contractor to deliver prototype payloads and associated capabilities by the end of rapid prototyping. Because the contractors will not deliver full satellites, a substantial amount of work will remain under the rapid fielding phase to build and launch the first satellite. For example, the program will assess the results of the prototype operational testing to competitively select one or more contractors for fielding, conduct additional integration of the payload with a compatible satellite, and carry out integrated testing before launch. The program identified integration of the technical components as a significant risk, and it has yet to determine who will be responsible for the integration—the government, the payload provider, or a third-party contractor. The program stated that it is designing a fielding phase strategy with an approach that minimizes integration 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. According to the program office, ESS continues the strategic SATCOM mission by providing worldwide secure communications for DOD assets in all operational environments. The program stated that its acquisition approach energizes the industrial base to drive innovation, reduce risk, and maximize demonstrated prototype capability within budget and schedule constraints. The program noted that its strategy uses lessons learned from other programs to target the highest technical risks, focused predominantly on payload development. The program also stated that ESS will leverage a modular open system approach that enables incremental technology insertion. The program stated that it is developing an overall integration strategy to drive innovation through competition, deliver enterprise capabilities, and avoid costs traditionally associated with using a single vendor in the follow-on fielding phase.

Source: © 2020 The Boeing Company.

F-15EX

The Air Force expects the F-15EX program, a middle-tier acquisition rapid fielding effort, to address F-15C/D readiness challenges and eventually replace the F-15C/D fleet. The F-15EX is based on the current foreign military sales (FMS) aircraft and will be upgraded with U.S. only capabilities, including operational flight program software and Eagle Passive/Active Warning and Survivability System (EPAWSS) 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 Essentials

Decision authority: Air Force

Program office: Wright-Patterson Air Force Base, OH

Prime contractor: Boeing

MTA pathway: Rapid Fielding

Contract type: IDIQ; future contracts in negotiations; FPIF (Lot 1 and 2 aircraft); CPFF/CPIF/FPIF/FFP (development and product support)

Estimated Middle-Tier Program Cost and Quantities

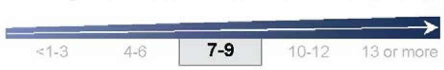
(fiscal year 2021 dollars in millions)

Software Development

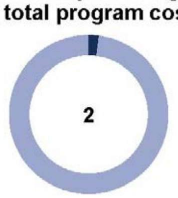
(as of January 2021)

Approach: Agile

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent Off the shelf

0 percent Modified off the shelf

100 percent Custom software

Program Background and Transition Plan

The Air Force initiated F-15EX as a rapid fielding program in September 2019. The Air Force reported that it awarded an undefinitized contract action in July 2020 for two development aircraft for test and evaluation. The program office stated that it is currently finalizing contract terms and conditions.

The Air Force plans to acquire 20 F-15EXs under the rapid fielding effort. According to program officials, two development aircraft are expected to be delivered by April 2021 to begin flight testing. The Air Force plans to procure an additional 18 aircraft after flight testing begins.

Transition Plan: Transition to the major capability acquisition pathway with entry at production.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition

Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	Demonstrate all critical technologies in form, fit, and function within a realistic environment	●
Complete system-level preliminary design review	●	Release at least 90 percent of design drawings	●
Test a system-level integrated prototype	◐	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	⊗
Demonstrate critical processes on a pilot production line	●	Test a production-representative prototype in its intended environment	◐

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, … Information not available, NA Not applicable

F-15EX Program

Key Elements of Program Business Case

The Air Force approved nearly all F-15EX program business case elements at its September 2019 initiation. The program subsequently updated the acquisition strategy in June 2020 with approval of production documentation prior to the July 2020 contract award. The acquisition strategy covers procurement of 20 aircraft using the current MTA pathway and plans for 124 additional aircraft using the major capability acquisition pathway.

In September 2019, the Air Force Cost Analysis Agency (AFCAA) completed an independent cost assessment based on the Air Force's original plan to purchase 26 MTA aircraft, estimated at $3.37 billion. In June 2020, the Air Force decreased the MTA quantity to 20 aircraft due to other priorities. Subsequently, AFCAA updated its estimate, which is currently $2.68 billion.

While the program did not conduct a formal assessment of schedule risk, the program office stated that Boeing's schedule includes at least 9 months of schedule margin. The program office stated that this is because Boeing made investments to accelerate production so that the first two F-15EX aircraft could be delivered by April 2021 to support testing. The program plans to conduct a formal schedule risk assessment in conjunction with the integrated baseline review in January 2021.

Technology and Design

The program identified 10 critical technologies in its September 2019 technology risk assessment, assessing eight as mature and two—advanced cockpit system and EPAWSS—as approaching maturity at that time. The program reports that all 10 critical technologies are now mature.

The program held an integrated design review in November 2020 to review the functional, allocated, and product baselines of the two development aircraft and evaluate their maturity to finish production and enter flight test. The program office stated that this review intended to focus on F-15EX-unique hardware and software design differences from the FMS aircraft configuration baseline.

Software Development and Cybersecurity

The program is using an Agile-like software development process to deliver its operational flight program software, Suite 9.1X. According to the program office, its process consists of developing and delivering increments of new software capabilities every 7 to 9 months. This approach differs from industry-standard Agile practices as reported by the Defense Innovation Board, which encourages delivery of working software to users on a continuous basis—as frequently as every 2 weeks—to receive user feedback and make needed adjustments. The program office stated that it completed systems integration lab testing for the Suite 9.1X software, and expects to complete developmental flight testing of the Suite 9.1 baseline software on legacy F-15C and F-15E aircraft in December 2020.

The Air Force Chief Information Security Officer approved the F-15EX cybersecurity strategy in June 2020. The program is tracking a cybersecurity vulnerability risk because the F-15EX design is derived from FMS aircraft that, according to the program, were not designed to the Air Force's cybersecurity requirements. The program plans to accept initial aircraft and perform government-led testing to determine the actual vulnerabilities.

Transition Plan

The F-15EX program plans to transition to the major capability acquisition pathway with entry at low-rate initial production (LRIP) in March 2022. Program officials stated they believe manufacturing risk at that time will be low because the F-15EX will be manufactured on the same production line—using many of the same manufacturing processes—as current FMS F-15 aircraft. In addition, manufacturing processes will have been proven on pilot production lines.

While those factors do mitigate manufacturing risks and meet DOD standards for beginning LRIP, they do not meet more stringent leading practice standards related to statistical control of critical manufacturing processes. DOD guidance calls for programs to demonstrate critical manufacturing processes on a pilot production line prior to LRIP, but does not require statistical control of those processes until the full-rate production decision. Leading acquisition practices, in contrast, call for this knowledge to be in hand at production start in order to ensure that manufacturing processes are repeatable, sustainable, and capable of consistently producing parts within quality standards.

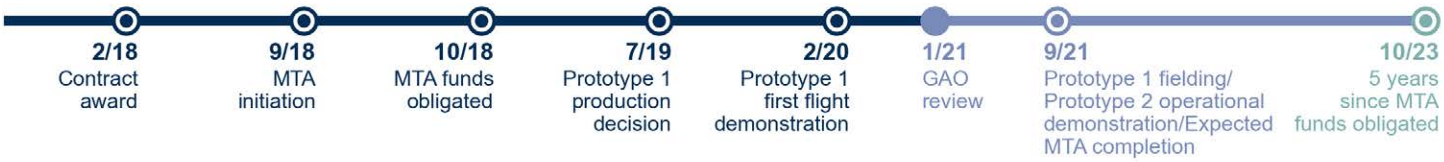
Program Office Comments

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, a system verification review in December 2020 confirmed F-15EX readiness for flight testing and further reduced the risk of design changes during production. In addition, the program office reiterated that it plans to achieve manufacturing maturity by full-rate production and that the risk of design changes to production aircraft is low because the F-15EX is being produced by the same line producing mature foreign military sales variants.

Source: Defense Visual Information Distribution Service.

F-22 Capability Pipeline

The Air Force's F-22 Capability Pipeline, a rapid prototyping and rapid fielding middle-tier acquisition effort, is intended to continuously develop, integrate, and deliver hardware and software capabilities to F-22 aircraft. The program plans for two prototypes of updated F-22 capabilities including enhancements to tactical information transmission, combat identification, navigation, and sensors. Prototype 1 is expected to provide capability updates and Prototype 2 is expected to build on the capabilities and provide further enhancements.



Program Essentials

Decision authority: Air Force

Program office: Wright-Patterson Air Force Base, OH

Prime contractor: Lockheed Martin

MTA pathway: Rapid prototyping, Rapid fielding

Contract type: CPFF/FFP (development)

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2021 dollars in millions)

The program expects to develop two prototypes of updated software and hardware capabilities. Based on these prototypes, the program plans to procure 170 aircraft kits as part of its fielding efforts.

Software Development

(as of January 2021)

Approach: Agile, DevOps, and DevSecOps

Average time of software deliveries (months)

Software percentage of total program cost

Software type

The program reported that it has multiple software releases ongoing simultaneously that often include various software types.

Program Background and Transition Plan

The Air Force initiated the F-22 Capability Pipeline program as a middle-tier acquisition effort in September 2018. The program uses both the rapid prototyping and rapid fielding pathways to support concurrent development and delivery of capabilities to F-22 aircraft. The program is expected to demonstrate two prototypes by September 2021 with fielding based on the prototypes after each demonstration. In February 2020, the program successfully completed an operational demonstration of the first prototype, which featured updated hardware and software capabilities and established a foundation for future updates. The Air Force plans operational demonstration of the second prototype by September 2021. However, it has yet to fully define the content of that prototype, according to program officials.

Transition Plan: Program has yet to determine a transition pathway.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	Demonstrate all critical technologies in form, fit, and function within a realistic environment	NA
Complete system-level preliminary design review	NA	Release at least 90 percent of design drawings	NA
Test a system-level integrated prototype	NA	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned,
… Information not available, NA Not applicable

We did not assess F-22 Capability Pipeline planned knowledge by MTA transition because the program has yet to determine its transition pathway.

F-22 Capability Pipeline Program

Updates to Program Performance and Program Business Case

While the Air Force made no program requirement or acquisition strategy changes since last year, the program experienced schedule delays that shifted the planned fielding date for Prototype 1 capabilities by approximately 1 year, from the end of 2020 to September 2021. Program officials attributed the delays to software development issues, including maturity and stability issues of Prototype 1 capabilities found during testing. The program deferred 20 percent of software content planned for Prototype 1 to Prototype 2 to remain on schedule for the September 2021 Prototype 1 fielding date. Prototype 2 is planned for operational demonstration by September 2021 to complete prototyping of the middle-tier effort's approved capabilities, but the program does not expect to deliver full software capabilities until September 2022.

Since last year, the program reported an increase in development funding needs to address software development challenges and schedule delays. However, program costs remained within established cost parameters, according to program officials. To help avoid further software development delays, program officials said the program has taken action to address potential funding issues; however, the Air Force diverted needed funding to higher priority items. If the program does not secure sufficient funding, future development could be delayed.

Technology

The program's one critical technology, Open System Architecture, provides an interface for legacy systems and enables future capabilities on F-22 aircraft. This technology has been demonstrated in an operational environment on an aircraft and remains mature.

Software Development and Cybersecurity

The program is utilizing Agile, Continuous Delivery, and DevSecOps for software development. Working software is delivered monthly to lab testers for feedback, but to the squadrons approximately every 12 months. According to the program, this delivery schedule aligns with its testing capacity and user preferences. However, this approach differs from industry's Agile practices as reported by the Defense Innovation Board, which encourage the delivery of working software to users on a continuing basis—as frequently as every 2 weeks—so that feedback can focus on efforts to deploy greater capability.

Air Force testing units performed cybersecurity assessments of several portions of the F-22 system, but not specifically the F-22 Capability Pipeline, according to program officials. A cybersecurity assessment for Prototype 1 of the F-22 Capability Pipeline is scheduled for April 2021.

Transition Plan

According to program officials, as of February 2021 they expected approval of F-22 Capability Pipeline transition plans by the end of the month. They noted, however, since the program utilizes both rapid prototyping and rapid fielding authority, they can field capabilities directly to the F-22 fleet.

Other Program Issues

The program reported that the Program Executive Officer, using delegated authority, approved a production decision for Prototype 1 hardware in July 2019, before the completion of developmental testing for Prototype 1. This risk-based decision was made to accelerate production and deliver capability to support a user need date, according to officials. However, this event sequence does not align with knowledge-based acquisition practices, which encourage gathering sufficient knowledge before key events such as production decisions. Our prior work found that, in general, weapon acquisitions that completed certain knowledge practices had better cost and schedule outcomes than programs that did not implement those same practices.

The program reported that it agreed to a level of effort contract with its contractor, Lockheed Martin, in February 2018. In June 2020, the program reported transitioning capability for the next fiscal year to a firm-fixed-price effort, which includes a specific delivery date, quality level, required content, and cost. The program reported that remaining developmental work will continue on the level of effort contract. According to program officials, the goal of the transition was to improve contractor accountability.

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 it initiated the F-22 Capability Pipeline to inform rapid acquisition techniques for an embedded hardware and software system. It added that after 2 years under the current middle-tier acquisition effort, it made notable changes to its contract strategy and emphasized quality and schedule accountability practices to the contractor. It also anticipates the program will undergo a restructuring in 2021 and split into two middle-tier acquisition efforts: a rapid prototyping effort and a rapid fielding effort. The program office noted the rapid prototyping effort will demonstrate a third and fourth prototype, while the rapid fielding effort will establish separate cost, schedule, and performance parameters. The program office stated that upon completion of both of these middle-tier acquisition efforts, it expects to continue to develop and field capabilities under the capability-centric major capability acquisition or software acquisition pathways, with a focus on rapid acquisition techniques.

Source: SAIC.

Future Operationally Resilient Ground Evolution (FORGE)

The Space Force's FORGE is using the rapid prototyping middle-tier acquisition pathway to develop a follow-on capability to the Space Based Infrared System (SBIRS) ground processing system. FORGE is designed to be a government-owned, open-architecture system 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.

- **12/19** MTA initiation
- **9/20** MTA funds obligated
- **1/21** GAO review
- **9/24** Operational demonstration
- **9/25** Expected MTA completion/ 5 years since MTA funds obligated

Program Essentials

Decision authority: Air Force

Program office: El Segundo, CA

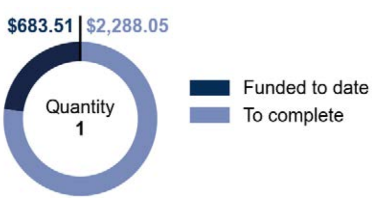
Prime contractor: Raytheon (for MDPAF)

MTA pathway: Rapid Prototyping

Contract type: Cost reimbursement with various fee structures (using other transaction authority)

Estimated Middle-Tier Program Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

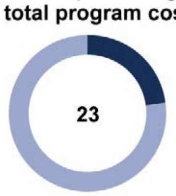
(as of January 2021)

Approach: Agile and DevSecOps

Average time of software deliveries (months)

<1-3 | **4-6** | 7-9 | 10-12 | 13 or more

Software percentage of total program cost



Software type

100 percent Off the shelf

0 percent Modified off the shelf

0 percent Custom software

Program officials anticipate adding modified and custom software at a later point, but have yet to determine the extent to which those types of software will be used.

Program Background and Transition Plan

The Air Force initiated FORGE as a rapid prototyping MTA effort in December 2019, with an objective to complete an operational demonstration by 2024. In August 2020, the program awarded a contract to Raytheon to create a software framework—referred to as the MDPAF Mission Data Processing Application Framework (MDPAF)—for processing satellite data. FORGE will provide enhanced ground processing capabilities for Next Gen OPIR satellites, the first of which is scheduled to launch in 2025. Due to the challenging schedule for FORGE, the program office is pursuing an interim ground effort—called Next Gen Interim Operations–FORGE (NIO-F)—to modify the SBIRS ground processing system to support the initial next generation satellites.

Transition Plan: Program has yet to determine a transition pathway.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition

Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	Demonstrate all critical technologies in form, fit, and function within a realistic environment	NA
Complete system-level preliminary design review	NA	Release at least 90 percent of design drawings	NA
Test a system-level integrated prototype	NA	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, … Information not available, NA Not applicable

We did not assess FORGE planned knowledge by MTA transition because the program has yet to decide its transition pathway.

FORGE Program

Key Elements of Program Business Case

The FORGE program had most business case elements approved at program initiation in December 2019. A classified Joint Requirements Oversight Committee Memorandum, approved in December 2017, provided the requirements. The Air Force Cost Analysis Agency (AFCAA) completed FORGE's cost estimate in September 2019. Additionally, the Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics signed the acquisition strategy document in December 2019.

FORGE uses monthly incremental reviews to assess contractor progress and leads design reviews for the NIO-F every 6 months, the first of which was conducted in May 2020. The program will use a two-phase migration process to demonstrate operational capability, with both phases involving migration of legacy system sensors and satellites onto FORGE. Program officials told us they consider this approach a pathway for the subsequent Next Gen OPIR GEO satellite migration.

While the FORGE program continues to report a September 2024 delivery estimate and $2.8 billion cost estimate for work within the scope of the MTA effort, other independent cost and schedule estimates varied widely. For example, an October 2019 independent technical risk assessment for the Next Gen OPIR program concluded FORGE would likely not be available in time to support the first Next Gen OPIR satellite launch in 2025. Specifically, the assessment predicted software complexity would delay FORGE delivery to December 2026.

According to AFCAA officials responsible for the June 2020 non-advocate cost assessment, AFCAA completed an updated cost and schedule estimate predicting FORGE delivery in 2028—nearly 4 years later than required to launch the first Next Gen OPIR satellite. The updated AFCAA estimate predicts total costs for FORGE at $6.3 billion through fiscal year 2037, which includes work beyond the initial MTA effort. FORGE officials stated the Space and Missile Systems Center estimates a total cost of $5.4 billion. The program office expects less systems engineering and integration resources required than the AFCAA estimate. At the same time, the program is developing a backup capability—NIO-F—in the event that FORGE is not available to launch the first satellite. As a result of the October 2019 independent estimate predicting a late delivery of the backup capability, the program reduced the scope of the system to meet the launch date.

Technology

The FORGE program office does not plan to conduct a formal assessment of technology risk and has yet to identify the program's critical technologies. Program officials said they do not intend to conduct a formal assessment because the program plans to use mature commercial off-the-shelf hardware and software to meet FORGE requirements and is not developing new technology. However, the technologies FORGE does use will need to work together so that the system can accomplish its intended mission. Our prior work shows that the integration phase can reveal unforeseen challenges leading to cost growth and schedule delays.

Software Development and Cybersecurity

The program uses an Agile and DevSecOps software development approach to deliver software every 2 to 3 weeks to developers and every 4 months to operators. The October 2019 Next Gen OPIR independent technical risk assessment identified software as high risk for FORGE due to the potential for unexpected command and control and mission data processing software development schedule growth. FORGE program officials said the program experienced software development cost increases due to updated requirements that reflect the contractor's increased technical understanding of the complexity and quantity of the effort.

The FORGE cybersecurity strategy was approved in May 2018. The program has one key performance parameter associated with cybersecurity, and completed tabletop exercises in February 2021, 2 months later than planned.

Transition Plan

By September 2024, FORGE plans to demonstrate partial capability in an operational environment by migrating legacy satellites onto FORGE. Following this demonstration, the Air Force will make transition recommendations on additional prototyping or sustainment strategies.

Other Program Issues

The Air Force is developing an interim ground system—NIO-F—to mitigate potential delays in FORGE development. However, NIO-F will use the SBIRS ground system for some functions and is not intended to be as robust a ground capability as the final FORGE system. For example, while NIO-F will utilize benefits such as faster revisit rates and improved sensitivity, tasking, and resiliency, it will not be able to exploit some enhanced capabilities offered by the upgrades on the Next Gen OPIR satellites or capitalize on FORGE processing and dissemination 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.

Source: U.S. Air Force.

Military Global Positioning System (GPS) User Equipment (MGUE) Increment 2

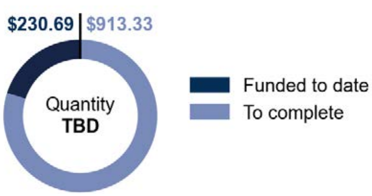
The Space Force's MGUE program is developing GPS receivers compatible with the military code (M-code) signal. MGUE Increment 2 includes two separate middle-tier acquisition rapid prototyping efforts intended to (1) mature core GPS technology for a smaller miniature serial interface (MSI) receiver card for use in handheld devices and munitions, and (2) develop a handheld receiver end item employing the MSI receiver card for use across the military services. We assessed the first effort for MSI receiver cards.

Program Essentials

Decision authority: Air Force
Program office: El Segundo, CA
Prime contractor: Rockwell Collins; Raytheon; Interstate Electronics
MTA pathway: Rapid prototyping
Contract type: CPIF/CPAF, CPFF, FFP

Estimated Middle-Tier Program Cost and Quantities

(fiscal year 2021 dollars in millions)



The program office stated that it has yet to determine the quantity of prototype units to be procured.

Software Development

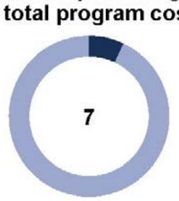
(as of January 2021)

Approach: Information not available

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

Information not available

Program officials told us that they have yet to determine details of the software development approach but more detailed plans are expected with the recent awards of development contracts.

Program Background and Transition Plan

The Air Force initiated MGUE Increment 2 in November 2018, but did not obligate funds for the effort until November 2020. In the interim, the Air Force worked with Increment 1 contractors via modifications to their Increment 1 contracts on a related effort to develop initial designs for a next-generation advanced application-specific integrated circuit (ASIC), a type of microelectronic component on which specific M-code receiver functionalities are encoded. The Air Force awarded contracts in November 2020. According to program officials, these build upon Increment 1 work and are intended to provide receiver cards ready to be procured and integrated with platforms.

Transition Plan: Develop MSI receiver cards that the military services produce and field. Additionally, the program plans to transition the handheld receiver device separately.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	Demonstrate all critical technologies in form, fit, and function within a realistic environment	NA
Complete system-level preliminary design review	NA	Release at least 90 percent of design drawings	NA
Test a system-level integrated prototype	NA	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, … Information not available, NA Not applicable

We did not assess planned knowledge by MTA transition because, rather than transition MSI cards to a specific pathway, the program plans to develop cards that the military services produce and field.

MGUE Increment 2

Key Elements of Program Business Case

The Air Force approved two of the program's five business case elements by program initiation. It also approved the capability development document in early 2018, which laid out requirements to facilitate munitions and handheld devices transitioning to M-code, along with space-based receivers (developed under a separate Air Force program). The Air Force also approved the MTA acquisition strategy by initiation.

In October 2020, the Air Force released a cost estimate based in part on an estimate by the Air Force Cost Analysis Agency, which was reconciled with the program executive officer's estimate. The program plans a formal schedule risk assessment within 6 months of the November 2020 contract award. Program officials do not conduct a formal technology risk assessment. Instead, officials said they conduct quarterly risk assessments of performance requirements.

Program initiation documents required a critical design review to be held for all Increment 2 contractors no later than the end of fiscal year 2023—about halfway through the program—to be followed by a new cost estimate. The review, planned for December 2022, is intended to provide early indication of the program's ability to meet requirements within the planned 5-year schedule.

Technology

The program did not identify any critical technologies. It plans to leverage Increment 1 technologies to the maximum extent possible. Additionally, the next-generation ASIC is manufactured using commercial technology.

Software Development and Cybersecurity

The program indicated that it expects to provide the first prototype article of an MSI receiver card by September 2025 as the minimum releasable software product. According to program officials, each contractor will propose its own software development plan before the preliminary design review, scheduled for December 2021. The Air Force approved the program's cybersecurity strategy in October 2020.

Transition Plan

The first MGUE Increment 2 rapid prototyping effort is expected to develop MSI receiver cards that enable the military services to begin procurement immediately, according to a program official. The official said that by the time the cards are ready for qualification testing near the end of development, contractors should achieve the Manufacturing Readiness Level described in DOD guidance to begin low-rate initial production. A program official said the Air Force plans to conduct an operational assessment of the cards in a relevant environment at the end of development. Officials said the MSI contract requirements are to design the next-generation ASIC to meet the requirements for ground, munitions, and aviation/maritime use. While no operational testing on weapon systems is anticipated as part of the Increment 2 program, such testing will be the responsibility of military services procuring the cards. The MSI receiver card will eventually be incorporated into the Increment 2 handheld receiver end item being developed under a separate MTA effort.

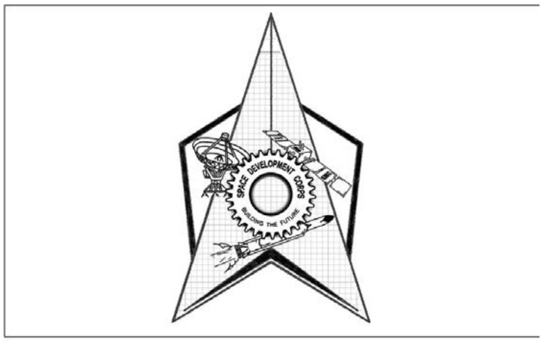
Other Program Issues

The program's ability to meet performance requirements is considered a top risk, according to a program official. For example, the next-generation ASIC technology is intended to enable both reduced power consumption and increased performance for the MSI receiver cards. However, the program is pursuing requirements that a program official said challenge these capabilities.

Additionally, Increment 1 ASICs are manufactured in a trusted environment in which threats related to modification or tampering are addressed to the extent possible. They are also subject to export control regulations, which restrict the design and production of export-controlled data for the ASIC from access by foreign persons, whether in the U.S. or abroad. There are no ASIC manufacturers that have met trusted environment accreditation requirements for the next-generation ASIC that will be used for Increment 2. Instead, as an alternative approach to mitigating manufacturing security risks, in July 2020, the Under Secretary of Defense for Research and Engineering approved a process for ensuring manufacturing security and complying with export controls. The process is expected to utilize advanced commercial technologies, wherein receiver card contractors can program defense-specific functionality into the ASIC chip after manufacture.

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 has made significant progress on the MSI with the next-generation ASIC and has reduced technical risk for the handheld acquisition, which is projected to begin in fiscal year 2023. It also stated it has addressed cost and performance within the current market for handheld technology development. The program office added that it awarded contracts to three Increment 1 contractors to address obsolescence and enhance the ASIC designs. It said the same three companies were awarded contracts in November 2020 to integrate their ASIC technology into the MSI receiver card and that the MSI MTA program is on track to deliver within the 5-year timeline.



Source: U.S. Air Force.

Next Generation Overhead Persistent Infrared (Next Gen OPIR) Block 0

The Space Force's Next Gen OPIR Block 0, 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 and two polar coverage highly elliptical orbit satellites. The Block 0 middle-tier acquisition rapid prototyping effort will deliver the main mission payload—an infrared sensor—for the GEO satellite. A separate middle-tier acquisition effort will modernize the ground segment.

Program Essentials

Decision authority: Air Force

Program office: El Segundo, CA

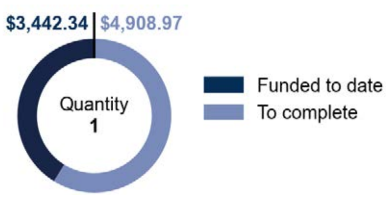
Prime contractor: Lockheed Martin Space (GEO); Northrop Grumman Corporation Space Systems (polar)

MTA pathway: Rapid prototyping

Contract type: CPIF (development)

Estimated Middle-Tier Program Cost and Quantities

(fiscal year 2021 dollars in millions)



Cost and quantities reflect fiscal years 2018 to 2024, which aligns with the expected MTA completion date. Program officials told us they do not track 5-year MTA costs separately and that the cost presented here also supports the spacecraft build and system upgrades to support the first launch in 2025.

Software Development

(as of January 2021)

Approach: Agile and Mixed

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Software type

0 percent Off the shelf

0 percent Modified off the shelf

100 percent Custom software

The program reported that it does not currently track software costs or releases delivered to end users.

Program Background

The Air Force initiated Next Gen OPIR Block 0 as a middle-tier acquisition in June 2018 and plans to complete rapid prototyping in 2023. According to program officials, the program awarded sole-source contracts in 2018 for Block 0 to Lockheed Martin Space to develop three GEO satellites and to Northrop Grumman Corporation Space Systems to develop two polar satellites. The Air Force plans to deliver the main mission payload for the first satellite in 2023, ending the rapid prototyping phase. The program expects the first Next Gen OPIR satellite to launch in 2025, and plans to launch all five Block 0 satellites by 2030. This represents a one-year change from the previous schedule, based on an updated assessment of current capabilities.

Transition Plan: Transition to the major capability acquisition pathway with entry at system development.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition

Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	◐	Demonstrate all critical technologies in form, fit, and function within a realistic environment	NA
Complete system-level preliminary design review	●	Release at least 90 percent of design drawings	NA
Test a system-level integrated prototype	NA	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, … Information not available, NA Not applicable

We assessed the GEO portion of the Next Gen OPIR Block 0 program, which contains the MTA deliverable. We did not assess critical technologies in a realistic environment because satellite technologies demonstrated in a relevant environment are considered fully mature. We did not assess design stability or manufacturing maturity metrics because the program plans to transition to a major capability acquisition with entry at system development.

Next Gen OPIR Block 0 Program

Updates to Program Performance and Program Business Case

In June 2020, the Air Force Cost Analysis Agency completed an updated cost assessment of the Next Gen OPIR Block 0 space segment, which was essentially the same as the cost estimate it completed in May 2019. However, the June 2020 estimate indicated a 2-year delay to the first GEO satellite launch—from 2025 to 2027—given expected delays to payload delivery and integration with the spacecraft.

During 2020, the program held design reviews to support an infrared sensor prototype. In May 2020, competing payload developers for the GEO satellite each completed preliminary design reviews for their respective payloads. Additionally, the program concluded a nearly year-long system preliminary design review campaign in September 2020, including reviews of subsystems and components. Program officials plan to hold a system-level critical design review in November 2021. According to program officials, Lockheed Martin Space, in consultation with the program office, will choose one of the payload designs for the first GEO satellite, and the other payload will fly on the second GEO satellite. For the third GEO satellite, program officials reported that Lockheed Martin Space will select one of the two payloads based on best value.

Technology

According to the program office, the program has 17 critical technologies, seven of which are immature. Most of the immature technologies are related to the payload. According to program officials, one critical technology will not be tested with the payload because its large physical size poses testing challenges. Program officials said this is typical of satellites with deployable mechanisms, and that all components will be validated to ensure proper functionality after launch.

Software Development and Cybersecurity

The program uses Agile and mixed development to develop custom software, and the timing of software deliveries is negotiated by various users, such as hardware and space vehicle integrators. The program uses continuous iterative development, as recommended by the Defense Science Board. However, the program does not provide training to support iterative development, which is not aligned with leading commercial practices. The program's cybersecurity strategy was approved in May 2018.

Transition Plan

At the completion of the rapid prototyping effort in late 2023, the Air Force plans to transition to the major capability acquisition pathway for the remaining Block 0 satellites. Space Force officials told us the program will develop the transition plan by mid-2022. They plan a competition for the Block 1 effort to add at least two additional GEO satellites, but have yet to determine the acquisition pathway for Block 1.

Other Program Issues

The program faces significant challenges in developing and integrating new technologies within an aggressive schedule. Driven by the 2025 launch requirement and minimal schedule margin, the program is concurrently developing mission payload engineering and flight units. Such concurrency raises the risk of schedule delays because issues identified during engineering unit testing will necessitate corrective flight unit rework. Also, while the program considers the spacecraft design to be mature, it will be modified to meet new mission requirements. DOD officials acknowledged the added schedule and cost risks presented by the first-time integration of a new sensor with a modified spacecraft.

In addition, the ground segment—developed under a separate program—may not be ready when the first satellite is delivered. To mitigate this risk, the program is designing the GEO satellites to integrate into the existing ground architecture to provide a continuation of existing missile warning 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. The program office stated that the Next Gen OPIR Block 0 program will provide missile warning to detect the evolving global launch capabilities and resilience to ensure operations in contested environments. The program office also noted that the use of the middle-tier acquisition pathway allowed the program to rapidly start, and that it is on track to meet its technical requirements within cost and schedule guardrails. The program office added that it continues to manage the program's schedule to achieve the aggressive launch schedule established at program outset, and that it is well-postured to transition to the planned major capability acquisition. According to the program office, the new capability it is developing will ensure the Next Gen OPIR Block 0 satellites outpace emerging threats and ensure the nation's missile warning capability is never in doubt.

Source: LinQuest.

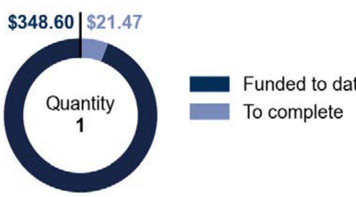
Protected Tactical Enterprise Service (PTES)

The Space Force's PTES middle-tier acquisition (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 Air Force's broader Protected Anti-Jam Tactical SATCOM (satellite communications) effort. We evaluated the planning and execution of the middle-tier acquisition rapid prototyping effort that the Air Force expects will demonstrate initial operational readiness for anti-jam tactical communications in the Pacific theater.

Program Essentials

Decision authority: Air Force
Program office: El Segundo, CA
Prime contractor: Boeing
MTA pathway: Rapid Prototyping
Contract type: CPIF (development)

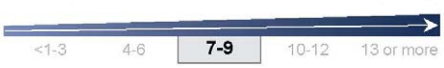
Estimated Program Cost and Quantities (fiscal year 2021 dollars in millions)



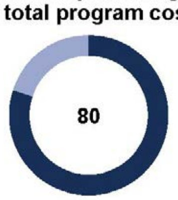
Software Development
(as of January 2021)

Approach: Agile and DevSecOps

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent
Off the shelf

44 percent
Modified off the shelf

56 percent
Custom software

Program Background and Transition Plan

The Air Force initiated PTES as a middle-tier rapid prototyping acquisition effort in June 2018 with an objective of completing an operational demonstration and the rapid prototyping effort in November 2021, events now planned for December. The program intends to field the capabilities developed during the rapid prototyping effort, referred to as release 1, to the Pacific theater in order to reach initial operational capability before the end of calendar year 2023.

After completing the first rapid prototyping effort and reaching initial operational capability, the program plans a rapid fielding effort for release 2 with the goal of providing full operational capability for Air Force, Army, and Navy operations by fiscal year 2026.

Transition Plan: Transition to a new middle-tier acquisition rapid fielding effort.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	◐	Demonstrate all critical technologies in form, fit, and function within a realistic environment	⊗
Complete system-level preliminary design review	◐	Release at least 90 percent of design drawings	⊗
Test a system-level integrated prototype	●	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	⊗
Demonstrate critical processes on a pilot production line	⊗	Test a production-representative prototype in its intended environment	◐

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, ... Information not available, NA Not applicable

PTES Program

Updates to Program Performance and Program Business Case

In June 2020, the program had an independent technical risk assessment that assessed technical risks to be moderate, driven by software and cryptographic certification concerns. The assessment found that the program is still working on coordinating systems engineering and software engineering processes, and that cryptographic certification is a risk due to potential COVID-19 effects and because it is to be conducted by an outside agency. The program began initial production of prototype units in April 2020. Additionally, the program tested a system-level integrated prototype and held a risk-reduction test in May and June 2020, respectively. The program has also conducted over the air tests of the prototype capability.

PTES delayed its planned operational demonstration date by one month, to December 2021, due to COVID-19 restricting access to secure workspaces and other constraints, according to program officials. The remaining business case elements have remained stable since our last assessment.

Technology

The program identified three technology areas—Joint Hub and Network, Dynamic Resource Allocation, and Crypto and Cross Domain Solution—critical for development, one of which is mature and two of which are currently immature. In December 2021, the program plans to operationally demonstrate a production-representative prototype.

Software Development and Cybersecurity

The PTES program uses an Agile software development process to develop a mixture of modified off-the-shelf and custom software. The program continues to use 2-week sprints, quarterly demonstrations, and 9-month builds to deliver operational software, according to program officials. The program plans to complete six demonstration builds by the end of 2020 and plans to work cooperatively with users and independent Air Force test organizations to ensure the software meet desired outcomes. The program plans to field a minimum viable product in November 2023 to support initial operational capability the following month, with the ability to incrementally add features.

PTES has an approved cybersecurity strategy and plans to conduct a vulnerability assessment and mission-based risk assessment in April 2021. Additionally, the program plans to conduct a cybersecurity tabletop exercise in March 2021.

Transition Plan

PTES currently plans to transition to a middle-tier acquisition rapid fielding effort at completion of the current rapid prototyping effort; however, alternative pathways are still in consideration. Through its planned operational demonstration in December 2021, the program office expects to demonstrate a prototype meeting at least the minimum needed capabilities in an operational environment prior to transition.

The follow-on rapid fielding effort is to provide systems to additional operational theaters and enhance system capabilities. However, the program does not plan to meet our knowledge-based leading practices before it transitions. For example, the program does not plan to demonstrate all critical technologies in an operational environment before transitioning to the rapid fielding pathway, an approach inconsistent with knowledge-based acquisition practices. The program also does not plan to demonstrate leading practices related to manufacturing that our past work has shown can help a program mitigate cost and schedule risks. The program office has identified production to be a low risk item for the PTES program as it is a software intensive program primarily using commercial hardware; the developed hardware of the modem and End Cryptographic Unit (ECU) have both been prototyped and demonstrated.

Other Program Issues

According to the program office, the ECU development effort, which requires National Security Agency certification, follows a waterfall development approach as opposed to an Agile development approach. The program office projects a 12-week slip to key events associated with ECU design as a result of effects from the COVID-19 pandemic, such as limited access to secure workspaces, but has not identified any overall program cost effects as a result.

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, given the accelerated timeline and focus on software development using Agile processes, plans to address traditional manufacturing concerns were given a lower priority. The program office noted that this decision was informed by the small quantities of hardware units being acquired, in addition to leveraging prior hardware risk reduction efforts. Additionally, it stated initial capabilities of the system will be showcased during a large-scale joint exercise planned for summer 2021. The program also noted that this event will enable additional, real-world warfighter feedback to improve usability in a realistic environment prior to the operational demonstration.

Source: U.S. Air Force.

Protected Tactical SATCOM (PTS)

The Space Force's PTS, a rapid prototyping middle-tier acquisition effort, is a space-based system that will transmit a protected, antijamming waveform to users in contested environments. The PTS MTA effort will 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 middle-tier acquisition effort.

11/18	6/19	3/20	1/21	TBD	6/24	8/24
MTA initiation	MTA funds obligated	First demonstration	GAO review	Critical design review	5 years since MTA funds obligated/Expected MTA completion	First flight test

Program Essentials

Decision authority: Air Force

Program office: El Segundo, CA

Prime contractor: Boeing, Northrop Grumman, Lockheed Martin (all prototype design)

MTA pathway: Rapid prototyping

Contract type: FFP (development)

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2021 dollars in millions)

Program officials said funding reflects the rapid prototyping phase, which includes development and on-orbit operations that span to fiscal year 2029.

Software Development

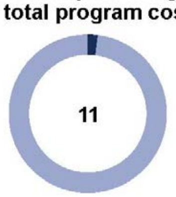
(as of January 2021)

Approach: Agile and Mixed

Average time of software deliveries (months)

<1-3 | 4-6 | 7-9 | 10-12 | **13 or more**

Software percentage of total program cost



Software type

5 percent Off the shelf

25 percent Modified off the shelf

70 percent Custom software

Program Background and Transition Plan

The Air Force initiated PTS using the middle-tier acquisition pathway in November 2018. Program officials reported awarding three contracts In February and March 2020 for different vendors to design hosted payload prototypes. Following component-level preliminary design reviews, officials reported the program plans to down-select to two contractors in March or April 2021 to build the prototype payloads and integrate them with space vehicles. The program expects to complete the rapid prototyping effort with the delivery of the two prototype payloads, which are planned to be available-to-launch by June 2024.

Transition Plan: Transition to the major capability acquisition pathway with entry at system development.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	○	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	◐	Demonstrate all critical technologies in form, fit, and function within a realistic environment	◐
Complete system-level preliminary design review	⊗	Release at least 90 percent of design drawings	NA
Test a system-level integrated prototype	NA	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned,
… Information not available, NA Not applicable

We did not assess PTS's planned knowledge by MTA transition for design stability and manufacturing maturity because the program plans to transition to a major capability acquisition with entry at system development.

PTS Program

Updates to Program Performance and Program Business Case

We reported last year that the program's critical design review was originally scheduled for June 2020, but after further clarification, we learned that the program's original projected date was actually June 2021. However, the program updated this projection once the prototype development contracts were awarded in February and March 2020. Program officials said they now expect the critical design reviews to occur between August 2021 and April 2022, depending on which contractors are selected to continue beyond March 2021. Officials said the design review date change is not expected to affect the payload delivery schedule.

The program has yet to conduct a formal schedule risk assessment, an important element in helping decision makers identify whether MTA programs are well-positioned to meet statute-based schedule objectives. Without such an assessment, decision makers may lack information about whether the program's revised schedule is achievable.

Program officials reported that the program is still on track to meet the statute-based objective for the acquisition program to field a prototype that can be demonstrated in an operational environment and provide for a residual operational capability, within 5 years. The statute-based objective for a rapid prototype middle-tier acquisition effort is to provide a prototype within five years of the development of an approved requirement. The program plans to meet this objective by ensuring the space vehicles' prototype payloads are available to launch by June 2024. However, no margin exists between the June 2024 available-to-launch date and the MTA completion date, putting the program's schedule at risk should significant schedule or technical issues arise during prototyping.

Technology

PTS's five critical technologies are currently immature based on the program's technology risk assessment and market research. However, program officials explained that, while many technologies themselves are mature, the technology risk assessment is assessed to be lower based on anticipated challenges associated with integrating those technologies to deliver protected antijam communications from space. According to program officials, the program plans to mature all critical technologies by June 2024.

Software Development and Cybersecurity

Each PTS contractor has a software development plan indicating its approach to incorporate a mix of custom, commercial, and government software products. Because of the unique digital signal processing needs of the satellites' antijam capabilities, program officials estimate that 70 percent of the software will be custom built, a significant increase over last year's 25 percent estimate. They attribute the change to each contractor's better understanding of its planned approach after contract award and to PTS officials' efforts with contractors on their software development plans.

The PTS program's cybersecurity strategy, finalized in August 2019, includes instructions on how contractors may select cybersecurity controls. Program officials met with contractors to ensure their understanding of the controls, and they plan to conduct cybersecurity assessments from in the third quarter of fiscal year 2021 to the first quarter of fiscal year 2022.

Transition Plan

PTS plans to transition to a new, major capability acquisition pathway with entry at system development. However, it does not plan to complete a system-level preliminary design review by that time, a practice that our prior work has found can help ensure requirements are feasible and can be met by the proposed design within cost, schedule, and other system constraints. Subsequently, the program plans to make a production decision in May 2025, delayed nearly 2 years from original plans due to funding cuts.

Other Program Issues

Program officials said that in order for PTS to be used effectively, military services must develop user terminals with specific requirements to ensure connectivity. To address this interdependency, PTS reported substantial coordination efforts with the other military services and contributed requirements to ensure terminal connectivity, among other coordination efforts.

Program Office Comments

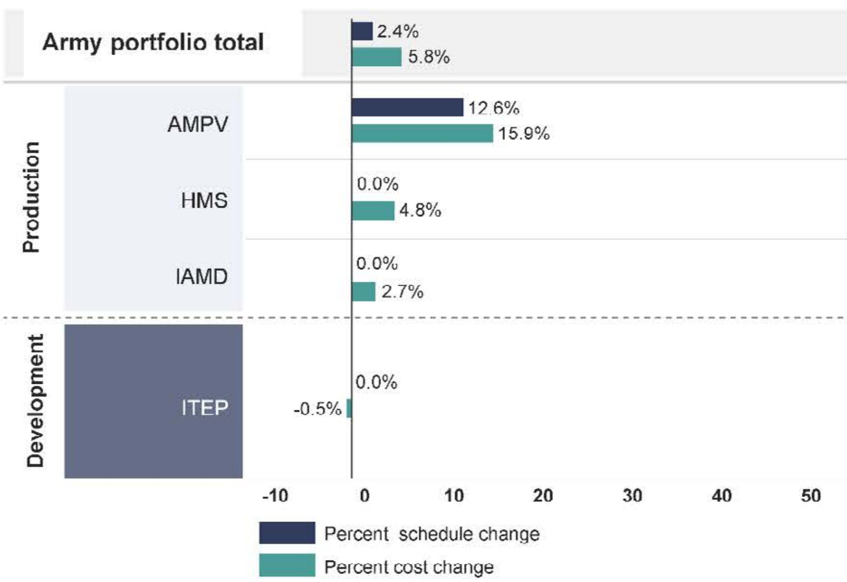
We provided a draft of this assessment for program office review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, PTS has made great progress over the last year and ultimately is expected to provide a robust antijam capability to warfighters in highly contested theaters. It noted that a rapid prototyping program is expected to provide capability 3 years earlier than if the program had used the major capability acquisition pathway.

The program office stated that the contractors conducted three system requirements and preliminary design reviews, which increased confidence in the contractors' ability to deliver a payload that will meet requirements. It also noted that contractors executed 18 demonstrations, which showcased capabilities, matured critical technologies, and reduced risk. Officials stated they plan to complete a schedule risk assessment later this year. A system-level preliminary design review is not planned, but the program office is considering a preliminary design review-like event to ensure requirements can be met. Officials said the payloads are on schedule for delivery by fiscal year 2024.

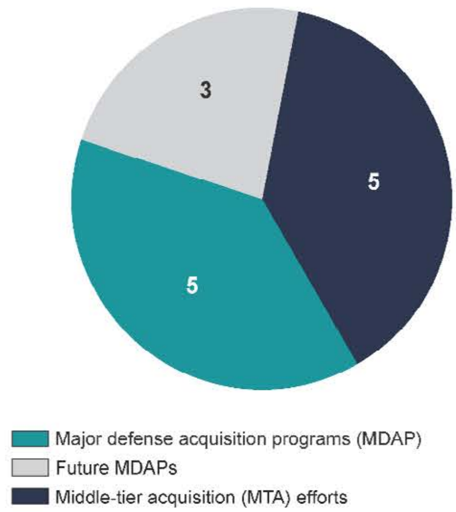
ARMY
PROGRAM ASSESSMENTS

Source: U.S. Army. | GAO-21-222

Most Army MDAPs Have Had Cost Growth, Schedule Delays, or Both Since 2020

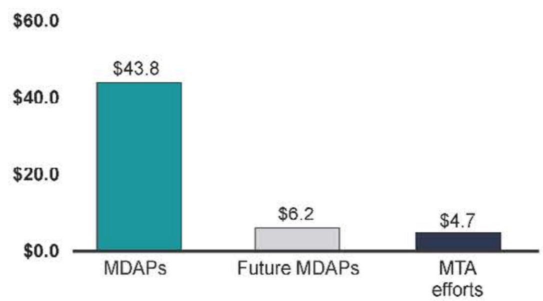


GAO Assessed 13 Army Weapon Programs



Army Programs Reported a Combined Acquisition Cost of $54.7 Billion

(Fiscal Year 2021 dollars in billions)



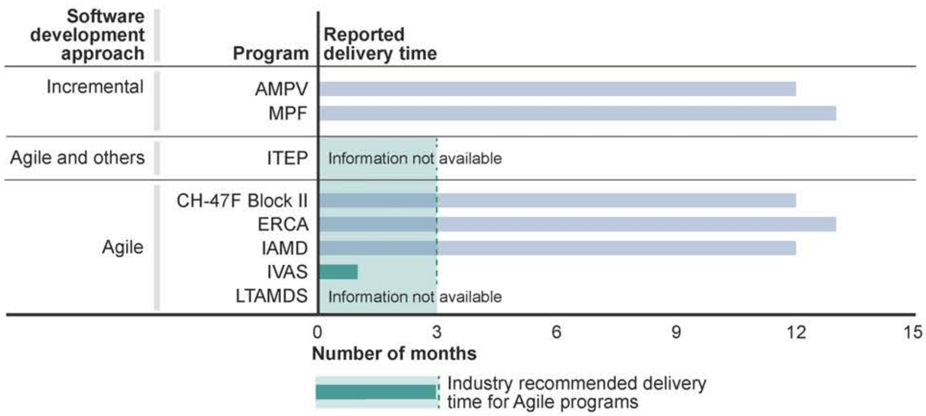
- Note: Acquisition costs for MTA programs reflect estimates for current efforts only. Additionally, cost estimates for future MDAPs may not reflect full costs since programs may still be defining them.

- The term "programs," when used alone in figure titles, refers to all MDAP, future MDAPs, and MTA programs that GAO assessed.
- Cost and schedule analyses are primarily based on estimates from DOD's Defense Acquisition Executive Summary reports. This information may differ from information reported in the Program Performance table and Funding and Quantities figures in individual assessments, which in some cases are based on more recent program estimates. See appendix I for details.

All data in figures are based on GAO analysis of DOD data and program office questionnaire responses. | GAO-21-222

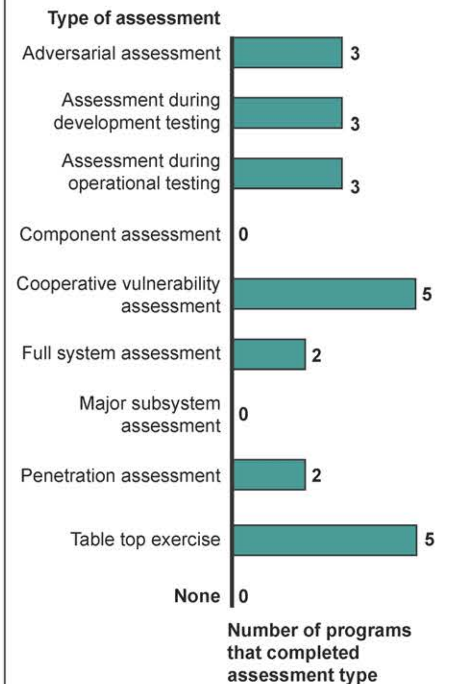
ARMY
PROGRAM ASSESSMENTS

Army Programs Often Reported Software Delivery Times Greater than Industry Recommendations



- Industry recommends deliveries on a continuing basis, as frequently as every 2 to 6 weeks for Agile programs. Programs reported deliveries to GAO in 0-3 month ranges and this figure represents the high end of those ranges.
- Software development approach was not available for the HMS and OMFV programs.

All Army Programs Completed At Least One Cybersecurity Assessment

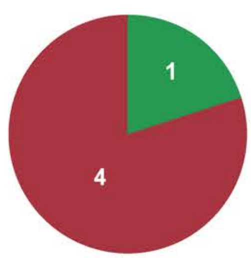


Army MDAPs Generally Did Not Attain Knowledge at Key Points on Time

- Program **attained** knowledge **by** knowledge point date
- Program **attained** knowledge **after** knowledge point date
- Program **had yet to attain** knowledge **by** January 2021

- Note: For each knowledge point, GAO assessed the MDAPs that had reached that point as of January 2021. GAO excluded programs for which it determined that the practice was not applicable.

All But One Army MTA Program Did Not Complete a Business Case on Time



- Program **completed** business case **by** initiation
- Program **completed** business case **after** initiation
- Program had **yet to complete** business case as of January 2021

Only One of the Army MTA Programs Plans to Attain Key Knowledge by Transition

Plan to Attain Knowledge by Transition

- Note: GAO assessed programs planning to transition to the major capability acquisition pathway or to a rapid fielding effort, and excluded programs planning to transition to another rapid prototyping effort or that had yet to determine transition plans.

All data in figures are based on GAO analysis of DOD data and program office questionnaire responses. | GAO-21-222

Source: BAE.

Armored Multi-Purpose Vehicle (AMPV)

The Army's AMPV is the replacement to the M113 family of vehicles at the brigade level and below. The AMPV is expected to replace the M113 in five mission roles: general purpose, medical evacuation, medical treatment, mortar carrier, and mission command. The Army determined that development of the AMPV is necessary due to mobility, survivability, and force protection deficiencies identified with the M113, as well as space, weight, power, and cooling limitations that prevent the incorporation of future technologies.

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

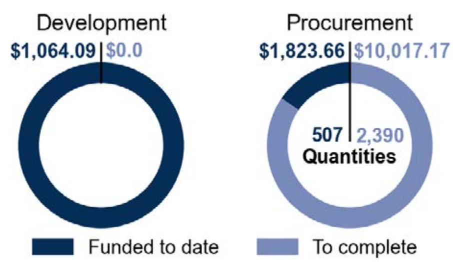
- 12/14 Development start
- 6/16 Critical design review
- 1/19 Low-rate decision
- 1/21 GAO review
- 1/22 Start operational test
- 4/22 End operational test
- 10/22 Full rate decision
- 2/23 Initial capability

Program Essentials

Milestone decision authority: Army
Program office: Detroit Arsenal, MI
Prime Contractor: BAE Systems Land & Armaments L.P.
Contract type: CPIF (development), FPI (procurement)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

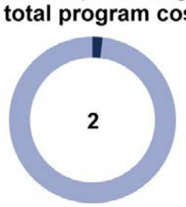
(as of January 2021)

Approach: Incremental

Average time of software deliveries (months)

<1-3 | 4-6 | 7-9 | **10-12** | 13 or more

Software percentage of total program cost



Software type

10 percent Off the shelf
0 percent Modified off the shelf
90 percent Custom software

Off-the-shelf software includes 1 percent government off-the-shelf.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (5/2015)	Latest (9/2020)	Percentage change
Development	$1,101.92	$1,064.09	-3.4%
Procurement	$10,857.05	$11,840.82	+9.1%
Unit cost	$4.07	$4.44	+9.0%
Acquisition cycle time (months)	87	98	+12.6%
Total quantities	2,936	2,936	+0.0%

Total quantities comprise 39 development quantities and 2,897 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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

AMPV Program

Technology Maturity, Design Stability, and Production Readiness

The AMPV program entered system development in December 2014 with mature critical technologies. The program also released over 90 percent of expected drawings to manufacturing, which indicates a stable design.

The AMPV contractor delivered the first two production vehicles in August 2020 but experienced delays to the overall manufacturing schedule. However, the program, which entered low-rate initial production in January 2019, has yet to ensure that its production processes are in statistical control. While DOD guidance does not require statistical control of production processes until the full-rate production decision, our prior work found that this standard falls short of leading industry practices. Further, the program did not demonstrate its critical manufacturing processes on a pilot production line. Program officials stated preproduction hulls were used to validate new weld processes and serve as pilots for fabrication. Until the program matures its manufacturing, it risks producing vehicles that do not meet its cost, schedule, and quality targets. The contractor projects higher than expected costs on the low-rate initial production contract due to production challenges associated with immature manufacturing processes. According to program officials, however, the government's financial exposure is generally limited to the contract ceiling price in the fixed-price incentive contract.

Immature production processes and lingering manufacturing challenges encountered during prototype fabrication—such as parts shortages, engineering changes, and quality issues—resulted in delays to the overall manufacturing schedule and several key programmatic events. The contractor delivered the first production vehicles 5 months later than originally planned. Initial operational testing start has been delayed by 11 months, now planned for January 2022. In addition, the program delayed the planned full-rate production decision and initial operational capability dates by 12 months to October 2022 and February 2023 respectively. Additionally, program officials reported that COVID-19-related restrictions resulted in a short production line shutdown and employee work restrictions. The program office and contractor are still evaluating the full effect of COVID-19-related restrictions, though they were not the primary driver of the delays encountered to date.

Software and Cybersecurity

AMPV program officials reported use of an incremental approach to develop software for vehicle control, communications, and other software. Program officials reported that the program has no significant software-related issues. Initial cybersecurity testing conducted in September 2018 revealed system vulnerabilities, and the program plans future testing to include mitigation of identified vulnerabilities.

Other Program Issues

In March 2020, the contractor rebaselined its development contract for the second in time in less than 3 years, projecting substantially higher contract costs than expected. According to the Defense Contract Management Agency (DCMA), the contractor's previous performance management baseline did not include all authorized, unpriced work and accordingly prevented DCMA from properly evaluating contract performance. The revised March 2020 contract baseline also reflects the delay that we reported last year in the planned end of system development to October 2021—more than 1 year later than originally planned—largely due to delays in developing logistics documentation such as operator technical manuals. However, program officials noted the Army's program cost position—based on the DOD's Office of Cost Assessment and Program Evaluation independent cost estimate—sufficiently accommodates these higher costs. Further, according to program officials, the new acquisition program baseline—approved in January 2021—addresses the contractor's continued lateness to deliver vehicles as well as the effects of COVID-19.

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 adjusted the program schedule as a result of challenges at the beginning of production. Program officials noted that the latest rebaseline will accommodate projected delays to vehicle deliveries. According to the program office, AMPV was projected to meet all of its key performance parameters at the start of production. In addition, program officials noted they have continued to work with their contractor to increase system performance beyond the capability demonstrated during development. Program officials stated that they will incorporate most of the user requested modifications from limited user testing prior to the start of operational testing. Further, program officials expect the initial production AMPV vehicles to outperform prototype vehicles, and provide a substantial improvement over the M113 that they will replace.

Source: U.S. Army.

CH-47F Modernized Cargo Helicopter (CH-47F Block II)

The Army's CH-47F Block II program upgrades existing CH-47F aircraft 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, among other capabilities, which are expected to increase lift in hot weather conditions. The Army also expects the improved fuel and rotor components 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.

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

- 7/17 Development start
- 12/17 Critical design review
- 1/21 GAO review
- 8/21 Low-rate decision
- 3/24 End operational test
- 11/24 Initial capability
- 12/24 Full-rate decision

Program Essentials

Milestone decision authority: Army
Program office: Redstone Arsenal, AL
Prime Contractor: Boeing
Contract type: CPIF (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)

Development: $756.85 | $69.67

Procurement: $989.6 | $15,364.18

Funded to date | To complete

Software Development

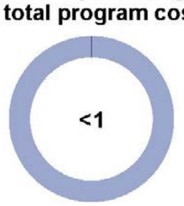
(as of January 2021)

Approach: Agile

Average time of software deliveries (months)

<1-3 | 4-6 | 7-9 | **10-12** | 13 or more

Software percentage of total program cost



Software type

5 percent Off the shelf
10 percent Modified off the shelf
85 percent Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (2/2018)	Latest (7/2020)	Percentage change
Development	$830.21	$826.53	-0.4%
Procurement	$16,479.36	$16,353.78	-0.8%
Unit cost	$32.43	$32.19	-0.7%
Acquisition cycle time (months)	88	88	+0.0%
Total quantities	542	542	+0.0%

Total quantities comprise three development quantities and 539 procurement quantities (including 73 MH-47G Block II aircraft for Special Operations Forces).

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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 production; however, the program stated that it tested a production-representative prototype in the system's intended environment.

CH-47F Block II Program

Technology Maturity and Design Stability

The program's two critical technologies—Advanced Chinook Rotor Blade (ACRB) and Ferrium C61 steel shafts—are now fully matured, but they still carry risks that the program is working to address. For example, if the program does not improve ACRB manufacturing and material costs, it will not meet affordability targets established in the acquisition strategy. The program is exploring options of new technologies that aim to increase manufacturing efficiency through automation. Additionally, the Ferrium C61 steel shafts are susceptible to stress-related cracking and corrosion. The program implemented design changes to lower stress levels and ongoing risk mitigation initiatives to reduce the amount of corrosion.

The program completed the critical design review in December 2017 with at least 90 percent of the design drawings released, a sign of a stable design. However, since then, design drawings increased by approximately 33 percent, and the program no longer meets this indicator for a stable design. Additionally, the program did not integrate all key subsystems and components and test them on a system-level integrated prototype prior to the critical design review in December 2017—an approach inconsistent with leading practices. Instead, the program initiated that system-level prototype testing in August 2019 and does not expect to complete it until March 2021. Until this testing is completed, the program cannot be sure that the design is stable, increasing the risk of costly and time-intensive rework on developmental aircraft already in production.

Production Readiness

The program office indicated that it tested a production representative prototype in its intended environment and that it plans to demonstrate critical manufacturing processes on a pilot production line prior to production start using a production-representative article, an approach that aligns with our leading practices. The program plans to enter production in August 2021, following the delivery of three developmental test aircraft. Currently, the program is monitoring several related risks, including delays in the procurement of long-lead items, incomplete design and qualification of the ACRB and fuel pods, and manufacturing processes for developmental tooling ill-suited for initial production. The program also plans to complete a formal manufacturing readiness assessment in April 2021 in preparation for a sole-source fixed-price production contract award planned for August 2021.

Software and Cybersecurity

Although the program does not have an approved software development plan, a DOD standard practice, it reports it is utilizing an Agile software development approach. Working software is delivered to the end users—pilots and aircrew—every 10 to 12 months. This approach differs from industry's Agile practices, which encourage the delivery of working software to users on a continuing basis—as frequently as every 2 weeks—so feedback can focus on efforts to deploy greater capability. Further, the program plans to defer some planned software functionality to future development and sustainment efforts, because it only partially funds the functionalities, which are at different levels of development and test readiness. According to the program, the delayed functionalities are for the display and avionics of both Block I and Block II aircraft and should have no cost or schedule effects.

The program has an approved cybersecurity strategy in place and completed several types of cybersecurity assessments; including a cooperative assessment, development testing, and tabletop exercises. Tabletop efforts identified risks that require additional testing and analysis related to areas, such as mission planning and software verification. Further cybersecurity testing for the Block II program is in progress.

Other Program Issues

According to program officials, COVID-19 affected the program by temporarily halting production and delaying component and flight testing. Flight test delays, caused by COVID-19-related travel and social distancing restrictions, ranged from 1 to 20 weeks. The program is still assessing COVID-19-related effects; however, the program expects projected overall cost and schedule to remain within the program baseline.

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 indicated it is actively identifying and mitigating risks associated with the ACRB and Ferrium 61 steel shafts. Additionally with regard to design stability, the program noted that the increased design drawings are intended to improve affordability and commonality with the MH-47G aircraft currently in production; that the Block II design remained stable since design review; and that it delivered 100 percent of technical data. Further, the program office reported that system-level prototype testing is an acceptable production readiness practice when developing aircraft. It noted that aircraft software requires extensive evaluation after development is complete (such as flight testing, airworthiness evaluation, and software materiel release), and these 10-to-12-month processes ensure the safety of the aircrews and passengers. The program is not affected by deferring software functionality, and all necessary functionality will be included prior to production, according to the program office. It also noted that it is executing specific mitigation plans for previously identified cybersecurity risks.

Source: U.S. Army.

Handheld, Manpack, and Small Form Fit Radios (HMS)

The Army's HMS program is procuring nondevelopmental software-defined radios to connect with existing radios and increase communications and network capabilities. HMS continues efforts under the former Joint Tactical Radio System to procure multiple radios, such as the Leader and Manpack, a subset operating with Mobile User Objective System (MUOS)—a worldwide, multiservice Navy satellite communication system. In 2020, the Army added single-channel data radios to support the Integrated Visual Augmentation System (IVAS).

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

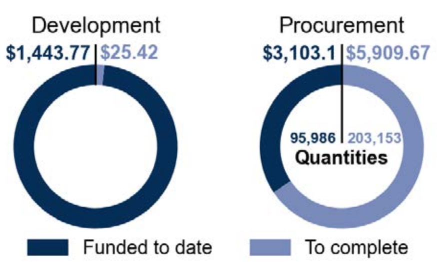
- 4/04 Program/development start
- 6/11 Initial low-rate decision
- 4/15 and 2/16 Contract awards-Rifleman and Manpack radios
- 9/18 Contract modification-Leader radio
- 6/19 Sixth low-rate decision-Leader and Manpack radios
- 1/21 GAO review/Start operational test
- 6/21 Full-rate decision

Program Essentials

Milestone decision authority: Army
Program office: Aberdeen Proving Ground, MD
Prime Contractor: Thales Defense & Security, Inc.; Harris Corporation; Rockwell Collins, Inc.
Contract type: FFP/IDIQ (procurement)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Nondevelopmental

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Information not available

Software type

0 percent
Off the shelf

0 percent
Modified off the shelf

100 percent
Custom software

The program procures nondevelopmental items and does not have its own software development approach.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (5/2004)	Latest (8/2020)	Percentage change
Development	$639.53	$1,469.2	+129.7%
Procurement	$11,145.65	$9,012.77	-19.1%
Unit cost	$0.04	$0.04	-1.8%
Acquisition cycle time (months)	85	124	+45.9%
Total quantities	328,674	299,972	-8.7%

Total quantities comprise 833 development quantities and 299,139 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	○	NA
Demonstrate all critical technologies in form, fit, and function within a realistic environment	○	NA
Complete a system-level preliminary design review	○	NA
Product design is stable	**Design Review**	
Release at least 90 percent of design drawings	○	NA
Test a system-level integrated prototype	●	NA
Manufacturing processes are mature	**Production Start**	
Demonstrate Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
Demonstrate critical processes on a pilot production line	○	NA
Test a production-representative prototype in its intended environment	●	NA

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

We did not assess the current status of HMS, other than its demonstration of manufacturing readiness levels, because the Army is now procuring radios as nondevelopmental items.

HMS Program

Technology Maturity, Design Stability, and Production Readiness

The HMS program revised its test plans in 2020. These plans reflect acquisition strategy changes over the last several years, including acquiring the radios as nondevelopmental items, switching to Leader Handheld radios, and incorporating MUOS and a commercially available waveform for the newer generation Manpack radio. The new test plan for the Manpack radio builds on prior HMS tests and waveform performance assessments. From July to October 2020, the program conducted technical testing and performance qualification tests for the Leader and Manpack radios to support the upcoming operational test, which was delayed from August 2020 to January 2021 due to COVID-19-related travel restrictions and social distancing requirements. Program officials stated that they have verified fixes for the issues that would affect operational testing and will address any new issues that may arise prior to that time.

The HMS program completed its contractor production readiness assessments for the Manpack radio in 2018 and the Leader radio in 2020 and found the contractors on track to support production decisions. However, as of November 2020, the program is still confirming that the contractors for both radios have achieved statistical control of manufacturing processes. The program also experienced 2 weeks of production schedule delays due to COVID-19, but has yet to observe any cost effects. The program delayed a full production decision by 4 months (now planned for June 2021) due to COVID-19-related effects on operational testing.

Software and Cybersecurity

The program office is tracking challenges with the progress of the radios' network management software. According to a DOD test official, the software currently does not include all intended capabilities and has not been independently tested with the radios. If this software is not ready by operational testing, the program will use a mix of developer tools and existing government solutions. This substitution could reduce the program's suitability and require follow-on testing for the final software fix. Program officials said they are monitoring the software's approval schedule and performance and expect risk resolution by the second quarter of fiscal year 2021.

According to the program office, the program updated its cybersecurity strategy in January 2021, but the updates are still under review. This is more than 6 years after the move to a nondevelopmental acquisition. Our past work shows that waiting to focus on cybersecurity until late in the development cycle or after a system deploys leads to more challenges than designing for cybersecurity from the start. The program conducted HMS cybersecurity testing in 2020 and another one is planned for January 2021. Program officials said that while there are currently no cybersecurity concerns, they are continuously analyzing test results and will develop appropriate mitigation strategies, which could include software fixes.

As we reported last year, DOD operational testers identified cybersecurity concerns with MUOS, although a test official stated that they can address some issues through operator training and awareness. The program plans to test the newer Manpack radio generation with MUOS during upcoming operational testing. According to program officials, radio accreditation and MUOS certification are critical to HMS's entry into operational testing. The contractors are scheduled to receive certifications from the National Security Agency in early 2021.

Other Program Issues

In January 2020, the Army removed Small Form Fit radio requirements and reduced the Rifleman Handheld radio quantity to be purchased from 93,279 to the previously procured amount of 21,579. In addition, the Army added requirements for 104,496 single-channel handheld data radios to support its IVAS program, a middle-tier acquisition rapid prototyping program. HMS officials said the Army incorporated IVAS radio requirements into the HMS program because HMS is the Army's primary office for management and procurement of tactical radios.

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.

Source: Dynetics.

Integrated Air and Missile Defense (IAMD)

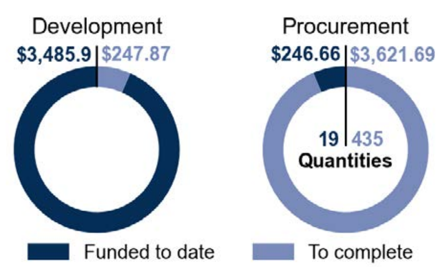
The Army's IAMD program links sensors, weapons, and a common battle command system across an integrated fire control network to support the engagement of air and missile threats. The IAMD battle command system provides a capability for the Army to control and manage IAMD sensors and weapons, such as the Sentinel radar and Patriot launcher and radar, through an interface module that supplies battle management data and enables networked operations.

Program Essentials

Milestone decision authority: Under Secretary of Defense, Acquisition and Sustainment
Program office: Redstone Arsenal, AL
Prime Contractor: Northrop Grumman Space & Mission Systems Corporation
Contract type: CPIF (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



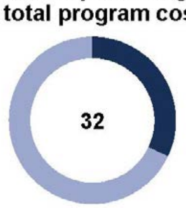
Software Development

(as of January 2021)

Approach: Agile

Average time of software deliveries (months)

Software percentage of total program cost



Software type

5 percent
Off the shelf

0 percent
Modified off the shelf

95 percent
Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (12/2009)	Latest (7/2020)	Percentage change
Development	$1,872.84	$3,733.77	+99.4%
Procurement	$4,031.12	$3,868.34	-4.0%
Unit cost	$19.95	$15.98	-19.9%
Acquisition cycle time (months)	80	148	+85.0%
Total quantities	296	479	+61.8%

Total quantities comprise 25 development quantities and 454 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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 IAMD manufacturing maturity metrics because the program has yet to finalize results of its production decision; however, the program stated that it tested a production-representative prototype in the system's intended environment.

IAMD Program

Technology Maturity and Design Stability

The IAMD program demonstrated that its four critical technologies are mature and that its system design is stable. According to program officials, the program finished a second limited user test in September 2020, which included two successful operational flight tests. These flight tests were originally planned to begin in May 2020 but were delayed until July 2020 due to COVID-19 mitigations, resulting in an associated delay to the completion of the limited user test. The program conducted the second test because it demonstrated an unsatisfactory performance of software for the Integrated Air and Missile Defense Battle Command System (IBCS)—which provides fire control and operational center capability—in 2016 during the initial limited user testing. The program expects the results from this test in April 2021.

The program identified several hardware performance issues during the recent limited user testing. Specifically, during the transportability and mobility portion of the testing, testers found that a trailer that provides storage space for IAMD's Integrated Collaborative Environment (ICE) components in transit and power, heating, and cooling to the ICE tent had multiple deficiencies, including deficiencies related to the tires, rail, bumper, and towing hardware. According to program officials, the program is conducting studies to determine the best path forward for a new design. In the meantime, it has planned modifications to the existing trailer. A new design will not be available prior to initial operational test and evaluation but will be available in time to support a fielding decision for the IBCS.

COVID-19 mitigation delayed limited user testing and resulted in an associated delay of 2 months to the low-rate initial production decision review, which was ultimately held in November 2020. The results of the decision review have yet to be finalized as of January 2021.

Production Readiness

The program completed a manufacturing readiness assessment in May 2020. The Army only included unique IBCS components in this assessment, although IAMD's architecture also includes various other components. As part of the assessment, the program identified risks for the prime contractor and its suppliers that could affect production readiness and recommended mitigation actions. According to program officials, this assessment showed that the prime contractor and its suppliers' production processes were approaching maturity. As a result, the Army concluded that the program was ready to enter into low-rate initial production. However, the assessment did not include a determination that all critical manufacturing processes were in statistical control, a practice that our prior work found helps programs lower the risk of costly production problems.

According to program officials, DOD weapon programs generally award a production contract to the same prime contractor that executed the development program. However, IAMD plans to competitively award the production contract in an effort to reduce production costs. To facilitate this award, currently planned for summer 2021, the program reported that it took ownership of the technical data package from the prime contractor at the end of development. According to the program, since the government obtained the technical data package and the hardware is comprised primarily of commercial-off-the-shelf hardware, the program deems the risk to the government of potentially having a new prime contractor acceptable.

Additionally, the program noted that, since IBCS contains a substantial amount of commercial-off-the-shelf electronics, potential obsolescence is and will remain a concern, but the program is continuously monitoring this risk. Program officials stated that they have a funded program effort to periodically refresh these electronic components, which, along with other efforts, is expected to help mitigate obsolescence in the short term.

Software and Cybersecurity

Program officials stated that all software issues found in the first limited user test were resolved, and there are no open software issues. Program officials noted the program is still going through a transition to Agile software development practices as part of a DOD Agile pilot program running from October 2020 to April 2021.

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: U.S. Army.

Improved Turbine Engine Program (ITEP)

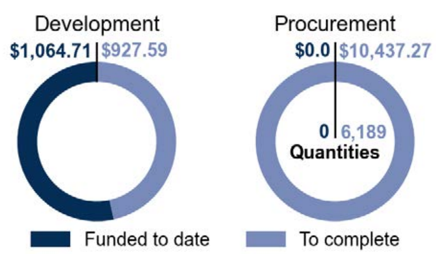
The Army's ITEP is developing a replacement engine for the Black Hawk and Apache helicopter fleets. The replacement engine is required to fit inside the existing engine compartments and is expected to provide up to a 50 percent increase in power, improved performance and fuel efficiency, enhanced reliability, and lower sustainment costs. 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. The Army plans to field the improved turbine engine in fiscal year 2027.

Program Essentials

Milestone decision authority: Army
Program office: Redstone Arsenal, AL
Prime Contractor: General Electric Aviation
Contract type: CPIF

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

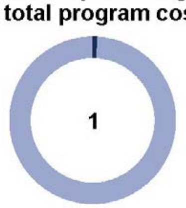
(as of January 2021)

Approach: Agile and Incremental

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

1 percent Off the shelf
0 percent Modified off the shelf
99 percent Custom software

The program said that post-development software deliveries will be dictated by field necessity.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (12/2019)	Latest (8/2020)	Percentage change
Development	$2,063.05	$1,992.3	-3.4%
Procurement	$10,435.39	$10,437.27	+0.0%
Unit cost	$2.01	$2.00	-0.6%
Acquisition cycle time (months)	102	102	+0.0%
Total quantities	6,258	6,258	+0.0%

Total quantities comprise 69 development quantities and 6,189 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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

ITEP's prime contractor assessed three of the five critical technologies—advanced inlet particle separator, compressor advanced aerodynamics, and hybrid bearings—as mature during the July 2020 critical design review based on their testing and application in its commercial products. The remaining two additive manufacturing processes are approaching maturity and will be verified during upcoming preliminary engine qualification and flight tests. Moreover, the program plans to have an independent technical risk assessment conducted prior to low-rate production in 2024 that will further validate the maturity of these technologies. However, this schedule does not leave much time to address potential maturity gaps and could delay the production decision or compel the program to use less efficient traditional manufacturing, in place of less mature additive manufacturing processes.

Early engine prototyping, initiated during a preceding program and continued through ITEP's technology maturation and risk reduction phase, reduced ITEP's program risk. The program has also released more than 90 percent of design drawings, indicating design stability. Moreover, the February 2020 engine fit tests confirmed that stability. However, the program did not complete other activities recommended by leading practices to ensure design stability, such as testing a system-level integrated prototype prior to its design review. According to the program office, ITEP's system-level prototype testing was scheduled for January 2021, but due to an optimistic contractor schedule and COVID-19 impacts, testing is now scheduled for October 2021, 15 months after design review. This delay increases the risk of design changes during system integration.

Production Readiness

Although an October 2018 review by the Office of the Under Secretary of Defense assessed the overall program manufacturing risk level as low, in June 2020, ITEP identified two new manufacturing risks. The first is related to a failure of a new production instrument to achieve the required manufacturing readiness level prior to design review. The second risk is related to delays in manufacturing the engine's front frame and oil tank hardware due to a delivery delay of two additive manufacturing machines. Two existing machines have been converted to the required configuration by the contractor, but this may not be enough to fully recover the resulting delays and may affect scheduling for future events even if the program remains within the baselined schedule.

Software and Cybersecurity

ITEP's software development plan, approved in August 2020, uses a combination of software development approaches—an Agile approach with a 4-to-6-week delivery cycle and a 7-to-8-month incremental approach—for the development of application and operating system software. ITEP plans to deploy software to end users—pilots and maintainers of Apache and Black Hawk platforms—in five releases from September 2020 to March 2024.

A cybersecurity tabletop exercise in February 2020 revealed avionics-related vulnerabilities and recommended that the program office separate the vulnerability penetration and the adversarial assessments by at least 6 months in addition to conducting a prevulnerability penetration test in the fourth quarter of fiscal year 2020. The timing would allow for resolution of findings prior to the actual vulnerability and adversarial assessments, as well as between the assessments, tentatively scheduled for July 2021. ITEP initiated prevulnerability planning activities in 2020 but did not set a test date. The pretest is dependent on an engineering software release scheduled for April 2021, increasing the likelihood of concurrency between the test event and assessments that could lead to risks if the program identifies deficiencies late in development.

Other Program Issues

According to the program office, due to COVID-19, the contractor is experiencing a delay in the delivery of two additive manufacturing machines, a reduction in engineering productivity, and rising labor rates. As of August 2020, the program office reported that the schedule was delayed by 3 months and the cost for fiscal year 2020 increased by $30.4 million. ITEP officials told us they are working on obtaining additional funding to offset these effects.

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 noted that despite the negative effects of COVID-19 restrictions on the commercial aviation sector, General Electric continues to execute ahead of the baselined schedule. In addition, the program office stated that during the COVID-19 pandemic, ITEP successfully conducted the software, engine control component, and engine system critical design reviews in a completely virtual environment.

Source: U.S. Army.

Future Long-Range Assault Aircraft (FLRAA)

The Army's FLRAA program plans to develop and produce a medium-size assault and utility rotorcraft to support the Army's Future Vertical Lift (FVL) capability needs. The Army expects FLRAA to deliver speed, range, agility, endurance, and sustainability improvements as compared to the Black Hawk helicopters that it is intended to augment. The Army also expects the program to provide combatant commanders with tactical capabilities at operational and strategic distances.

CONCEPT
- 3/20 Contract award
- 1/21 GAO review
- 4-6/21 Request for proposals
- 4/22 Initial design concept review
- 4-6/22 Design and development contract award
- 6/23 Preliminary design review

SYSTEM DEVELOPMENT
- 7/23 Development start
- 3/24 Critical design review
- 7-9/25 Prototype first flight

PRODUCTION
- 10-12/27 Low-rate decision
- 2030 First unit equipped

Program Essentials

Milestone decision authority: Army

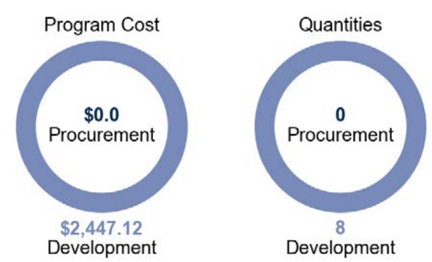
Program office: Huntsville, AL

Contractors: Bell Textron, Inc.; Sikorsky Aircraft Corporation

Contract type: cost reimbursable with cost share (conceptual prototype design and risk reduction) (using other transaction authority)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



The estimated cost reflects funding for fiscal years 2018-2025. The program has yet to determine planned procurement quantities.

Software Development

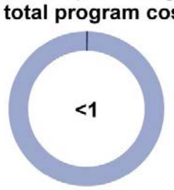
(as of January 2021)

Approach: Incremental, Agile, Model-Based Design

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

25 percent Off the shelf

25 percent Modified off the shelf

50 percent Custom software

According to the program office, the Army has yet to fully determine system software needs and costs.

Current Status

In March 2020, the Army selected two contractors to develop conceptual prototype designs for air vehicles and subsystems, among other design elements, under an existing other transaction agreement. To reduce risk, the Army is conducting trade studies for hundreds of requirements. Program officials said they also have asked contractors to assess key requirements and design attributes to help optimize cost, performance, and schedule.

Program officials stated that they intend the conceptual prototype designs to inform the competitive award of a single contract in 2022 that supports a preliminary design review and virtual prototyping. Officials anticipate that ongoing design efforts and planned subsystem design reviews will mature designs to a level typical for preliminary design review prior to the contract award. Following the award, the program plans to conduct rapid virtual prototype development activities through the middle-tier acquisition pathway, which officials said would allow for increased knowledge before finalizing formal requirements. In 2023, the program plans to transition to a major capability acquisition.

Attainment of Technology Maturation Knowledge (as of January 2021)

Conduct competitive prototyping	◐	Complete independent technical risk assessment	◐
Validate requirements	◐	Complete preliminary design review	◐

● Knowledge attained, ◐ Knowledge planned, ○ Knowledge not attained, … Information not available, NA Not applicable

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 said it is focused on optimizing FLRAA design and requirements, with the program currently executing plans to award agreements to the current contractors in March 2021 for a second phase of conceptual design and risk reduction. These agreements are intended to result in updated designs and requirements to support a competitive contract award to a single prime contractor in 2022. Additionally, the program office said its approach to risk reduction and design facilitates an accelerated schedule that is intended to enable the first Army unit to receive these new aircraft by 2030.

Source: U.S. Army.

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 and fire control system, and a new air defense launcher and interceptor missile. We previously assessed IFPC efforts to provide an interim capability, which is now a separate program.

CONCEPT

- 3/14 Program start
- 1/21 GAO review
- 3/21 Transition to middle tier acquisition
- 4-5/21 Live-fire demonstration
- 8/21 Contract award
- 7-9/23 Fielding of initial prototype
- 6/26 Initial capability

Program Essentials

Milestone decision authority: Army

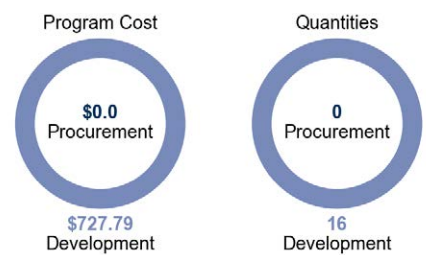
Program office: Huntsville, AL

Prime contractor: TBD

Contract type: TBD (using other transaction authority)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

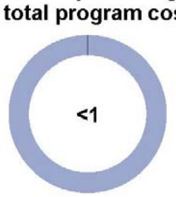
(as of January 2021)

Approach: Information not available

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

Information not available

Program officials stated they cannot assess software at this time because it is too early in the program's life cycle.

Current Status

IFPC Inc 2 plans to acquire a new air defense launcher and interceptor to integrate with the Army's existing Sentinel radar and the Integrated Air and Missile Defense Battle Command System (IBCS), which another program is in the process of developing. Program officials stated that they received four proposals in May 2020 for the new launcher and interceptor, two of which remain in consideration as of January 2021. The Army plans to conduct a competitive live-fire demonstration in spring 2021 before awarding a prototype project other transaction agreement in August 2021. Program officials stated that the Army plans to field the first IFPC Inc 2 system prototypes in late 2023.

The Army plans to officially designate the program as a middle-tier acquisition rapid prototyping effort in March 2021 to develop, test, and qualify prototypes. Program officials said that the program is currently on schedule for fielding the first system in 2023 but acknowledge there is little margin for error. According to the Army, IBCS integration with potential IFPC Inc 2 solutions is a source of risk for the program. The Army stated that mitigating this risk requires the two competing contractors to design and integrate the launcher and interceptor to work in an IBCS architecture and to develop and deliver technical data packages in a timely manner for the live-fire demonstration. The technical data packages provided by the contractors are to support digital simulations of the IFPC system and verify that the contractors' launchers and interceptors are successfully integrated into the IBCS. Any delays in delivering these data packages risks delays to the program schedule.

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 integration with IBCS remains a top priority.

Source: U.S. Army.

Precision Strike Missile (PrSM)

The Army's Precision Strike Missile (PrSM) is a ballistic missile designed to attack area and point targets beyond ranges of 400 kilometers. The Army anticipates that each PrSM missile container will hold two missiles for launch, which is double the legacy missile's capacity. The Army plans to design PrSM as one of a family of munitions for compatablity with existing rocket launcher systems and to comply with statutory requirements for insensitive munitions and DOD policy on cluster munitions.

Program Essentials

Milestone decision authority: Army

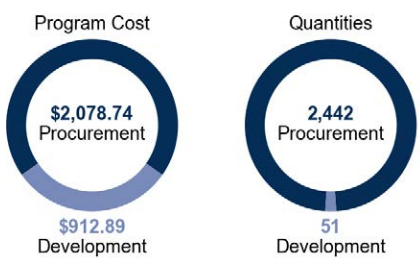
Program office: Redstone Arsenal, AL

Prime contractor: Lockheed Martin

Contract type: CS (technology maturation and risk reduction) (using other transaction authority)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Agile and Waterfall

Average time of software deliveries (months)

Software percentage of total program cost

Software type

2 percent Off the shelf

0 percent Modified off the shelf

98 percent Custom software

Program officials said they have yet to determine the percentage of software to total cost.

Current Status

During 2020, PrSM continued to pursue competitive prototyping to mature technologies and to reduce risk before entering system development, planned for June 2021. As of April 2020, the Army reported that Lockheed Martin had three successful flight tests of its prototype missile, while Raytheon withdrew from competition due to its inability to conduct a successful test flight. Consequently, the Army will continue PrSM's technology maturation with only Lockheed Martin. As a result of the testing community's feedback, Army officials told us that they accelerated their production schedule by several months and also plan to demonstrate PrSM's maximum range in a flight test during fiscal year 2021 at Vandenberg Air Force Base.

The Army reported contracting with subject matter experts to conduct an independent technology review assessment of PrSM. These experts found that PrSM's critical technologies were generally approaching full maturity. In July 2020, the Army concurred with this assessment and stated that PrSM could proceed to system development. According to program officials, competitive prototype testing contributed to this level of maturity and PrSM plans to achieve full maturity by its entry into development.

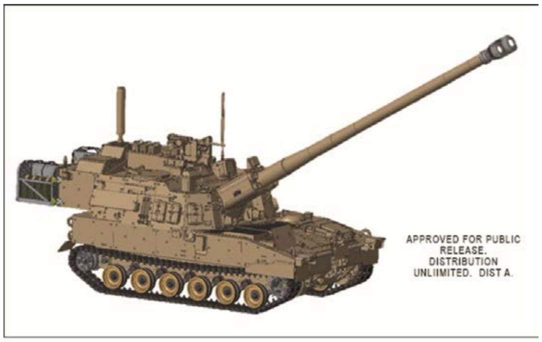
Attainment of Technology Maturation Knowledge (as of January 2021)

Conduct competitive prototyping	●	Complete independent technical risk assessment	◐
Validate requirements	◐	Complete preliminary design review	●

● Knowledge attained, ◐ Knowledge planned, ○ Knowledge not attained,
… Information not available, NA Not applicable

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, a 2020 Army assessment confirmed critical technologies are nearing maturity, and the program's overall risk is low. It anticipates that PrSM requirements will be validated, the Office of the Secretary of Defense will conduct an independent technology readiness assessment, and updated affordability and detailed schedule analyses will occur prior to development start.



Source: U.S. Army.

Extended Range Cannon Artillery (ERCA)

The Army's ERCA program is an upgrade to the M109 self-propelled howitzer intended to improve lethality, range, and reliability. The ERCA program, using the middle-tier rapid prototyping pathway, will add armament, electrical systems, and other upgrades to the existing vehicle. Since our last assessment, the program changed its acquisition strategy. Rather than entering a second rapid prototyping effort, as previously planned, it now plans to deliver future rate of fire improvements after transitioning to the major capability acquisition pathway.

9/18	10/18	7/19	8/19	1/21	5/21	1-3/22	11/22	9/23	10/23
MTA initiation	MTA funds obligated	Contract award	Preliminary design review	GAO review	Prototype design review	Critical design review	Operational demonstration	First unit issued	Expected MTA completion/ 5 years since MTA funds obligated

Program Essentials

Decision authority: Army

Program office: Warren, MI

Prime contractor: BAE Systems, integrated by the Army's Development Command, Armaments Center

MTA pathway: Rapid prototyping

Contract type: CPFF (development) (using other transaction authority)

Estimated Middle-Tier Program Cost and Quantities

(fiscal year 2021 dollars in millions)

With the Army's change in acquisition strategy, ERCA absorbed some costs previously planned for a second rapid prototyping effort.

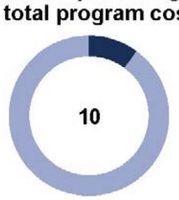
Software Development

(as of January 2021)

Approach: Agile

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent
Off the shelf

90 percent
Modified off the shelf

10 percent
Custom software

According to program officials, the modified off-the-shelf software is government-owned from the M109A7 program.

Program Background and Transition Plan

The Army initiated ERCA using the middle-tier acquisition rapid prototyping pathway in September 2018. The program has an objective of building 20 prototypes beginning in fiscal year 2021. The rapid prototyping effort—previously known as Increment 1C—is projected to end in October 2023, at which point the Army plans to issue 18 of the prototypes to an artillery battalion. In March 2020, the program demonstrated the system's extended range capability.

Transition Plan: Transition to the major capability acquisition pathway with entry at production.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	◐	Demonstrate all critical technologies in form, fit, and function within a realistic environment	◐
Complete system-level preliminary design review	●	Release at least 90 percent of design drawings	◐
Test a system-level integrated prototype	◐	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	⊗
Demonstrate critical processes on a pilot production line	⊗	Test a production-representative prototype in its intended environment	◐

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, … Information not available, NA Not applicable

ERCA Program

Updates to Program Performance and Program Business Case

The ERCA program faces multiple challenges, including test delays due in large part to the pandemic and delays in the delivery of software due to cybersecurity work, which contributed to cost growth. As of August 2020, the program office delayed completion of developmental testing by about 9 months to March 2023, 3 months before the expected completion of all 20 prototypes. Any deficiencies discovered during testing could require rework before the planned operational assessment, which could increase costs. Program officials said precautions taken for COVID-19 are the primary cause of schedule delays and resulted in a testing-related vehicle arriving 4 months later than planned. Officials acknowledged that current time frames leave little room for further delays.

The program has yet to conduct a formal technology risk assessment, which is an element of its business case. Program officials plan to conduct such an assessment in March 2021—a year later than previously planned and nearly 3 years since program initiation. We have updated our Key Elements of a Business Case table to reflect the change to the technical risk assessment after receiving further detail from the program office this year. The program delayed its planned prototype design review by 8 months to May 2021, in part to help ensure the program has more complete information about the maturity of technologies and plans for any further maturation, according to program officials. The prototype design review is intended to confirm its configuration and safety.

The program currently has a “rough order of magnitude” cost estimate, which an Army-level cost and economic analysis office certified in August 2019 for use in evaluating options. However, in January 2021, program officials told us that the estimate does not reflect the program’s current structure and has not been independently assessed. We have updated our Key Elements of a Business Case table to reflect the change to the cost estimate. According to program officials, the 40 percent cost growth since our last assessment is largely due to the change in acquisition strategy that resulted in the program absorbing work related to rate of fire improvements previously planned for a second rapid prototyping effort, formerly known as Increment 2.

Technology

The program office reported that its critical technologies are generally less mature than planned. Previously, program officials estimated the technologies would near maturity by mid-fiscal year 2020. As of October 2020, program officials said that two of the eight current technologies are approaching maturity while six, including the gun mount and cradle, are immature. Program officials anticipate the eight critical technologies will be approaching maturity in March 2021 and will be fully mature prior to the completion of the rapid prototyping effort in 2023. In addition to the eight technologies the program is responsible for maturing, ERCA relies on a projectile developed by another Army program office to achieve its required ranges.

Software Development and Cybersecurity

Program officials reported to us that they use Agile software development to develop a mix of customized government off-the-shelf and custom software to support ERCA fire control software, and completed one software delivery. Program officials said the next delivery is expected in 6 months. However, as we reported last year, the program’s planned deliveries to end users continue to be less frequent than industry’s Agile practices encourage. Program officials said software development is taking longer than planned because ongoing cybersecurity evaluations require the same resources; however, they also said cybersecurity efforts will be beneficial in the long term.

Transition Plan

The Army plans to transition ERCA to the major capability acquisition pathway with entry at production in fiscal year 2024. While the program plans to transition with mature technologies, it also plans to complete its demonstration of critical manufacturing processes after this decision, counter to leading practices. Our prior work shows that programs beginning production without this knowledge face increased risk of missing cost, schedule, and quality targets.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that the Army is modifying the acquisition strategy for the ERCA program and is committed to maturing technology to provide the extended capability to the Army. It said the Army is first prototyping the ERCA range effort (previously referred to as Increment 1C), which focuses on extending the range of the self-propelled howitzer fleet, and is then modifying the ERCA range platform to increase the rate of fire (formerly Increment 2). The program also stated that the prototyping effort is ongoing and will deliver seven prototypes in fiscal year 2021 for testing in fiscal years 2021 through 2023. Additionally, it noted that testing has been delayed primarily due to COVID-19. According to the program office, it has a formal risk review process and shares the risks with Army senior leaders. It also stated that it is working to support a production decision by the end of fiscal year 2023.

Source: Microsoft, Redmond, WA.

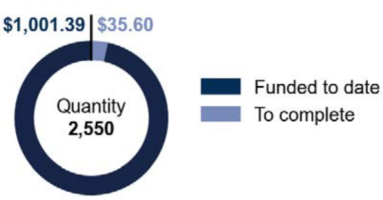
Integrated Visual Augmentation System (IVAS)

The Army's IVAS, a program using the middle-tier acquisition rapid prototyping and fielding paths, seeks to improve warfighter close combat capabilities. This assessment reviews the rapid prototyping effort. IVAS is expected to provide a single platform that allows the warfighter to fight, rehearse, and train with the use of 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 through a 24/7 situational awareness tool.

Program Essentials

Decision authority: Army
Program office: Fort Belvoir, VA
Prime contractor: Microsoft
MTA pathway: Rapid prototyping
Contract type: FFP (development) (using other transaction authority)

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2021 dollars in millions)



Cost and quantity only reflect the IVAS rapid prototyping effort.

Software Development (as of January 2021)

Approach: Agile

Average time of software deliveries (months)

Software percentage of total program cost

Software type

0 percent
Off the shelf

100 percent
Modified off the shelf

0 percent
Custom software

According to program officials, software cost cannot be distinguished from firmware and hardware costs under the IVAS firm-fixed-price other transaction agreement.

Program Background and Transition Plan

The Army initiated IVAS as a program using the middle-tier acquisition rapid prototyping pathway in September 2018. In November 2018, the Army used other transaction authority to award an agreement to Microsoft, which, according to program officials, is intended to deliver a total of 2,550 prototypes in four capability sets, each to provide increasing capabilities. As of November 2020, Microsoft delivered 950 systems over three capability sets. The fourth capability set of 1,600 systems is scheduled for delivery in April 2021. The Army approved the start of the IVAS middle-tier rapid fielding effort in December 2020. IVAS also plans to continue development under the existing rapid prototyping effort through September 2023.

Transition Plan: Start of a new middle-tier acquisition rapid fielding effort approved in December 2020.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	Demonstrate all critical technologies in form, fit, and function within a realistic environment	●
Complete system-level preliminary design review	●	Release at least 90 percent of design drawings	⊗
Test a system-level integrated prototype	●	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	⊗
Demonstrate critical processes on a pilot production line	●	Test a production-representative prototype in its intended environment	⊗

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, … Information not available, NA Not applicable

We assessed IVAS's planned knowledge by MTA transition as of December 2020 because that date reflects the program's rapid fielding decision approval by the Army Acquisition Executive.

IVAS Program

Updates to Program Performance and Program Business Case

The IVAS rapid prototyping effort has most business case elements but continues to proceed without an independent cost estimate or formal schedule risk assessment and does not plan to complete them for the rapid prototyping effort.

IVAS demonstrated the second capability set in November 2019. Based on this demonstration, the office of the Director, Operational Test and Evaluation (DOT&E) made a number of recommendations to the Army—such as improving several technologies and software reliability, and measuring IVAS against existing military equipment. Program officials said they took steps to address these recommendations for the third capability set and expect to continue to develop solutions for final verification before Initial Operational Test and Evaluation (IOT&E) by August 2021.

According to program officials, IVAS delayed the demonstration of the third capability set from July 2020 to October 2020 due to COVID-19-related travel restrictions and supply chain disruptions. However, these delays did not impact the program's ability to obtain a rapid fielding decision in December 2020, as planned. The program updated its completion date from November 2020 to September 2023 and total estimated costs are now $26.44 million more than we reported last year. Program officials explained that the change in the completion date and cost were an error in their prior reporting, not a change to the program's planned schedule or cost. The program did not previously report these values because they are for rapid prototyping activities that occur after the program begins rapid fielding.

Technology

Program officials reported that all 15 critical technologies were mature at the second capability set's demonstration in November 2019. The program expects to further mature these technologies for the militarized capability set three demonstrated in October 2020. DOT&E reported continued challenges with the color waveguide display, stating that during testing of the second capability set, the display module continued to limit the field of view and light emissions were too bright for night operation. IVAS officials said they implemented design changes with the third capability set and expect to continue to develop solutions for final verification before IOT&E in August 2021.

Software Development and Cybersecurity

IVAS officials reported they use an Agile software development approach and adopted Microsoft's development practices to deliver customized commercial software. Software is delivered in small segments of functionality every 3 weeks to end users for feedback. Working software is deployed to warfighters for evaluation at each of the four capability set demonstrations. DOT&E officials found needed software reliability improvements, and IVAS officials said they focused significant attention on improving software reliability and expect to continue to develop improvements before IOT&E.

IVAS officials expect the program's cybersecurity plan to be completed by March 2021. The program will conduct a Cooperative Vulnerability and Penetration Assessment on capability set four units, with results to feed into system updates in preparation for a planned April 2021 operational testing adversarial assessment and for the first unit equipped in September 2021 under the rapid fielding effort.

Transition Plan

The Army Acquisition Executive and the Under Secretary of Defense for Acquistion and Sustainment approved the IVAS rapid fielding effort in December 2020 and January 2021, respectively. The program concurrently plans to continue work under the rapid prototyping effort through September 2023. Contrary to leading practices, the program plans to demonstrate a stable product design and mature critical manufacturing processes in April 2021, after the rapid fielding decision. Our prior work shows that programs beginning production without this type of knowledge face increased risk of not meeting cost, schedule, and quality targets. Program officials said they consider the risk of not achieving this knowledge in April 2021 to be low. The Under Secretary of Defense for Acquistion and Sustainment's approval of the rapid fielding effort is conditional on verifying the correction of certain technical deficiencies prior to IOT&E in August 2021.

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 IVAS is one of the Army's first programs to use the middle-tier acquisition pathway, and it continues to work aggressively to deliver next generation capabilities at the speed of relevance to the close combat force. The program office stated that it expects these capabilities will change how close combat soldiers operate in various domains. The program office stated it overcame significant obstacles, including supply-chain issues due to COVID-19, to build the first military-grade IVAS unit within 18 months from contract award and achieve a rapid fielding decision in December 2020. The program office stated that IVAS is on track to meet its first unit equipped milestone in the fall of 2021.

Source: U.S. Army.

Lower Tier Air and Missile Defense Sensor (LTAMDS)

The Army's LTAMDS, a middle-tier acquisition effort, is planned as a multifunction radar that will replace the legacy Patriot radar. The legacy radar faces changing threats, growing obsolescence, and increasing operational costs. The Army expects that the LTAMDS, as the 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, among other things. The Army plans to deploy the system worldwide.

- 7/17 Concept definition start
- 9/18 MTA initiation
- 11/18 MTA funds obligated
- 9/19 Concept definition end
- 10/19 Contract award
- 1/21 GAO review
- 7-9/21 Qualification testing start
- 11/21 Start developmental test and evaluation
- 7-9/22 Initial capability
- 9/22 Expected MTA completion
- 11/23 5 years since MTA funds obligated

Program Essentials

Decision authority: Army

Program office: Redstone Arsenal, AL

Prime contractor: Raytheon

MTA pathway: Rapid prototyping

Contract type: FFP (build and test prototypes) (using other transaction authority)

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2021 dollars in millions)

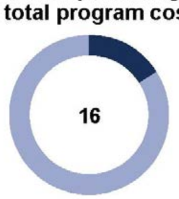
Software Development (as of January 2021)

Approach: Agile

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

0 percent Off the shelf

74 percent Modified off the shelf

26 percent Custom software

Program Background and Transition Plan

The Army initiated LTAMDS as a middle-tier acquisition in 2018 with plans to complete prototyping by the end of fiscal year 2022. In October 2019, the Army awarded Raytheon a contract to build, test, and deliver six production representative prototypes. According to program officials, the program demonstrated an early system prototype for the first time in October 2020, which they said confirmed the functionality of the integrated radar, demonstrated compliance against scaled requirements, and used the same hardware expected in the deliverable prototype systems.

Transition Plan: Transition to a new middle-tier acquisition rapid fielding effort.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	○	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	Demonstrate all critical technologies in form, fit, and function within a realistic environment	◐
Complete system-level preliminary design review	●	Release at least 90 percent of design drawings	●
Test a system-level integrated prototype	●	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	⊗
Demonstrate critical processes on a pilot production line	⊗	Test a production-representative prototype in its intended environment	◐

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, … Information not available, NA Not applicable

LTAMDS Program

Updates to Program Performance and Program Business Case

The LTAMDS program will not have completed all the elements of a sound business case before its next major milestone—qualification testing—in the fourth quarter of fiscal year 2021. Program officials stated that they completed a schedule risk assessment in February 2020 that focused on prototype delivery and expect to complete a full schedule risk assessment, which will include external program integration activities, in early 2021. Officials said they assessed technology risk in 2019 during technology demonstration and design review, and will not complete a formal technology risk assessment until the program enters the major capability acquisition pathway.

In February 2020, the program office completed its initial cost estimate, projecting an approximately $600 million cost for the rapid prototyping effort. Program officials stated that they plan to meet with Army cost analysts in March 2021 to reconcile updates to the program's initial cost estimate and the Army's draft independent cost estimate. According to program officials, such reconciliation will occur annually until the program enters the major capability acquisition pathway where it will develop a baseline for budgeting and planning across its life cycle.

Technology

The program plans to begin qualification testing in the fourth quarter of fiscal year 2021 to assess whether the prototype can operate in environmental conditions such as wind and rain, among others, without damage or performance degradation. Program officials stated that developmental testing and evaluation will occur in November 2021 and will assess the prototype's capabilities in a variety of air and missile defense missions in its operational environment. Warfighters—LTAMDS's end users—will operate the prototype in the final phase of testing.

Program officials stated that they replaced earlier versions of four critical technologies with new, less mature ones after the Army placed more stringent requirements on the LTAMDS in 2019. Officials noted that the program plans to demonstrate the maturity of these technologies—three amplifiers and a signal limiter—through ground, tracking, and missile flight tests in an operational environment during developmental testing. As a result, program officials expect these technologies to reach maturity in the third quarter of fiscal year 2022

Software Development and Cybersecurity

Program officials stated that all planned software deliveries remain on schedule. The program said it completed the first of three planned software increments in September 2020 and plans to complete the final software increment in the fourth quarter of fiscal year 2021. The program uses an Agile approach to develop custom software to run on custom hardware through monthly sprints. Officials said that software planning and testing has occurred within developer laboratories and government test facilities, but they will not field working software to warfighters until the fourth quarter of fiscal year 2022. According to program officials, warfighters will then provide feedback through open discussion with user representatives, the program's software team, and the software developer. This approach differs from industry's Agile practices—as reported by the Defense Innovation Board—which encourage working software delivery to users on a continuing basis—as frequently as every 2 weeks—so that feedback can focus on efforts to deploy greater capability.

The program has an approved cybersecurity strategy and plans to conduct cybersecurity activities throughout its life cycle. Program officials told us that they plan to conduct four major cybersecurity events in fiscal year 2022. LTAMDS officials noted the program works with stakeholders to identify warfighters' training needs and to develop actionable guidance to mitigate and recover from cyberattacks.

Transition Plan

LTAMDS officials plan to transition LTAMDS to a middle-tier acquisition rapid fielding effort to field 16 radars after completing rapid prototyping in 2022. The program then plans to transition to the major capability acquisition pathway at the production and deployment phase and field the final 65 radars. However, it does not plan to demonstrate several key production knowledge aspects prior to the rapid fielding pathway transition. Our work shows programs lacking this knowledge at production start face increased risk of missing cost, schedule, and quality targets. Program officials indicated they plan to meet all planned knowledge criteria before transitioning from the rapid fielding pathway into the major capability acquisition pathway.

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 has taken steps to reduce production risks and has drafted a production readiness plan that describes activities to ensure LTAMDS prototype hardware is fabricated, integrated, and tested in accordance with all requirements.

Source: U.S. Army.

Mobile Protected Firepower (MPF)

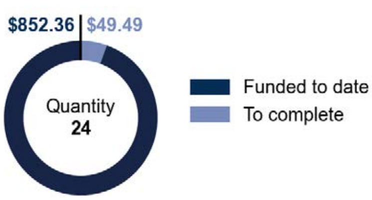
The Army's MPF, a program using the middle-tier acquisition pathway, is intended as a new direct fire capability for the infantry brigade combat team. Infantry brigades aim to employ MPF across a range of military operations in direct support of infantry. The Army requires MPF to be air-transportable to enable initial entry operations and expects it to work in conjunction with other vehicles such as the Light Reconnaissance Vehicle and Ground Mobility Vehicle. MPF is one of several vehicles in the Next Generation Combat Vehicle portfolio.

9/18	12/18	6/19	8/20	1/21	6/22	9/23
MTA initiation/ MTA funds obligated	Contract award	Design maturity review	First vehicle to test	GAO review	Expected MTA completion	5 years since MTA initiation/ MTA funds obligated

Program Essentials

Decision authority: Army
Program office: Warren, MI
Prime contractor: BAE Systems; General Dynamics Land Systems
MTA pathway: Rapid Prototyping
Contract type: FFP

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2021 dollars in millions)

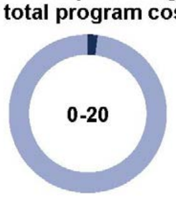


Software Development
(as of January 2021)

Approach: Incremental

Average time of software deliveries (months)

Software percentage of total program cost



Software type
92 percent Off the shelf
5 percent Modified off the shelf
3 percent Custom software

Program officials said the above time frame reflects the initial software release and subsequent deliveries that are made as required for the platform.

Program Background and Transition Plan

The Army initiated MPF as a middle-tier rapid prototyping effort in September 2018 with an objective to complete prototyping by June 2022. In December 2018, the program awarded contracts to two companies to each develop 12 preproduction vehicles for test and evaluation, which are prototypes, totaling 24 prototypes to demonstrate nearly all required capabilities in an operational environment by the end of the middle-tier effort.

Transition Plan: Transition to the major capability acquisition pathway with entry at production.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	●	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	Demonstrate all critical technologies in form, fit, and function within a realistic environment	NA
Complete system-level preliminary design review	●	Release at least 90 percent of design drawings	●
Test a system-level integrated prototype	●	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	⊗
Demonstrate critical processes on a pilot production line	⊗	Test a production-representative prototype in its intended environment	◐

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned, … Information not available, NA Not applicable

For planned knowledge by MTA transition, we did not assess MPF critical technologies because the program office stated that the system does not have any.

MPF Program

Updates to Program Performance and Program Business Case

Since last year, the program reported about a $40 million decrease in planned costs that, according to the program, primarily resulted from reduced contract pricing achieved through the employment of competition and efficiencies in planned testing and program management efforts. The remaining business case elements have remained stable since last year's report. MPF compressed its testing schedule due to delays to the start of testing of the contractors' prototype designs. According to program officials, COVID-19 and integration challenges delayed the contractors' prototype deliveries. While the program has a plan in place to mitigate these delivery delays, further delays to testing will increase the risk that the program's planned completion date will not be achieved. Program officials stated that the program had planned for each of the two contractors to begin delivering 12 prototypes by the second quarter of fiscal year 2020, with warfighters assessing each contractor's vehicles separately over the course of 3 months. However, contractor prototype deliveries did not start until the third quarter of fiscal year 2020, which delayed the start of testing to August 2020. The MPF contractors plan to deliver the remaining prototypes for testing as they are built and the Army expects these deliveries will continue throughout fiscal year 2021.

To accommodate the delays, the program plans to test the prototypes from each contractor as they are received, leveraging remaining time to complete as much testing as possible to support the contractor down-select and planned low-rate production decisions. Program officials told us the program plans to complete all tests within the original schedule. In June 2019, the program held its design maturity review. According to the program office, the review demonstrated that the system will meet suitability, performance, affordability, supportability, manufacturability, and schedule goals.

Technology

As we reported last year, the Army determined that MPF does not have any critical technologies because its technologies already exist and are approaching maturity or are mature. However, program officials continue to monitor system integration efforts, which they have identified as a significant risk.

Software Development and Cybersecurity

The program reported that software development was a medium risk based on the potential limited availability of software labs and because the program has already experienced testing delays. Under the incremental software development approach, contractors are to deliver three to five software releases during the MTA phase. According to the program, as of December 2020, one of the two contractors had delivered its first software release. According to the program office, users will provide feedback on software systems during tests in the fourth quarter of fiscal year 2021. The program plans some cybersecurity tests during the rapid prototyping effort. However, some network components that the program will rely on are still under development, and full cybersecurity testing in an operational environment will not occur until after the program transitions to the major capability acquisition pathway.

Transition Plan

The MPF program plans to transition to the major capability acquisition pathway with entry at production in June 2022 with a single vendor. The Army's goal is to equip the first MPF unit in fiscal year 2025. However, the program does not plan to meet our leading acquisition practices for acquiring knowledge prior to beginning production. For example, the program will not demonstrate critical processes on a pilot production line and plans to enter production before manufacturing process are demonstrated to be stable, adequately controlled, and capable. This could increase risk that the program may not be able to meet its cost, schedule, and quality targets.

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 continues to execute an MTA rapid prototyping effort using competition between two contractors. It noted that the program has achieved acquisition knowledge including requirements, an acquisition strategy, and assessments for technology, cost, and schedule. The program office noted that the second contractor has provided its first software release since our initial review. The program office stated that schedule risk has remained high since the inception of the program, but that the program has a mitigation plan that includes the use of competition, fixed-price contracts, and low risk technologies. According to the program, MPF was well prepared to capitalize on the designation as an MTA effort because the program had already developed a great deal of the documentation required of a Major Defense Acquisition Program. The program noted that a highlight of the program's schedule will be a 5-month, unit-led Soldier Vehicle Assessment event that provides a warfighter touch point to assess the competitive vehicle prototypes.

Source: U.S. Army.

Optionally Manned Fighting Vehicle (OMFV)

The Army's OMFV, a middle-tier rapid prototyping acquisition, is planned as the Armored Brigade Combat Team solution to maneuver the warfighter on the battlefield to advantageous positions for close combat. In addition, the OMFV is intended to allow for manned or remote operation. The OMFV is intended to replace the existing Bradley Fighting Vehicle, a legacy vehicle that no longer has the capacity to integrate new technologies the Army needs.

9/18	1/21	7/21	8/23	8/24	9/24	7/26
MTA initiation	GAO review	MTA funds obligated/ Contract award	Preliminary design review	Critical design review	Expected MTA completion	5 years since MTA funds obligated

Program Essentials

Decision authority: Army
Program office: Detroit Arsenal, MI
Prime contractor: TBD
MTA pathway: Rapid prototyping
Contract type: FFP

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2021 dollars in millions)

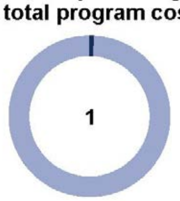
Software Development

(as of January 2021)

Approach: Information not available

Average time of software deliveries (months)

Information not available

Software percentage of total program cost	Software type
	Information not available

The program reported that the software approach and type has yet to be determined.

Program Background and Transition Plan

The OMFV program planned to obligate funds in March 2020 with the award of contracts to up to two vendors for delivery of 14 prototype vehicles each by 2022 and an objective to complete prototyping in fiscal year 2023. In January 2020, the Army canceled the contract solicitation, citing industry difficulty in achieving the program's desired requirements within the planned time frame. Under an updated, five-phase acquisition approach, including the middle-tier portion of the program and a subsequent major capability pathway effort, the program plans to award the first set of design contracts in July 2021. The program continues to follow the Army's approach to OMFV, which initiates the 5-year time frame at the first obligation of funds.

Transition Plan: Transition to the major capability acquisition pathway with entry at system development.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	○	○
Approved middle-tier 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

Planned Knowledge by MTA Transition

Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	…	Demonstrate all critical technologies in form, fit, and function within a realistic environment	…
Complete system-level preliminary design review	◐	Release at least 90 percent of design drawings	NA
Test a system-level integrated prototype	NA	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned,
… Information not available, NA Not applicable

We assessed the current status of OMFV business case elements based on the updated acquisition approach, with the exception of the cost estimate, which remained the same under the new approach. For knowledge by MTA transition, we did not assess OMFV critical technologies because the Army has not identified them; or design and manufacturing knowledge because those metrics are not applicable to programs transitioning at system development.

OMFV Program

Updates to Program Performance and Program Business Case

Over the past year, the OMFV program worked to realign key business case elements with its new acquisition approach. In January 2020, the Army cancelled OMFV's solicitation in order to revisit the requirements, acquisition strategy, and schedule before awarding contracts. Subsequently, the Army developed a new, five-phase acquisition approach. Under this approach, the program office provided desired program characteristics to industry but does not plan to finalize requirements until it receives the vendors' design proposals in December 2026 to inform the production contract decision.

The Army is developing a full acquisition strategy document and expects to approve it by June 2021, according to program officials. They now plan to award concept design contracts to up to five vendors in July 2021, initiating the 5-year middle-tier time frame, over 1 year later than initially planned. The Army then plans to award detailed design contracts to up to three vendors in early 2023.

The Army plans to update its existing life-cycle cost estimate throughout the program effort. The current independent assessment was developed during the prior approach. As we previously reported, the original cost estimate did not fully account for uncertainties in the program. Additionally, the program plans to complete a formal schedule risk assessment in August 2023. However, the preliminary schedule for fielding OMFV to the warfighter shifted the Army's goal for the first fielded unit from 2026 to 2029.

Technology

The Army has not identified OMFV's critical technologies. The Army plans to evaluate concept designs, allowing the program to identify new technologies that may expand program capabilities and define critical technologies by August 2023. In February 2023, the Army plans to evaluate the risks associated with technologies for each of the vendors to support the award of detailed design contracts.

The Army's new acquisition approach might mitigate some technical risk we identified in past work. Previously, the Army planned to begin system development prior to conducting a preliminary design review. Under the new approach, the Army plans to hold a preliminary design review in the summer of 2023 as part of the detailed design phase, an approach more consistent with our leading practices and one that lessens the risk of cost growth and schedule delays.

Software Development and Cybersecurity

Details of the program's software development effort have yet to be determined since they are dependent on the design(s) selected and the vendors' software development plans. The program will require vendors to produce this software development plan as part of concept design contracts planned for award in July 2021. The program plans to develop and finalize a cybersecurity strategy in early 2024.

Transition Plan

The Army plans to transition OMFV to a new, major capability acquisition program at system development in 2024. According to officials, the planned acquisition strategy will clarify the program office's business case for transitioning OMFV to the major program pathway.

Other Program Issues

The Army plans several steps that officials anticipate will improve its validation of program requirements and design. For example, the five-phase effort allows the Army to reassess the prototyping process at decision points throughout development. In addition, the Army plans to incorporate a modular open systems architecture into OMFV to allow for incremental upgrades of capability. Similarly, under the revised approach, the program office scheduled several opportunities for warfighter touchpoints to review the program and provide feedback, largely during scheduled design phases. These reviews of the design(s) will culminate with a critical design review in the fall of 2024 to support the acquisition decisions leading into system demonstration efforts.

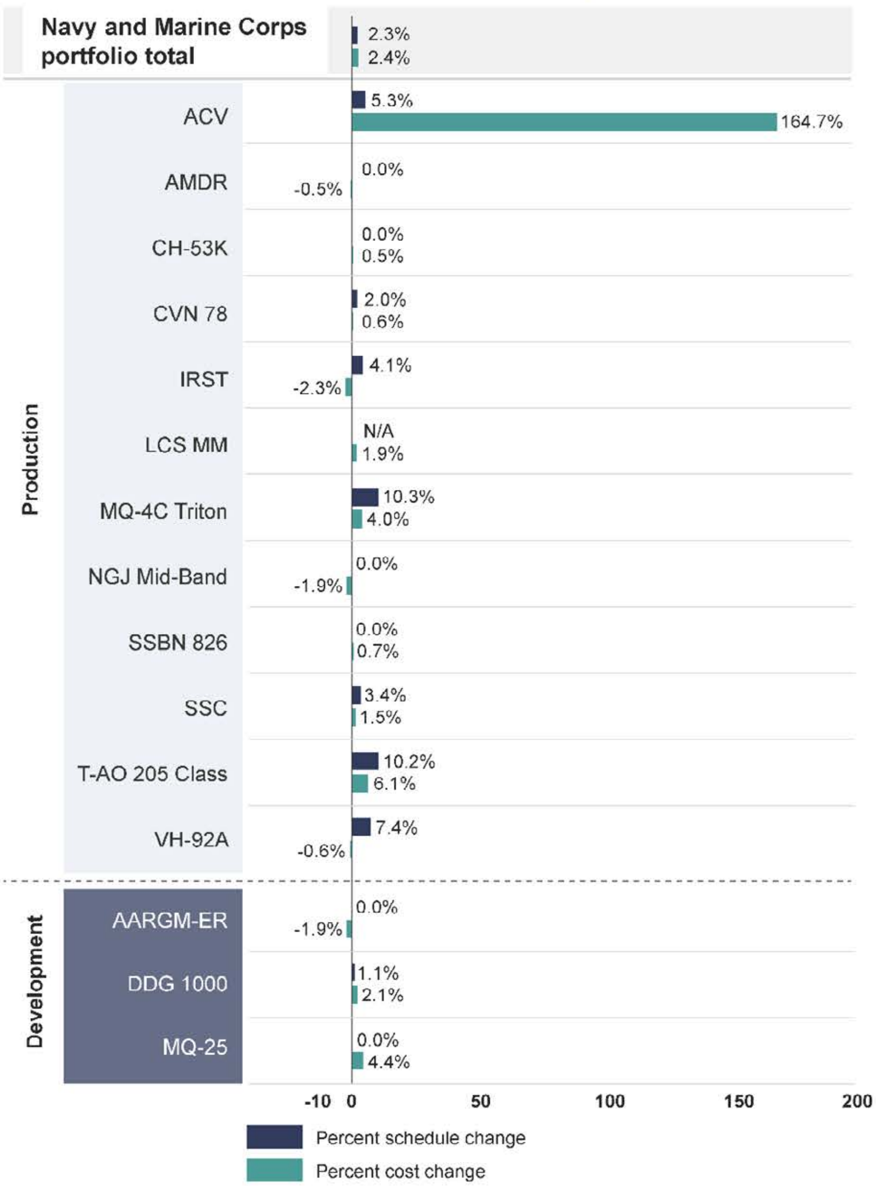
Program Office Comments

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 its acquisition approach was revised based on feedback from industry and is aligned with the Army Future Command's new approach to the refinement of requirements. The program office noted that the original acquisition approach included conducting detailed design activities prior to establishing formal requirements, which could result in unnecessary increases to program cost and schedule. The revised approach balances the Army's desire to remove constraints to industry innovation at the outset and the need to begin preliminary engineering activities aligned to an industry-informed and more detailed requirement later in the process, according to the program office.

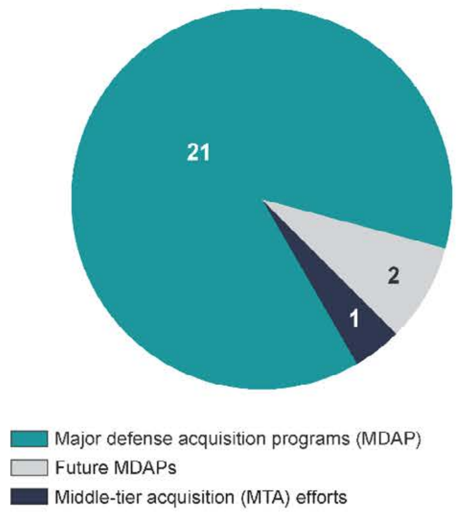
NAVY AND MARINE CORPS PROGRAM ASSESSMENTS

Source: U.S. Navy. | GAO-21-222

Most Navy MDAPs Had Cost Growth, Schedule Delays, or Both Since 2020

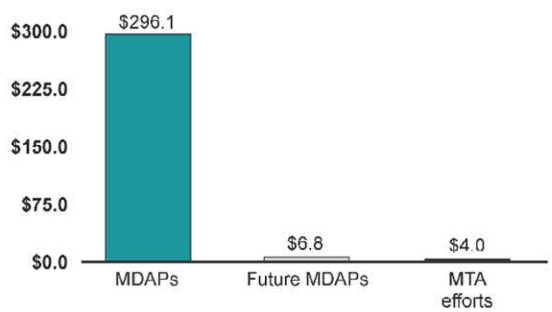


GAO Assessed 24 Navy Weapon Programs



Navy Programs Reported a Combined Acquisition Cost of $306.9 Billion

(Fiscal Year 2021 dollars in billions)



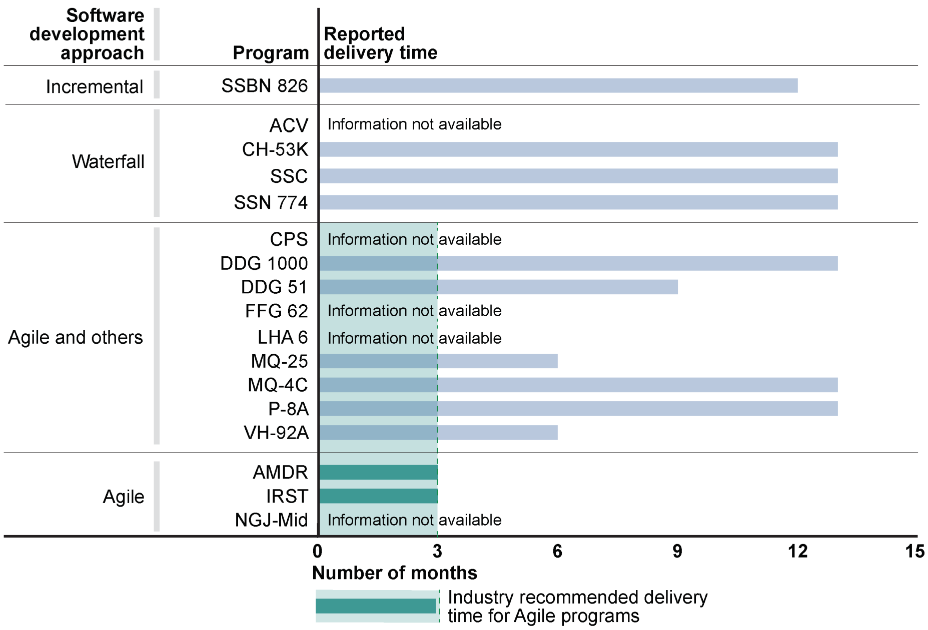
- Note: Acquisition costs for MTA programs reflect estimates for current efforts only. Additionally, cost estimates for future MDAPs may not reflect full costs since programs may still be defining them.

- The term "programs," when used alone in figure titles, refers to all MDAP, future MDAPs, and MTA programs that GAO assessed.
- Cost and schedule analyses are primarily based on estimates from DOD's Defense Acquisition Executive Summary reports. This information may differ from information reported in the Program Performance table and Funding and Quantities figures in individual assessments, which in some cases are based on more recent program estimates. See appendix I for details.

All data in figures are based on GAO analysis of DOD data and program office questionnaire responses. | GAO-21-222

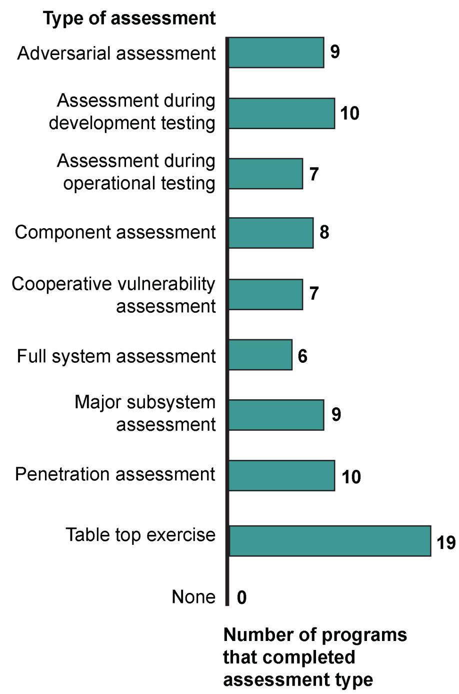
NAVY AND MARINE CORPS PROGRAM ASSESSMENTS

Navy Programs Often Reported Software Delivery Times Greater than Industry Recommendations

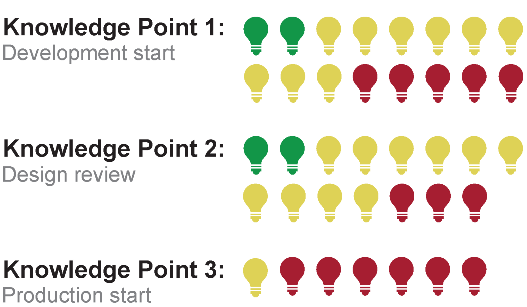


- Industry recommends deliveries on a continuing basis, as frequently as every 2 to 6 weeks for Agile programs. Programs reported deliveries to GAO in 0-3 month ranges and this figure represents the high end of those ranges.
- Software development approach was not available for the AARGM-ER, CVN 78, LCS MM, LPD 17 Flight II, and T-AO 205 programs.

All Navy Programs Completed At Least One Cybersecurity Assessment



Navy MDAPs Generally Did Not Attain Knowledge at Key Points on Time



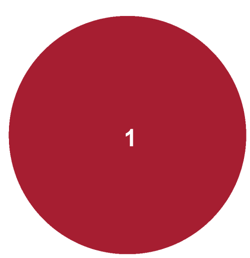
Program **attained** knowledge **by** knowledge point date

Program **attained** knowledge **after** knowledge point date

Program **had yet to attain** knowledge **by** January 2021

- Note: For each knowledge point, GAO assessed the MDAPs that had reached that point as of January 2021. GAO excluded programs for which it determined that the practice was not applicable.

The Sole Navy MTA Program Has Yet to Complete a Business Case



Program **completed** business case **by** initiation

Program **completed** business case **after** initiation

Program had **yet to complete** business case as of January 2021

- Note: GAO did not assess the Navy's only MTA program's knowledge planned by transition because it plans to transition to another rapid prototyping effort. GAO assessed programs planning to transition to the major capability acquisition pathway or to a rapid fielding effort, and excluded programs planning to transition to another rapid prototyping effort or that had yet to determine transition plans.

All data in figures are based on GAO analysis of DOD data and program office questionnaire responses. | GAO-21-222

Source: Northrop Grumman Innovation Systems (NGIS).

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 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
- 1/21 GAO review

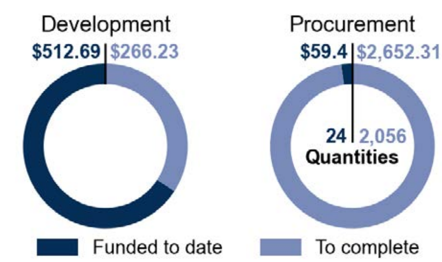
PRODUCTION
- 3/21 Low-rate decision
- 7/23 End operational test
- 9/23 Initial capability
- 3/24 Full-rate decision

Program Essentials

Milestone decision authority: Navy
Program office: Patuxent River, MD
Prime Contractor: Alliant Techsystems Operations, LLC
Contract type: CPIF (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



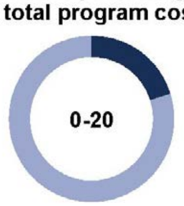
Software Development

(as of January 2021)

Approach: Spiral

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Off the shelf

0 percent Modified off the shelf

100 percent Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (12/2018)	Latest (8/2020)	Percentage change
Development	$778.82	$778.92	+0.0%
Procurement	$2,802.23	$2,711.71	-3.2%
Unit cost	$1.71	$1.66	-2.5%
Acquisition cycle time (months)	56	56	+0.0%
Total quantities	2,097	2,097	+0.0%

Total quantities comprise 17 development quantities and 2,080 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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 AARGM-ER's manufacturing maturity because the system has not yet reached production.

AARGM-ER Program

Technology Maturity and Design Stability

The AARGM-ER program expects that its one critical technology will be mature and its design stable by the planned March 2021 production decision. However, the program has conducted a limited amount of testing, so it is still at risk of design changes. When AARGM-ER began development in March 2019, the program's one critical technology, a flame retardant insulation for the rocket motor, was immature. The program successfully tested its rocket motor since then through a series of tests that began in November 2019. It expects to demonstrate the technology is fully mature when the missile is flight tested for the first time in March 2021. As of July 2020, the program reported that 98 percent of its design drawings were complete. However, contrary to leading practices, the Navy will not test a system-level integrated prototype until just prior to the program's production decision, an approach that raises the risk of late design changes and cost increases.

Production Readiness

By the time the AARGM-ER program starts production, it plans to demonstrate most of its key production processes, but contrary to leading practices, does not plan to have tested a production-representative prototype in an operational environment. The program expects to conduct only a single free-flight test of a nonproduction representative missile immediately before its production decision. At the conclusion of the test, the program expects to demonstrate that the missile can be safely carried and launched by an F/A-18 aircraft; the guidance, navigation, and control hardware and software perform in free flight as expected; and the rocket motor can meet the extended range requirement.

However, the program will not integrate and test several key upgrades before production, including upgraded electronics and software and its new warhead design. According to an official from DOD's independent test organization, the testing the program plans to complete will not allow for a meaningful operational assessment of the missile's capability before the program's production decision. The aggressive development and testing schedule also leaves little room to address any unanticipated risks or make any needed changes based on test results, which heightens the risk of cost growth and schedule delays.

Software and Cybersecurity

AARGM-ER software development and integration is a challenge for the program because it is reliant on the baseline AARGM program for a key software upgrade that gives its missile upgraded capabilities related to advanced threats. The AARGM software development efforts are behind schedule, according to an official from DOD's independent test organization. The official stated that the software was supposed to be tested in the baseline AARGM before it was included in the AARGM-ER, but that is no longer the case. The Navy's AARGM-ER test schedule does not reflect this change in strategy, any additional testing and evaluation time and resources needed, or any additional risks. In April 2020, a technical review board also noted that most of the capability was to be delivered in the last AARGM-ER software build, which allowed very limited time for rework. The program moved the planned integration into an earlier software build to help reduce this risk. Additionally, program officials stated that testing different software releases for early discovery of any potential issues helps mitigate the complexity of separate software efforts.

AARGM-ER is continuing to assess cybersecurity according to program officials. The program completed two cybersecurity assessments with the baseline AARGM program and plans to conduct an assessment specific to the AARGM-ER before its production decision.

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, results from component testing and system-level integration testing continue to demonstrate technical maturity and design stability. The program office also stated that the final series of design verification tests of production-representative rocket motors was successfully completed and that flight testing began in fiscal year 2020 with a focus on integration, and will continue in fiscal year 2021.

Source: BAE.

Amphibious Combat Vehicle (ACV)

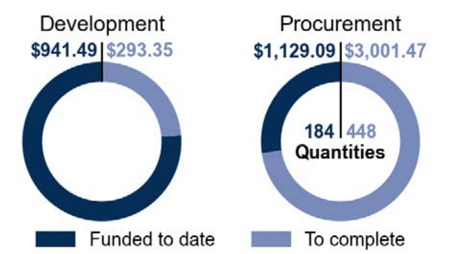
The Marine Corps expects the ACV will replace the legacy Assault Amphibious Vehicle. The ACV is intended to transport Marines from ship to shore and provide them with improved mobility and high levels of protection. The Navy was initially pursuing the first increment, ACV 1.1, as a separate program but subsequently merged the first two planned increments—ACV 1.1 and ACV 1.2—into a single program, the ACV Family of Vehicles, and added plans to develop variants with different mission profiles.

Program Essentials

Milestone decision authority: Navy
Program office: Stafford, VA
Prime Contractor: BAE Systems Land and Armaments LP
Contract type: FPI/FFP/CPFF (development and procurement),

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

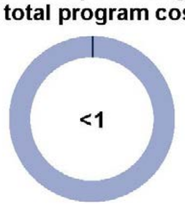
(as of January 2021)

Approach: Waterfall

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

36 percent
Off the shelf

0 percent
Modified off the shelf

64 percent
Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (5/2016)	Latest (11/2020)	Percentage change
Development	$861.67	$1,234.84	+43.3%
Procurement	$1,144.87	$4,130.55	+260.8%
Unit cost	$8.58	$8.04	-6.3%
Acquisition cycle time (months)	57	60	+5.3%
Total quantities	240	678	+182.5%

Total quantities comprise 46 development quantities and 632 procurement quantities. Since the first full estimate, the Marine Corps decided to increase production quantities to include variants with different mission profiles.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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

ACV Program

Technology Maturity, Design Stability, and Production Readiness

The program matured its critical technologies and stabilized its design. However, while the program's manufacturing processes matured since low-rate production started in June 2018, it has yet to meet the level of maturity that leading acquisition practices recommend. The program has also yet to demonstrate that its critical manufacturing processes are in statistical control. Program officials noted that the contractor identified two critical manufacturing processes since production start:

- inspecting the alignments of vehicle components, such as the transfer case and engine motor mounts, during hull fabrication and vehicle assembly, and
- using thermal examination weld quality inspections of the vehicle hull after fabrication to determine weld quality.

According to program officials, the contractor does not track statistical process control due to the low planned production quantity of ACVs. However, if the manufacturing processes do not reach recommended maturity levels, the program faces increased risk that ACVs may not be produced at the program's cost, schedule, and quality targets.

Program officials stated that the program experienced minor delays related to COVID-19, including shutting the production line down for 2 weeks and delayed supplier shipments. The program pushed back the full-rate production decision by an additional 3 months beyond the 3-month delay from late vehicle deliveries that we reported last year, but it still met schedule targets established at production start.

During testing to support the full-rate production decision, testers determined that the ACV was operationally effective, suitable, and survivable. However, it did not meet all reliability, availability, and maintainability threshold requirements. Testers' recommendations included authorizing additional special tools for maintenance teams to increase availability and establishing a reliability improvement program to address subsystems with a high failure rate, such as the remote weapon station, suspension, and hatches.

The program updated its cost estimate in November 2020 to reflect the decision to expand its planned production quantity from 240 to 678, which includes variants with different profiles. Last year, the Marine Corps reported a plan to manufacture 1,122 production vehicles, but according to program officials, the amount was reduced as part of the Marine Corps' Force Design restructure that was formalized in August 2020. While the estimated total cost for the program more than doubled since the program started due to the increased quantity of ACVs, the unit cost estimate decreased by over 6 percent due to greater economies of scale.

Software and Cybersecurity

Program officials noted that estimated software development cost is less than 1 percent of total estimated program costs. The first ACV variant to be developed after the personnel transport variant (ACV-P) is expected to rely primarily on previously developed software. According to program officials, the command and control (ACV-C) variant will use the same automotive software as the ACV-P and a command and control software suite used in the legacy vehicles that the ACV will replace, reducing development risks. They also noted that the program has had two software update deliveries since June 2019, both of which addressed issues identified in testing of early production vehicles.

The program updated its cybersecurity strategy in May 2020 to include the three planned variants—ACV-C, medium caliber weapon (ACV-30), and maintenance/recovery (ACV-R)—in addition to the original ACV-P variant. The updated strategy also includes plans to address a new cybersecurity survivability requirement added at production start.

Other Program Issues

According to program officials, the program initiated design for two of the three planned additional variants—ACV-C and ACV-30. The Marine Corp initiated the development of the variants through a June 2019 modification to the original development contract. According to program officials, the modifications are being executed as engineering change proposals to the ACV-P because they share a high level of design commonality with the original design. Additionally, program officials said that the variants will be built on the same production line as the ACV-P. According to program officials, the ACV contractor plans to deliver three production-representative ACV-C prototypes to support testing in fiscal year 2021 and start production of the first 10 ACV-Cs in fiscal year 2022.

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: Raytheon Company.

Air and Missile Defense Radar (AMDR)

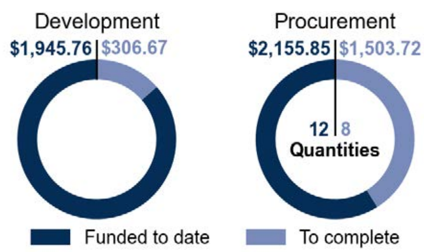
The Navy's AMDR is a next-generation radar program supporting surface warfare and integrated air and missile defense. The Navy expects AMDR’s radar—known as AN/SPY-6(V)1—to provide increased sensitivity for long-range detection to improve ballistic missile defense against advanced threats. The program office is also developing a radar suite controller that is expected to interface with an upgraded Aegis combat system to provide integrated air and missile defense for DDG 51 Flight III destroyers.

Program Essentials

Milestone decision authority: Navy
Program office: Washington, DC
Prime Contractor: Raytheon
Contract type: FPI (procurement)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



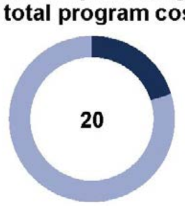
Software Development

(as of January 2021)

Approach: Agile

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent
Off the shelf

0 percent
Modified off the shelf

100 percent
Custom software

Program officials updated the average software delivery time to reflect delivery of usable, working software releases to end users as opposed to reporting as major builds, which was reported in our last assessment.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (10/2013)	Latest (7/2020)	Percentage change
Development	$2,128.39	$2,252.43	+5.8%
Procurement	$4,401.99	$3,659.57	-16.9%
Unit cost	$298.33	$297.24	-0.4%
Acquisition cycle time (months)	156	167	+7.0%
Total quantities	22	20	-9.1%

Total quantities comprise zero development quantities and 20 procurement quantities. GAO’s general methodology is to use the objective initial operational capability (IOC) date to determine cycle time. However, we have adjusted the cycle time calculation for AMDR to use the threshold date because AMDR shares the same IOC date as DDG 51 Flight III, which reported the threshold date as its IOC date.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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 no critical manufacturing processes are used on this program.

AMDR Program

Technology Maturity, Design Stability, and Production Readiness

AMDR will not demonstrate its critical technologies in a realistic environment until after the Navy integrates AMDR and Aegis on the lead DDG 51 Flight III ship during activation of the Aegis combat system in 2022. Until this occurs, we will continue to disagree that the program's critical technologies are fully mature, despite the program reporting them mature since 2017. The Navy will then test AMDR and Aegis in a realistic, at-sea environment on the lead DDG 51 Flight III ship in 2023. The design remains at risk for further disruption until the Navy completes operational testing in fiscal year 2024. Any deficiencies the Navy discovers during testing could require revisions to existing design drawings or retrofitting to already-built radars, likely increasing costs, delaying future radar deliveries, or both.

While AMDR's overall design is currently stable, according to officials, the program redesigned the Digital Receiver Exciter (DREX)—a critical technology component—in 2020 because it did not meet vibration specifications, leading to cost increases. Program officials said the new design met all qualification testing specifications and is easier to manufacture. However, the fourth radar array—which completes the first AMDR unit—was delivered to the shipyard in October 2020, 2 months later than planned due in part to the redesign. To maintain the delivery schedule and offset further delays due to the component redesign, the program delivered the first radar to the lead DDG 51 Flight III ship without the complete set of DREX components installed. Officials said the remaining components will be installed in the radar once it is installed on the ship prior to shipyard testing and activation of the Aegis combat system in 2022.

AMDR has yet to demonstrate statistical control of its critical manufacturing processes despite initiating production in May 2017, an approach inconsistent with leading practices. In 2020, the program experienced a manufacturing issue with a Transmit/Receive Integrated Microwave Module (TRIMM) component—another critical technology—that caused cost increases and rework. A TRIMM component's incorrect adhesive application caused unexpected heat exposure, which could result in premature component failure, demonstrating the risks of these immature manufacturing processes. Officials said the contractor fixed the issue for future deliveries. They added that samples of the weakened TRIMM components were re-tested for confidence that they will not prematurely fail and do not present a significant reduction in operational capability for AMDR on the lead DDG 51 Flight III ship.

Software and Cybersecurity

AMDR has used Agile development to complete eight software deliveries that support core radar capabilities. In 2020, the AMDR program tested new Aegis software at the Pacific Missile Range Facility (PMRF), where the Aegis combat system and an AMDR radar array interfaced and tracked an aircraft, according to officials. The program delivered a radar array to the combat system land-based test site and started integration and testing of AMDR and Aegis at the land-based test site in October 2020. These tests will inform software development and integration of AMDR and Aegis, in development concurrently, in preparation for Aegis combat system activation, planned in January 2022.

In the future, the program plans to integrate an Advanced Distributed Radar (ADR) capability through AMDR and Aegis software upgrades. ADR is expected to add radar enhancements and address future threats to the current system. Officials expect to finalize ADR requirements in fiscal year 2021 and begin software development in 2022, with the plan to deliver a capability after 2024. Program officials reported that software development costs increased due to unanticipated complexity and new system requirements such as ADR, among other things.

Officials said that AMDR cybersecurity is addressed within the Aegis combat system. The Aegis program plans to conduct three cyber exercises in 2021, but complete cybersecurity testing will not occur until at least 2023.

Other Program Issues

Since last year, the Navy reduced the number of radar units from 22 to 20—lowering procurement costs—to better align with the number of DDG 51 Flight III ships planned through 2025.

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 first AMDR was delivered in October 2020, this delivery supported DDG 51 Flight III construction schedule, and AMDR performance exceeded thresholds during testing in a maritime environment at PMRF. The program also stated that while radar testing with Aegis and other components at the combat system land-based test site and PMRF will help decrease risk, complete AMDR testing with the ship is necessary to fully retire risk. Additionally, the program noted that the new DREX component is in production and will be installed in all future arrays. According to the program, the use of an FPI firm target production contract for AMDR procurement minimizes the impact of component price variances.


Source: U.S. Navy.

CH-53K Heavy Replacement Helicopter (CH-53K)

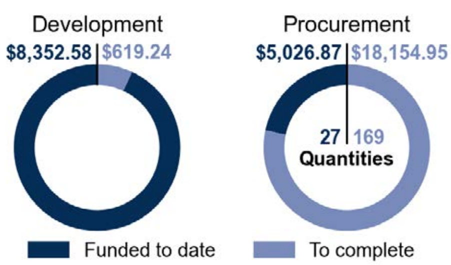
The Marine Corps' CH-53K heavy-lift helicopter is intended to transport armored vehicles, equipment, and personnel to support operations deep inland from a sea-based center of operations. The CH-53K is expected to replace the legacy CH-53E helicopter and to provide increased range and payload, survivability and force protection, reliability and maintainability, and coordination with other assets, while reducing total ownership costs.

Program Essentials

Milestone decision authority: Navy
Program office: Patuxent River, MD
Prime Contractor: Sikorsky Aircraft Corporation; General Electric Aviation
Contract type: CPIF (development), FPIF/ FFP (procurement)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



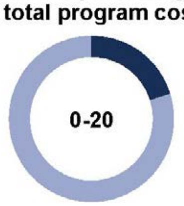
Software Development

(as of January 2021)

Approach: Waterfall

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent
Off the shelf

0 percent
Modified off the shelf

100 percent
Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (12/2005)	Latest (7/2020)	Percentage change
Development	$5,141.45	$8,971.83	+74.5%
Procurement	$14,299.12	$23,181.82	+62.1%
Unit cost	$124.62	$160.84	+29.1%
Acquisition cycle time (months)	117	189	+61.5%
Total quantities	156	200	+28.2%

Total quantities comprise four development quantities and 196 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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

Technical issues and associated design changes have slowed the testing schedule. During the last year, the program has continued flight tests to verify redesigns and fixes for several technical issues in preparation for operational testing. Since 2017—when the program entered production—the program office identified 126 different technical issues during developmental testing, including exhaust gas reingestion in the aircraft and high stress on the main gear rotor box, a critical technology. Program officials state they identified a solution to the exhaust gas reingestion issue and they are completing an effort to redesign the main gear box.

The deficiencies discovered to date and ongoing developmental testing efforts may cause the program to undertake additional design changes. For example, the main gear box, the tail flex beam, and the main rotor damper underwent redesign efforts due to shorter-than-expected lifespans, negatively affecting the operating and support costs. According to program officials, for the issues discovered during developmental testing, the aircraft will have all the technical fixes installed on the aircraft by the full rate production decision, scheduled for November 2022. However, the program plans developmental test efforts through 2025. Some of these efforts will test the aircraft in the “deployable” configuration when all 126 fixes for the technical issues have been installed. Until these efforts are complete, the program is at risk of costly and time-intensive rework to aircraft already in production.

According to program officials, operational testing—which often identifies new and significant problems missed in earlier program development—is scheduled to begin in June 2021 and will be conducted in three phases, ending in September 2022. Program officials stated that the program extended the duration of operational testing to allow for a phased approach, which starts with a pared down configuration, with each phase adding on more capabilities. The final phase culminates by testing a production configured aircraft direct from the production line.

The prime contractor and the program office lack up-to-date information about production processes. For example, the program office stated that it last assessed production line capacity in 2017 and has not assessed Sikorsky’s maximum production capability, among other things, since the company relocated its production line in 2018. This leaves the program at risk of quality issues during low-rate production. Additionally, as we reported last year, the production line was not in statistical control at the time the program entered production, which, while not required by DOD guidance until the full-rate production decision, is an approach inconsistent with leading practices. Program officials stated they will not reassess the production line again until the full-rate production decision, currently scheduled for November 2022.

The first two low-rate aircraft are expected to be delivered in September 2021 and January 2022, respectively. Supplier capacity issues are causing critical parts shortages that may delay deliveries of subsequent low-rate aircraft.

Software and Cybersecurity

According to the program office, it successfully tested a fix for a software-related issue we raised in our last assessment—a failure in software to detect the transition from ground to flight, causing increased safety concerns.

Since our last assessment, the program delayed the award of a contract to improve its cybersecurity practices. According to officials, the program planned to award a contract in mid-2020 to establish a cybersecurity risk management approach that includes the implementation of controls and provides mitigation needed to support operational testing. However, according to program office officials, that award has been delayed until mid-fiscal year 2021 because the program required additional time to identify funding and to develop a statement of work. Our past work shows that programs benefit from a focus on cybersecurity early in the development cycle in order to avoid costly redesigns.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. According to the program office, the program is continuing to execute to its schedule. The program office noted that the aircraft completed 90 percent of the necessary developmental tests events required to begin operational testing, including aerial refueling and ship compatibility, degraded visual environment, external load assessments, and hot weather testing. According to the program office, there are solutions identified for 93 percent of the technical issues. Further, the program office stated that developmental tests will continue through 2025 to validate that the aircraft can reach its full flight performance. It also added that while a formal production line assessment will be performed to support a full-rate decision, the program is constantly assessing production line transition risks and manufacturing process maturity. Lastly, the program office noted that the cybersecurity contract is on track to be awarded in the second quarter of fiscal year 2021.

Source: Defense Visual Information Distribution Service.

CVN 78 Gerald R. Ford Class Nuclear Aircraft Carrier (CVN 78)

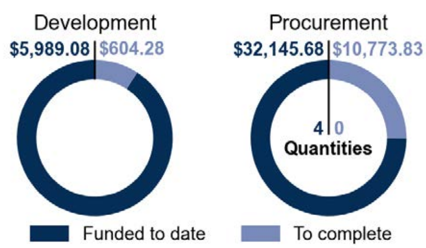
The Navy developed the CVN 78 (or Ford Class) nuclear-powered aircraft carrier to introduce new propulsion, aircraft launch and recovery, and survivability capabilities to the carrier fleet. The Ford Class is the successor to the Nimitz Class aircraft carrier. Its new technologies are intended to create operational efficiencies and enable a 33 percent increase in sustained operational aircraft flights over legacy carriers. The Navy also expects the new technologies to enable Ford Class carriers to operate with reduced manpower.

Program Essentials

Milestone decision authority: Navy
Program office: Washington, DC
Prime Contractor: Huntington Ingalls Industries Newport News Shipbuilding
Contract type: FPI (CVN 79) detail design & construction; FPI (CVN 80) detail design & construction

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Information not available

Average time of software deliveries (months)

Information not available

Software percentage of total program cost	Software type
Information not available	Information not available

The program does not separately track software, as it is provided by other Navy programs.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (4/2004)	Latest (9/2020)	Percentage change
Development	$5,640.08	$6,593.36	+16.9%
Procurement	$36,131.42	$42,919.52	+18.8%
Unit cost	$13,923.83	$12,447.79	-10.6%
Acquisition cycle time (months)	137	207	+51.1%
Total quantities	3	4	+33.3%

Total quantities comprise zero development quantities and four procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Construction Preparation Contract Award**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit, and function within a realistic environment	○	●
Complete a system-level preliminary design review	○	●
Product design is stable	**Fabrication Start**	
Complete basic and functional design to include 100 percent of 3D product modeling	○	●

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

We assessed the 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

Although Navy officials report that the program's 12 critical technologies are fully mature, challenges persist with using these technologies and demonstrating their reliability. For example, as of October 2020, the Navy had certified only six of the 11 elevators to operate on the ship. Further, according to Navy officials, while six elevators are currently operational—three Upper Stage, one utility elevator, and two Lower Stage—only the two Lower Stage elevators are capable of delivering munitions to the main deck. The Navy is working with the shipbuilder to complete the five remaining elevators—all Lower Stage units—by the spring of 2021. The Navy plans to begin testing at a land-based site in early 2022—following a one-year delay due to contract issues—to assess the elevators' performance and reliability. With units already operating on CVN 78, any changes to the elevators resulting from land-based testing are likely to be costly and time-consuming for the Ford-class program.

The Navy also continues to struggle with achieving the reliability of the electromagnetic aircraft launch system (EMALS) and Arresting Gear (AAG) in support of its requirement to rapidly deploy aircraft. The Navy is conducting shipboard testing as it prepares for operational testing to begin in the summer of 2022. However, if these systems do not reliably function during this test phase, CVN 78 may not be able to demonstrate it can rapidly deploy aircraft. The Navy also does not expect EMALS and AAG to demonstrate their required reliability until after CVN 78 has begun deploying to the fleet.

Since 2013, we have identified concerns with the Ford Class test schedule, which have been borne out as the start of operational testing has now been delayed by over 5 years to a planned date of August 2022. Most recently, program officials confirmed that the lead ship (CVN 78) will reach initial capability in July 2021—4 months later than they reported last year—to align with the completion of post-delivery testing. The Navy will declare initial capability without demonstrating capability or performance through successful operational testing, missing an opportunity to determine whether the ship is capable of conducting mission operations. The Navy plans to complete operational testing in November 2023.

Further, the 2013 test and evaluation master plan is no longer current and program officials told us they anticipate sending the revised plan for Navy leadership review in early 2021. Without an approved test plan, we cannot comment on the Navy's test events and whether current areas of technical risk inform the plan. We found past test plans to be optimistic, with little margin for delays. Program officials stated that test plan revisions are not delaying any required testing.

Software and Cybersecurity

Separate program offices manage software development for CVN 78's critical technologies. The CVN 78 program is scheduled to complete an evaluation for potential cybersecurity vulnerabilities connected with section 1647 of the National Defense Authorization Act for Fiscal Year 2016 in May 2022.

Other Program Issues

The lead ship (CVN 78) cost cap is currently $13.2 billion, more than $2.7 billion higher than its initial cap. Program officials do not believe they will need additional funding to correct deficiencies found in CVN 78's acceptance trials. However, until CVN 78's testing is completed, the risk of discovering more costly deficiencies persists.

The Navy is unlikely to obtain planned cost savings on CVN 79 due to several factors. CVN 79 is 74 percent complete, but as of June 2020, ship construction is lagging behind cost saving goals. Further, according to program officials, the shipbuilder's COVID-19 pandemic mitigations also reduced construction efficiency. Officials also explained that the Navy is making additional changes for CVN 79, including integrating F-35 aircraft and adjusting to a new single-phase delivery schedule, but has yet to assess how these factors will affect cost and schedule. The Navy reported awarding fixed-price contracts for CVNs 80 and 81 in January 2019, which it expects to limit cost liability and incentivize shipbuilder performance. The Navy made optimistic assumptions that this two-ship contract will save over $4 billion. We previously reported that the Navy's own cost analysis showed that CVNs 80 and 81 have a high likelihood of cost overruns, which aligns with our findings on CVN 78 and CVN 79 cost growth.

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 CVN 78 has completed 15 of 18 months of the ship's post-delivery test schedule. It added that during this time, CVN 78 recorded nearly 6,400 aircraft launches and recoveries. According to the program office, the ship completed carrier qualification for over 400 aviators and cleared 99 percent of discrepancies from its acceptance trials. The program office noted that CVN 78 broke records for number of aircraft landings in one day and for consecutive days at sea. Additionally, the program office stated that CVN 80 will start construction in February 2022. Lastly, the program office reported that COVID-19 continues to affect construction performance.

Source: BAE Systems San Diego.

DDG 1000 Zumwalt Class Destroyer (DDG 1000)

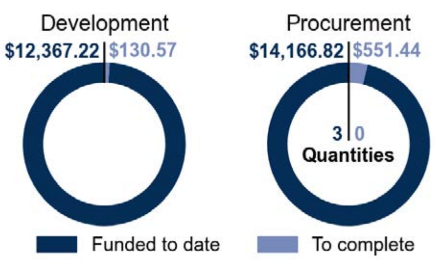
The DDG 1000 is a multi-mission surface ship initially designed to provide advanced capability to support forces on land. DDG 1000 class ships feature a stealth design, integrated power system, and total ship computing environment. The Navy adopted a phased acquisition strategy, which separates delivery and acceptance of hull, mechanical, and electrical systems from combat system activation and testing. In 2017, the Navy changed DDG 1000's primary mission from land attack to offensive surface strike.

Program Essentials

Milestone decision authority: Navy
Program office: Washington, DC
Prime Contractor: General Dynamics Bath Iron Works; Huntington Ingalls Industries; Raytheon
Contract type: FPI/FFP/CPFF (ship construction); CPFF/CPAF (mission systems equipment)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Agile and DevOps

Average time of software deliveries (months)

Software percentage of total program cost

Software type

10 percent Off the shelf

20 percent Modified off the shelf

70 percent Custom software

The program does not track software cost elements.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (1/1998)	Latest (9/2020)	Percentage change
Development	$2,674.6	$12,497.79	+367.3%
Procurement	$38,185.42	$14,718.26	-61.5%
Unit cost	$1,276.88	$9,072.02	+610.5%
Acquisition cycle time (months)	128	288	+125.0%
Total quantities	32	3	-90.6%

Total quantities comprise zero development quantities and three procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Detail Design Contract Award**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit, and function within a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	**Fabrication Start**	
Complete basic and functional design to include 100 percent of 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 continues to have several immature technologies as it approaches the planned conclusion of operational testing in 2021. Four technologies have yet to demonstrate effectiveness on board the ship—the vertical launch system, infrared signature, volume search radar, and total ship computing environment. The Navy expects to mature these technologies as it completes ship construction, certification, and operational testing over the next 2 years. Maturing these technologies throughout the construction and testing process will likely lead to additional cost and schedule delays as the Navy may need to conduct onboard upgrades to facilitate the systems' effectiveness.

To begin to enable the new surface strike mission, the Navy also added three additional immature critical technologies: a communication system, an intelligence system, and an offensive strike missile with an immature seeker technology. In addition, the Navy received $15 million in funding to begin initial integration of a prompt strike (hypersonic) weapon.

As of September 2020, the Navy plans to request $169 million to install its four new systems on at least one or more DDG 1000 ships and would need to request further funding to complete the remaining ships' systems. Though the Navy plans to fully mature these technologies by ship integration, the integration will not occur until several years after the Navy plans to achieve initial operational capability in December 2021. As a result, the DDG 1000 class ships will remain incomplete and incapable of performing their planned mission until at least 2025.

In 2020, the Navy achieved a major milestone with DDG 1000's final delivery—including combat systems activation—in April 2020, but cost growth and schedule delays continue to mount for the third and final ship. Additionally, delivery of DDG 1001 has been delayed again and is now planned for fiscal year 2022. The Navy now plans delivery of DDG 1002 with its combat systems in January 2024—a 16-month delay compared to last year's estimate of September 2022—and further delays are possible given its planned change in delivery approach. The program manager attributed the current delay to a strike at the shipyard and COVID-19-related complications.

Software and Cybersecurity

The Navy now plans to complete software development for the class in fiscal year 2022—a 24-month delay since our 2020 assessment, largely due to overly optimistic development schedules. Although the lead ship was initially delivered in 2016, the program continues to deliver software builds only providing a portion of initially planned automation and to complete programming for the ship's communication systems, as we reported last year. Without the originally planned level of capability and automation, the Navy has had to permanently grow the crew size by 31 sailors, increasing life-cycle costs.

The program expects that a cybersecurity strategy planned for fiscal year 2023 which, along with the remainder of a 2-year regimen of certifications and testing, should demonstrate the full functionality of the ships' systems and their cybersecurity. Our prior work has shown that not focusing on cybersecurity until late in the development cycle or after a system has been deployed is more difficult and costly than designing it in from the beginning. According to the program manager, no cybersecurity issues have been identified to date.

Other Program Issues

For DDG 1002, the Navy changed its delivery plan over the past year. According to the program manager, instead of taking custody of the ship from the builder's yard and completing the combat system at Naval Base San Diego, the Navy is now planning to contract with a private shipyard to install the combat system and will not take delivery or commission DDG 1002 until it is fully complete. The program manager stated that this new approach may result in additional schedule delays; however, it will free up valuable pier space in Naval Base San Diego and enable the Navy to avoid moving the crew onboard DDG 1002 until it is ready to operate. The program manager identified the change as a response to lessons learned from DDG 1000 and 1001—specifically, that completing combat system activation and final construction is complicated by onboard crew, in part, because access to spaces is more constrained.

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 continues to make significant progress in the construction, testing, activation, and sustainment of the Zumwalt class. It added that final delivery of DDG 1000 marked the transition to the next phase of development and integrated at-sea testing. According to the program office, DDG 1000 conducted the class's first live fire test of the vertical launching system in October 2020, and DDG 1000 will continue lead ship developmental and integrated at-sea testing in support of achieving initial operational capability, planned for December 2021. The program office stated that DDG 1001 completed installation of its combat systems in March 2020 and is currently activating its weapons, sensors, and communications systems. Additionally, it noted that construction of DDG 1002 is 97 percent complete, and on a path to delivery following activation of its combat systems.

Source: Fincantieri Marinette Marine.

Constellation Class Frigate (FFG 62)

The Navy's FFG 62 guided missile frigate program is intended to develop and deliver a small surface combatant based on a proven ship design that provides enhanced lethality and survivability as compared to the Littoral Combat Ship. The Navy plans to rely on government-furnished equipment from other programs or known contractor-furnished equipment to produce an agile, multi-mission ship that provides local air defense and maximizes surface and anti-submarine warfare capabilities, among other capabilities.

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

- 5/19 Preliminary design review
- 4/20 Development start/Lead-ship detail design contract
- 1/21 GAO review
- 8/21 Critical design review
- 10/21 Lead-ship fabrication start
- 2026 Lead-ship delivery
- 12/28-4/29 Operational testing
- 9/29 Initial capability

Program Essentials

Milestone decision authority: Navy

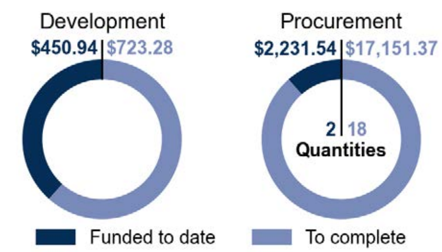
Program office: Washington Navy Yard, DC

Prime contractor: Fincantieri Marinette Marine

Contract type: FPI (detail design and construction)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Agile, DevOps, and DevSecOps

Average time of software deliveries (months)

Information not available

Software percentage of total program cost	Software type
Information not available	Information not available

The program office stated it is working with the shipbuilder and other Navy stakeholders to develop estimates for software types and costs, with availability of this information anticipated later in fiscal year 2021.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (4/2020)	Latest (6/2020)	Percentage change
Development	$1,174.21	$1,174.21	+0.0%
Procurement	$19,382.9	$19,382.9	+0.0%
Unit cost	$1,062.81	$1,062.81	+0.0%
Acquisition cycle time (months)	139	139	+0.0%
Total quantities	20	20	+0.0%

Total quantities comprise zero development quantities and 20 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Detail Design Contract Award**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	NA
Demonstrate all critical technologies in form, fit, and function within 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 100 percent of 3D product modeling	NA	NA

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

We did not assess critical technologies for the FFG 62 program because the Navy's technology readiness assessment and independent technical risk assessment for the program found that the ship does not have any. We also did not assess the ship's design stability because the program has yet to reach fabrication start.

FFG 62 Program

Technology Maturity

The FFG 62 program uses many existing combat and mission systems, which are intended to reduce technical risk. The Navy completed a technology readiness assessment in March 2019, identifying no critical technologies. In February 2020, the Navy also completed an independent technical risk assessment that identified 12 areas of low to moderate programmatic risk. Specifically, the assessment noted some potential risks for mission capability, integration, and testing plans related to Navy-provided equipment. One example of this equipment is the new Enterprise Air Surveillance Radar (EASR) that will provide long-range detection and engagement capability for several Navy shipbuilding programs. The Navy completed EASR development and initiated production in 2020, with plans to integrate the radar system on other ship classes before FFG 62. However, the Navy stated that if integration of EASR with software from a new Aegis combat system baseline is not completed by 2023, the FFG 62 program may require additional funding and time for capability development and testing.

Design Stability and Production Readiness

The Navy worked with five industry teams during a FFG 62 conceptual design phase to mature designs based on ships already built and demonstrated at sea. The results informed the program's May 2019 preliminary design review and request for proposal. In April 2020, the program competitively awarded a detail design and construction contract for the lead ship. Program officials stated they will complete the critical design review and production readiness review in summer 2021 to support construction start in October 2021, 9 months sooner than previously estimated. The Navy said the updated schedule reflects the maturity of the ship design selected for the April 2020 award. Program officials noted they expect the Navy to review the basic and functional design for the ship's 34 design zones prior to construction start, and for each major construction module, the shipbuilder plans to complete the detail design and construction drawings before starting the module's construction.

Software and Cybersecurity

The FFG 62 program expects to have an approved software development plan in March 2021. The independent technical risk assessment identified software as a moderate risk. It noted that the program's plan for on-ship testing late in lead ship construction may identify problems that could result in design change or delays in the test program schedule. The assessment stated that the program plans to mitigate software risk through early integration testing at land-based test sites prior to initial testing on the ship.

The Navy approved the FFG 62 cybersecurity strategy in March 2019. The program reported it performed a tabletop exercise as part of its cybersecurity assessment activities.

Other Program Issues

The Navy identified the availability of high-efficiency super capacity chillers as a significant longer-term risk to the FFG 62 program's production schedule. In particular, the Navy reported that high demand for this equipment across shipbuilding programs and limitations to the vendor's production capacity could result in the FFG 62 shipbuilder's inability to procure the required amount of chillers to support the production schedule.

In March 2020, we reported that the Navy set the FFG 62 program's sustainment requirement for operational availability unacceptably low from the fleet's perspective. Specifically, the program can meet its operational availability requirement even if a ship is completely inoperable for several months per year. The Navy does not plan to update this sustainment requirement to better reflect the fleet's needs.

The Consolidated Appropriations Act, 2020, prohibited the frigate program from using funds provided in the act to award a new contract for the acquisition of certain ship components unless those components were manufactured in the U.S. It also provided that the Navy must incorporate U.S.-manufactured propulsion engines and reduction gears in the program by the 11th ship. In October 2020, the Navy reported that many components in the April 2020 contract award were manufactured in the U.S., and the propulsion equipment will be manufactured completely in the U.S. beginning with the second ship.

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. In its comments, the program office said it is moving methodically through the detail design phase to deliver capability and reduce risk. The program office also noted that since identifying the availability of chillers as a longer-term risk, the Navy has coordinated across program offices and worked with the vendor to meet shipyard schedules. Regarding FFG 62's operational availability, the program office said that it coordinated with surface fleet representatives to assess the requirement against its warfare areas, where critical failures could reduce or degrade capability in one area without affecting another area. The program office added that it responded to recommendations from the March 2020 GAO report by mapping warfare areas to system suitability characteristics and determining the probability of mission success by warfare area through a robust modeling and simulation program.

Source: U.S. Navy.

F/A-18E/F Infrared Search and Track (IRST)

The Navy is integrating new and existing infrared search and track (IRST) 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 or 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

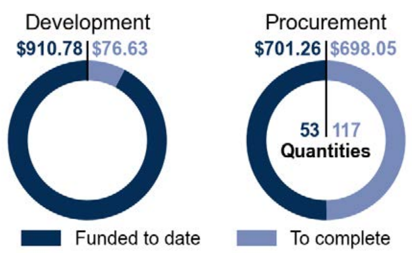
PRODUCTION
- 3/15 Low-rate decision (Block I)
- 8/18 Block II initiation
- 12/18 Low-rate decision (Block II)
- 1/21 GAO review
- 2/21 Start operational test
- 1/22 Full-rate decision
- 2/22 Initial capability

Program Essentials

Milestone decision authority: Navy
Program office: Patuxent River, MD
Prime Contractor: Boeing
Contract type: CPIF (development), FPI (procurement)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



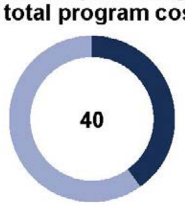
Software Development

(as of January 2021)

Approach: Agile

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Off the shelf
0 percent Modified off the shelf
100 percent Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (2/2017)	Latest (9/2020)	Percentage change
Development	$942.74	$987.41	+4.7%
Procurement	$1,419.79	$1,399.31	-1.4%
Unit cost	$13.20	$13.80	+4.5%
Acquisition cycle time (months)	123	128	+4.1%
Total quantities	179	173	-3.4%

Total quantities comprise three development quantities and 170 procurement quantities. Funding and quantities reflect amounts for the full program, consistent with how the program reports these data.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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 assessed IRST knowledge metrics using the August 2018 Block II initiation date provided by the IRST program.

IRST Program

Technology Maturity, Design Stability, and Production Readiness

IRST Block II's one critical technology—passive ranging algorithm tracking software—is mature, and the program released all 352 expected Block II design drawings, indicating a stable design as of July 2020.

Program officials reported developmental flight testing began and a tailored formal technical readiness review was conducted in March 2020 with a Block II system-level integrated prototype. While stating the testing went well, program officials also confirmed the hardware build-up process revealed defects—circuit boards equipped with faulty soldering joints—that limited prototype availability and delayed testing of Version 2, Build 3.0 software. Officials report they no longer expect the program to achieve initial operational capability in September 2021, stating this milestone is now planned to take place 5 months later in February 2022.

The program has yet to ensure critical manufacturing processes are within statistical control, nor did they demonstrate these processes on a pilot production line prior to production. Program officials stated they plan for these processes to be mature and within statistical control in early 2021 after gradually demonstrating their maturity during the transition from a system-level integrated prototype to a production representative prototype. By that time, however, the program expects to have awarded contracts for approximately 16 percent of the total production quantity. Our prior work shows that maturing manufacturing processes before production reduces the risk of costly rework. However, program officials have previously affirmed their use of concurrent development—and its inherent risk—based on Block I and Block II system similarities, long lead procurement, and urgency of need.

Software and Cybersecurity

As previously mentioned, program officials stated rework of defects found during hardware build-up also contributed to software testing delays. Specifically, the flight testing of Version 2, Build 3.0 software—which began in November 2020—could not occur until the manufacturer delivered a functioning prototype. Moreover, operational testing cannot start until Version 2, Build 3.1 software is released in February 2021. Program officials confirmed initial operational capability is now expected to be achieved in February 2022, 5 months later than the September 2021 date we reported last year. The program also confirmed the scheduled delivery of three additional software builds prior to completing final operational test and evaluation, meaning the program will likely face challenges addressing software deficiencies found in testing due to this accelerated schedule.

Program officials also reported that limited prototype availability delayed preliminary cybersecurity testing by 5 months to early September 2020. According to the program office, a Cyber Table Talk was conducted to kick off this preliminary cybersecurity testing—a planning event to inform actual test events, which includes a cooperative vulnerability and penetration assessment scheduled for September 2021. Program officials plan to use the results of this assessment to inform the design of an adversarial assessment—to be completed 3 months after initial operational capability is achieved—which Navy operational testers will use to assess IRST cybersecurity.

Other Program Issues

Officials stated preliminary estimates indicate the program's average procurement unit cost may exceed baseline costs by 8.2 percent. Program officials attributed this increase to a reduction of eight low-rate initial production (LRIP) units driven by fiscal year 2020 funding constraints, as well as future LRIP unit reductions pending potential additional funding constraints in fiscal year 2021. While the program undertakes efforts to mitigate unit cost growth—negotiating cost savings on future contracts and increasing foreign military sales—officials may not know if such efforts are effective until the start of full-rate production, which is planned for January 2022.

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 concurrency elevates risk in execution but considers it necessary for Block II due to accelerated fleet demand and long lead procurement times. According to the program office, the risk is mitigated based on Block I system similarities. The program office stated that the incremental approach to development began with flight-testing new critical technology in 2019 and continued with a successful live fire and fleet demonstration from 2019 to present with the upgraded Block I technology. Further, it noted that as part of the 2020 fleet demonstration, 12 upgraded Block I IRSTs flew and performed successfully in combat, generating an increased fleet demand for IRST units. The program office added that there is a clear and executable path to design validation and production, informed by proven technology elements, high confidence in a design stability, and a planned demonstration of production readiness. It also stated that unit cost growth and schedule adjustments are all within the program's ability to correct.

Source: U.S. Navy.

Littoral Combat Ship-Mission Modules (LCS Packages)

The Navy's LCS packages—composed of weapons, helicopters, boats, sensors, and other systems deployed f rom LCS—are intended to provide mine countermeasures (MCM), surface warfare (SUW), and antisubmarine warfare (ASW) capabilities. The Navy planned to swap packages among LCS but has now assigned each LCS a semipermanent package and is delivering some systems as they become available rather than as full packages. We assessed the status of delivered systems against the threshold requirements for baseline capabilities for the complete mission package.

CONCEPT | SYSTEM DEVELOPMENT

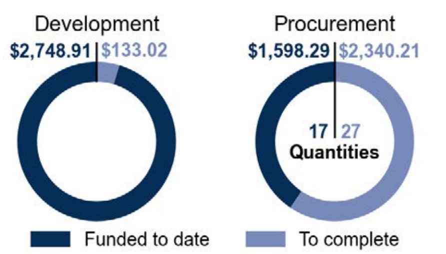
- 9/07 First MCM delivery
- 7/08 First SUW delivery
- 7/13 DOD program review
- 11/14 Initial capability SUW
- 11/18 First ASW delivery
- 3/19 Initial capability SUW with missile
- 1/21 GAO review
- 7-9/21 Initial capability ASW
- 6/22 Initial capability MCM

Program Essentials

Milestone decision authority: Navy
Program office: Washington Navy Yard, DC
Prime Contractor: Northrop Grumman Systems Corp
Contract type: FFP/CPFF/FPI/CR (procurement)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



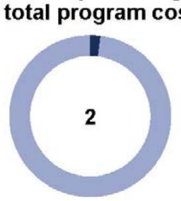
Software Development

(as of January 2021)

Approach: Incremental

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Off the shelf
0 percent Modified off the shelf
100 percent Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (8/2007)	Latest (9/2020)	Percentage change
Development	N/A	$2,881.93	N/A
Procurement	$3,826.67	$3,938.49	+2.9%
Unit cost	N/A	$139.93	N/A
Acquisition cycle time (months)	N/A	N/A	N/A
Total quantities	64	49	-23.4%

Total quantities comprise five development quantities and 44 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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; or manufacturing maturity metrics because the program office delivers systems over time and considers a production date as not applicable.

LCS Packages Program

Mine Countermeasures (MCM)

The Navy reduced MCM package requirements to focus on the ability of individual systems to integrate with and communicate on an LCS rather than achieve a mine clearance rate, according to program officials. The Navy approved the changes in 2019 and expects DOD approval in 2021, but it has yet to release a revised capabilities development document. If the reduced requirements are not representative of expected missions and environments, the program may not be acquiring systems that can achieve effective military capabilities.

Program officials stated they are working with DOD and Navy test officials to revise the MCM package's operational test strategy to reflect the reduced requirements. As a result, DOD and program officials stated the program has proposed eliminating some testing. Nevertheless, according to a DOD test official, a test strategy focused on integration and communication could limit the program's ability to identify problems with how systems interact on an LCS and whether the crew can operate and maintain sufficient systems, which could limit package capability.

Following individual MCM system testing in 2019 and 2020 of the Knifefish Unmanned Undersea Vehicle and the Unmanned Influence Sweep System—intended to detect mines at or buried under the ocean floor and to provide semiautonomous minesweeping, respectively—the program reported that all LCS package critical technologies are fully matured.

The Navy plans to buy 24 MCM packages for 15 MCM-assigned LCS but has yet to determine how it will deploy all nine unassigned packages. Program officials stated that although LCS is the only ship class with MCM package requirements, the program demonstrated some capabilities in April 2020 on an expeditionary sea base ship.

Antisubmarine Warfare (ASW)

The ASW package's initial operational capability (IOC) has been delayed from June 2020 to late fiscal year 2021, program officials noted. They stated that delays resulted from limited test assets due to operational demands, LCS test ship reliability, and problems with the ASW system. Further, the Navy was executing design changes to the package's Escort Mission Module (EMM)—the towed system that carries the variable depth sonar. We reported in our 2020 assessment that testing delays could jeopardize the planned ASW package IOC.

The Navy plans to procure 10 ASW packages for eight ASW-assigned LCS, one for test ships, and one spare. The Navy expects to begin deploying LCS with full ASW packages in 2022. We have revised the first ASW delivery date that we reported in previous years to reflect delivery of the EMM pre-production test article in November 2018.

Surface Warfare (SUW)

The Navy deployed a full SUW package—including the gun mission module, maritime security module, and Hellfire surface-to-surface missile module—on one LCS in 2019. The Navy has fielded partial packages without the missile module on both LCS variants. It plans to procure 10 SUW packages for eight SUW-assigned LCS, one for test ships, and one spare.

Software and Cybersecurity

The program is not delivering modified software functionality within the 6 months recommended by the Office of Management and Budget for incremental development. Longer delivery periods could limit operator feedback and increase the risk of discovering issues late in testing.

The program and Navy test officials are working to schedule additional SUW cybersecurity testing in 2021. Program officials stated they also plan further ASW and MCM cybersecurity testing during package initial operational test and evaluation, leaving little time to correct any new issues before their planned IOC dates.

Other Program Issues

COVID-19 and mitigation efforts, including quarantine requirements and social distancing measures, have slowed analysis of test results, extended test periods, and increased 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. According to the program office, all MCM systems have transitioned to production and will complete operationally realistic, system-level testing prior to full package testing. The program office stated that MCM package operational test plans reflect the command, control, and integration requirements for the system-of-systems, and any eliminated package testing removes redundancy for requirements demonstrated during individual system testing. The program office noted that, despite any changes to the MCM package testing, it assesses how individual systems deploy on an LCS and whether crews can simultaneously operate and maintain those systems as planned. The program added that the revised ASW package IOC date is within the program's current schedule baseline.

Source: Boeing.

MQ-25 Unmanned Aircraft System (MQ-25 Stingray)

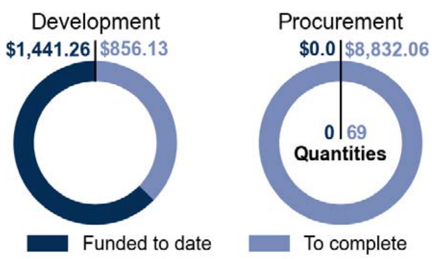
The Navy's MQ-25 is a catapult-launched, uncrewed aircraft system to operate from aircraft carriers. The Navy expects MQ-25 to provide a refueling capability for the carrier air wing. The MQ-25 is also intended to provide the intelligence, surveillance, and reconnaissance capabilities needed to identify and report on surface targets. The program is comprised of an aircraft segment, a control station segment, and a carrier modification segment. We evaluated the aircraft development segment and identified related control station issues.

Program Essentials

Milestone decision authority: Navy
Program office: Patuxent River, MD
Prime Contractor: Boeing
Contract type: FPI (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



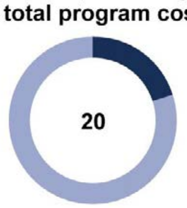
Software Development

(as of January 2021)

Approach: Agile, Waterfall, and Incremental

Average time of software deliveries (months)

Software percentage of total program cost



Software type

22 percent Off the shelf
28 percent Modified off the shelf
50 percent Custom software

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (8/2018)	Latest (8/2020)	Percentage change
Development	$3,699.43	$2,297.39	-37.9%
Procurement	$9,294.0	$8,832.06	-5.0%
Unit cost	$176.03	$155.64	-11.6%
Acquisition cycle time (months)	72	72	+0.0%
Total quantities	76	76	+0.0%

Total quantities comprise seven development quantities and 69 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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

The Navy identified no critical technologies for MQ-25. However, the program relies on two fully mature critical technologies being developed under another program. The program tested a system-level integrated prototype of the aircraft from September 2019 through February 2020 and found the engine inlet's shape could lead to engine damage, potentially requiring design changes. Program officials said the system-level integrated prototype completed a planned modification to incorporate instrumentation to further characterize the risks involving the engine inlet. Flight testing restarted in December 2020 to assess and address the engine inlet design, as well as flight stability with additional aerial refueling equipment installed.

Following the start of development, the program conducted a series of iterative design reviews that culminated in a system-level review equivalent to a critical design review in April 2020. The program released over 90 percent of total planned test aircraft design drawings. While leading acquisition practices recommend the release of 90 percent of design drawings prior to critical design review as an indicator of design stability, the program released many of the drawings after the final critical design review, consistent with the program's original plan.

Production Readiness

Program officials stated that Boeing is not contractually required to provide manufacturing readiness level data. Leading acquisition practices suggest that the absence of this type of data could limit the program's ability to assess whether Boeing can consistently produce the aircraft while meeting cost, schedule, and quality expectations. Instead, program officials told us they are collecting other information to determine manufacturing maturity. For example, they noted they conduct biweekly reviews to assess critical suppliers' manufacturing readiness. Before COVID-19 limited travel, they regularly visited suppliers' facilities.

Software and Cybersecurity

As a part of system design reviews, the program assessed software development and integration efforts, including aircraft and control station software integration. Program officials reported to us that software development delays may affect the program's overall schedule. Similar to last year's assessment, they attributed the delays to continued challenges in finding and hiring government and contractor staff with required expertise and availability of lab facilities to perform planned software development work.

Program officials reported to us they currently plan to complete software integration efforts by August 2024, when the program is scheduled to deliver initial operational capability. They said these efforts are expected to address any vulnerabilities identified during forthcoming cybersecurity assessments.

Other Program Issues

Program officials reported they are developing a new ground control station, which will include an embarkable version that can be transferred from ship to ship to increase opportunities for ship-based testing. This flexibility is expected to help the program reach a full-rate production decision 8 months earlier than we reported last year. Program officials expect the embarkable control station will increase the number of carriers available for developmental testing from two to five, mitigating a key risk we identified last year. Program officials also said that this change better aligns the program with the Navy's broader command and control strategy and Unmanned Campaign Plan because the new control station is expected to be interoperable with other future uncrewed platforms. Program officials said the program's cost estimates will increase to account for the new control stations and that the program is coordinating with Navy leadership on additional funding for the stations in fiscal years 2021 through 2025.

The contract with Boeing does not include options for the 69 planned production aircraft. The Navy plans to award the production contract to Boeing on a sole-source basis in the second quarter of fiscal year 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.

Source: U.S. Air Force.

MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)

The Navy's MQ-4C Triton is an unmanned aircraft system intended to provide maritime and littoral intelligence, surveillance and reconnaissance, and data collection and dissemination. Each system includes an air vehicle, communications suites, and mission payloads, among other components. The Navy plans a baseline Triton with subsequent variants. The baseline variant, Integrated Functional Capabilities (IFC)-3, includes two assets with early operational capability. The second version, IFC-4 with signals intelligence capability, is in development.

CONCEPT

SYSTEM DEVELOPMENT
- 4/08 Program/development start
- 02/11 Critical design review IFC-3

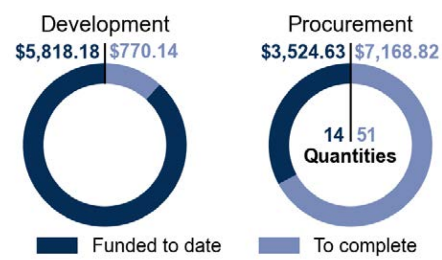
PRODUCTION
- 9/16 Low-rate decision
- 11/17 Critical design review IFC-4
- 1/20 Early capability IFC-3
- 1/21 GAO review
- 2/22 Start operational test
- 8/22 End operational test/Initial capability
- 11/26 Full-rate decision

Program Essentials

Milestone decision authority: Navy
Program office: Naval Air Station Patuxent River, MD
Prime Contractor: Northrop Grumman
Contract type: Cost-sharing (development), FPI (procurement)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



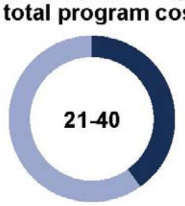
Software Development

(as of January 2021)

Approach: Agile and Incremental

Average time of software deliveries (months)

Software percentage of total program cost



Software type
- 22 percent Off the shelf
- 11 percent Modified off the shelf
- 67 percent Custom software

We assessed average time of software deliveries for the IFC-4 aircraft.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (2/2009)	Latest (7/2020)	Percentage change
Development	$3,688.67	$6,588.32	+78.6%
Procurement	$10,946.69	$10,693.44	-2.3%
Unit cost	$215.49	$252.14	+17.0%
Acquisition cycle time (months)	92	172	+87.0%
Total quantities	70	70	+0.0%

Total quantities comprise five development quantities and 65 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	NA
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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 the current status of critical technologies because the program said it no longer has any. Additionally, this year we assessed the design stability and manufacturing maturity of the IFC-4 aircraft because that is the program's current development effort, whereas in the past we had not distinguished between MQ-4C variants.

MQ-4C Triton Program

Technology Maturity, Design Stability, and Production Readiness

According to the program, Triton has no critical technologies, and released nearly all design drawings. However, the aircraft has proven more difficult to design and manufacture than anticipated. Development and production problems delayed IFC-3 capability, and IFC-4, the more advanced variant now in development, experienced persistent development difficulties with regard to integrating new, multiple intelligence sensors and associated architecture. The program noted that these and other challenges led to a 2019 breach of development cost and initial operational capability (IOC) schedule thresholds. Additionally, according to the program office, funding was insufficient to meet the scope of work. The program office said that, as a result, it delayed modifying the IFC-4 contract from May to August 2020 to enable time to address funding needs.

The program has yet to meet two leading acquisition practices for IFC-4 related to prototyping—testing a system-level integrated prototype by critical design review and a production representative prototype in the system's intended environment by the low-rate production decision. Our prior work found these practices mitigate performance risks and help ensure a system is producible within cost and schedule targets. According to the program, it performed these tests for IFC-3. However, these tests are also important for the IFC-4 aircraft, in part, because the Navy plans to retrofit its 12 IFC-3 Tritons to the IFC-4 configuration by 2026.

The program indicated that it intends to complete IFC-4 system prototype testing in March 2021 and begin IFC-4 production prototype testing in May 2021. Both events are past the time frame for the program to most effectively mitigate risks of deficiencies emerging in testing because Triton's low-rate production decision occurred in 2016 and the IFC-4 critical design review occurred in 2017. We have updated our Attainment of Product Knowledge table to reflect our focus this year on assessment of knowledge specific to IFC-4.

The Navy has also purchased about 20 percent of the planned total procurement units, in a mix of IFC-3 and IFC-4 aircraft, without yet achieving the manufacturing readiness level recommended by leading acquisition practices for determining that production processes are in statistical control. According to the program, it bought these aircraft to establish the production base and efficiently increase the production rate. DOD guidance does not require statistical control of production processes until the full-rate production decision, but our prior work shows achieving manufacturing maturity prior to the decision to enter production reduces risks of quality issues, cost growth, and delays. The program told us last year that it was not then using manufacturing readiness levels to assess production. This year the program clarified that it uses them but is not conducting periodic reevaluations of those levels unless it determines reassessment is required. We have updated our Attainment of Product Knowledge table accordingly. The program anticipates achieving statistical control of manufacturing processes in 2024, well into production.

Software and Cybersecurity

The program indicated that, to correct defects, it has made more software deliveries than planned and has deferred some functionality to future builds beyond the initial IFC-4. The Defense Contract Management Agency (DCMA) predicted in 2020 assessments that, due to development delays, the software will not achieve full functionality until January 2022 at the earliest. If delays continue, the program could reach its anticipated August 2022 IOC date with a less-capable system than planned.

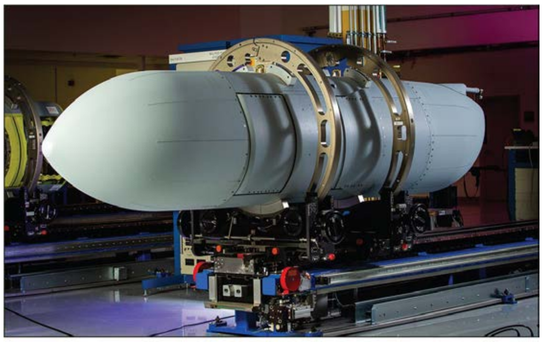
The program conducted a cybersecurity adversarial assessment in early 2020. It reported cost and schedule growth related to addressing cybersecurity controls.

Other Program Issues

The program is currently in the process of updating its baseline and expects delays from the prior baseline—IOC by more than a year to August 2022 and full-rate production by 5 years to November 2026. The schedule change includes a production pause from fiscal year 2021 until fiscal year 2023, during which the program plans to retrofit IFC-3 aircraft to the IFC-4 configuration and perform ground and flight testing. DCMA noted that the contractor has fallen behind in modifying IFC-3 aircraft for use as IFC-4 test assets, and that IFC-4 cannot be flight-tested nor can engineering for all future Triton builds be assessed until the modifications are complete. DCMA reported that, consequently, Triton flight testing may be shortened or subdivided in order for the program to achieve IOC in August 2022.

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: The Raytheon Company.

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 will augment, then replace, the ALQ-99 jamming system in the mid-band frequency range and provide enhanced airborne electronic attack capabilities to disrupt adversaries' electromagnetic spectrum use for radar detection, among other purposes. The Navy plans to field the mid-band system in 2022. The Navy has a low-band frequency program and will roll out a high-band program at a later date. We assessed the mid-band program.

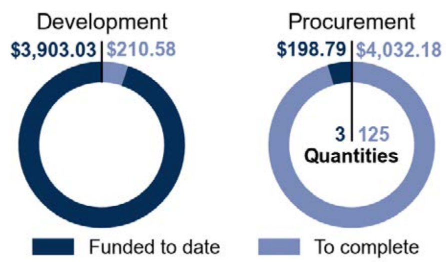
CONCEPT
7/13 Program start
SYSTEM DEVELOPMENT
4/16 Development start
4/17 Critical design review
PRODUCTION
1/21 GAO review
3/21 Low-rate decision
3/22 Start operational test
6/22 End operational test
9/22 Initial capability
12/22 Full-rate decision

Program Essentials

Milestone decision authority: Navy
Program office: Patuxent River, MD
Prime Contractor: Raytheon; Boeing
Contract type: CPIF (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

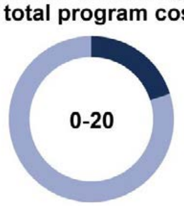
(as of January 2021)

Approach: Agile

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

2 percent Off the shelf

2 percent Modified off the shelf

96 percent Custom software

According to program officials, time of software deliveries is not applicable because the program has not yet made any software deliveries to the user—the fleet.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (4/2016)	Latest (9/2020)	Percentage change
Development	$3,806.17	$4,113.61	+8.1%
Procurement	$4,410.58	$4,230.96	-4.1%
Unit cost	$60.92	$61.87	+1.6%
Acquisition cycle time (months)	98	110	+12.2%
Total quantities	135	135	+0.0%

Total quantities comprise seven development quantities and 128 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	NA	NA
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 NGJ MB manufacturing maturity because the system has yet to reach production.

NGJ MB Program

Technology Maturity and Design Stability

The NGJ MB program demonstrated that its critical technologies are mature and its design is stable, although the program did so later than recommended by leading practices. According to NGJ MB officials, the program fully demonstrated the maturity of its seven critical technologies, including the jamming pod's arrays and power generation system, when it successfully flight tested a prototype pod on an EA-18G aircraft in August 2020. When the NGJ MB program began development in April 2016, its critical technologies were approaching maturity.

As of July 2020, the NGJ MB contractor released 100 percent of the system's design drawings and demonstrated the pod's stability. In April 2017, the program discovered design deficiencies with the pod structure at its critical design review, contributing to a 1-year schedule delay and an over $400 million increase in the program's development cost. The program completed the pod structure's redesign in April 2018, finished ground testing the structure in October 2019, and began flight testing in August 2020. Program officials said that they considered the pod structure's redesign stable, although the contractor continues to make minor changes to it. Since our 2020 assessment, the total number of design drawings increased due to structural updates to improve the pod's life.

Production Readiness

The NGJ MB program will not meet all the leading practices for production readiness before its planned production decision in March 2021. The program office does not plan to test a production-representative prototype until 5 months after its production decision. We previously found that starting production before demonstrating that a system will work as intended increases the risk of deficiencies that require costly and time-intensive design changes. Program officials told us that they have mitigated this risk by gathering hundreds of hours of test data about pod performance in ground test chambers and through flight testing engineering development models. They added that the program was on track to demonstrate key performance requirements for the power, area and frequency coverage, and stability of the pod's jamming beam, as required before it can be approved for production.

However, the program office plans to demonstrate its critical manufacturing processes on a pilot production line before that milestone, which would be consistent with leading practices. Program officials stated that as of September 2020, the program completed in-person and virtual manufacturing readiness assessments with its suppliers and planned to mitigate any outstanding risks with the prime and subcontractors by conducting follow-on reviews once COVID-19 restrictions on travel and facility visits were lifted. According to program officials, the program completed a production readiness review in December 2020.

Since our 2020 assessment, the NGJ MB program moved its production decision out 6 months to March 2021. According to program officials, the delay was due to late test pod deliveries from the contractor, the resulting delays in testing, and limited availability of acquisition personnel. Program officials cited manufacturing challenges, difficulties in integrating test equipment into the pods, and COVID-19 effects, including limits on the number of personnel at facilities, as drivers of the delays. For example, although the contractor delivered the first six pods with wiring deficiencies, it reworked the pods to fix the deficiencies and changed the design and manufacturing process for future pods, per program officials. They noted that the low-rate initial production contract award is planned for June 2021 and that the production decision delay will not affect the overall program time frames because they had built margin into the program schedule.

Software and Cybersecurity

Consistent with our assessment from last year, program officials continued to identify software development as a program risk, stating that the software effort is more difficult than expected. They noted that, more recently, COVID-19-related social distancing led to software development inefficiencies and delays, but the COVID-19 effects have not affected the overall program schedule.

The program has an approved cybersecurity strategy from December 2015 and plans to complete its evaluation for potential cybersecurity vulnerabilities in March 2021.

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 program officials, as of January 2021, the NGJ MB engineering development model pods have been installed and flight tested on an EA-18G aircraft and tested in ground test chambers. According to program officials, these efforts demonstrate the maturity of the pod's critical technologies and design stability. Program officials also noted the production pods currently under assembly are built on the same production facility that the engineering development model pods are manufactured, which they anticipate will significantly reduce the risk of immature manufacturing processes.

Source: General Dynamics Electric Boat.

SSBN 826 Columbia Class Ballistic Missile Submarine (SSBN 826)

The Navy's Columbia class (SSBN 826) will replace its current fleet of Ohio class ballistic missile submarines, which the Navy plans to retire starting in 2027. The submarine will serve as a sea-based, strategic nuclear deterrent that is expected to remain in service through 2084. According to the Navy's current acquisition plan, the lead ship will make its first patrol in June 2030.

CONCEPT
- 1/11 Technology development start

SYSTEM DEVELOPMENT
- 9/17 Detail design contract award
- 6/20 Contract modified to provide an option to build first two submarines
- 8/20 DOD program review

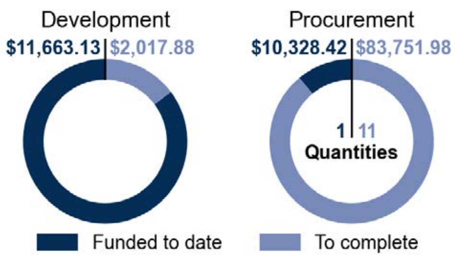
PRODUCTION
- 10/20 Lead ship major construction start
- 11/20 Contract option exercised
- 1/21 GAO review
- 10/27 Lead-ship delivery
- 6/30 Initial capability

Program Essentials

Milestone decision authority: Under Secretary of Defense, Acquisition and Sustainment
Program office: Washington Navy Yard, DC
Prime Contractor: General Dynamics Electric Boat
Contract type: CPIF (development and construction)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Incremental

Average time of software deliveries (months)

Software percentage of total program cost

Software type

0 percent
Off the shelf

0 percent
Modified off the shelf

100 percent
Custom software

Officials said they are not tracking software in their cost reporting system.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (1/2017)	Latest (7/2020)	Percentage change
Development	$13,704.74	$13,681.01	-0.2%
Procurement	$94,730.2	$94,080.4	-0.7%
Unit cost	$9,049.54	$8,995.90	-0.6%
Acquisition cycle time (months)	231	233	+0.9%
Total quantities	12	12	+0.0%

Total quantities comprise zero development quantities and 12 procurement quantities. The change in acquisition cycle time is the result of an adjustment to our calculation to use the program's current estimate instead of threshold date, consistent with our methodology

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Detail Design Contract Award**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit, and function within a realistic environment	○	○
Complete a system-level preliminary design review	●	●
Product design is stable	**Fabrication Start**	
Complete basic and functional design to include 100 percent of 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.

SSBN 826 Program

Technology Maturity, Design Stability, and Production Readiness

The program considers all of its critical technologies to be mature, though three systems remain below our definition of maturity. Based on leading acquisition practices, we consider technologies to be mature after successful testing of a prototype near or at the planned operational system configuration in a realistic environment. Until this testing is complete, the program risks costly, time-intensive rework if deficiencies emerge in these immature technologies during testing or production.

The shipbuilder completed basic and functional design before the lead submarine's start of major construction—consistent with leading practices for ensuring design stability—but design risks remain. Design stability assumes mature critical technologies, which the program has yet to fully demonstrate. Further, the program's cost estimate assumed that design disclosures—a more detailed design phase—would be 83 percent complete by October 2020, which the program did not achieve due to problems with the shipbuilder's design software. As a result, the program will likely not realize the cost savings it estimated would result from achieving this detailed design completion goal. Program officials reported that the shipbuilder added design staff in an effort to recover its schedule, at greater cost. Further, problems with the design software slowed early construction progress.

The Navy began major construction efforts in October 2020, but had already begun some advanced construction work in 2016 in an effort to meet the lead submarine's 84-month construction schedule. However, as of July 2020, some advance construction efforts were behind schedule. For example, advance construction on the submarine's missile tube section was considerably behind schedule. The program office told us that by November 2020, it had met its schedule. However, based on our analysis, the program adjusted the schedule and delayed some work on the common missile compartment. As a result, the program will need to complete more work in less time to meet its planned delivery date. As we reported in January 2021, the program experienced delays that affected this section's progress because some missile tubes had weld defects requiring repair and rework. The program also encountered early construction delays for the submarine's other sections, which it will now need to complete as part of major construction efforts. The program's inability to recover the planned schedule during early construction could affect its ability to accomplish its already aggressive construction goals.

Software and Cybersecurity

The program does not track software development cost separately because, according to program officials, some of its software was developed by another Navy program, or is reused with minor modifications.

The shipbuilder estimated the cost to implement a portion of the new DOD cybersecurity requirements for the first two submarines. The program has yet to determine the cost to implement the remaining cybersecurity requirements.

Other Program Issues

In June 2020, the program modified the design contract to include a contract option for constructing the first two submarines. The program reported that it exercised this option in November 2020. However, the associated budget request for fiscal year 2021 underestimated the most likely cost to construct these submarines and did not reflect the updated cost estimate in order to preserve a competitive negotiating position with the contractor. As a result, the program will likely require additional funding in future budget years to accommodate the expected cost increase. In September 2020, the program reported providing Congress with an update on the program's most recent cost estimate, which reflects increasing costs. These costs will be incorporated into the program's fiscal year 2022 budget request and subsequent budget requests.

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 took measures to reduce program risk through actions such as ensuring stable operational and technical requirements; executing manufacturing readiness and supplier base efforts to support construction; and pursuing cost reduction actions. The program office stated that it exceeded 83 percent overall design maturity required by the milestone decision authority by the start of lead ship construction and it worked through initial design tool development and implementation issues. Further, the program office added that the Navy updated its cost estimate in 2020, including information from DOD's Office of Cost Assessment and Program Evaluation. According to the program office, construction is on track. The program office also stated that the program continues to comply with all Navy, DOD, and statutory requirements associated with managing critical technologies and engineering integration efforts.

Source: Textron Marine and Land Systems.

Ship to Shore Connector Amphibious Craft (SSC)

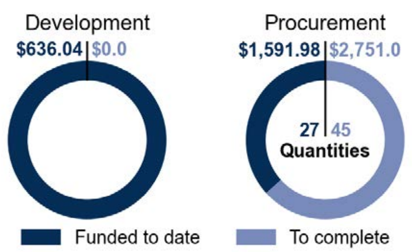
The Navy's SSC is an air-cushioned landing craft intended to transport personnel, weapon systems, equipment, and cargo from amphibious vessels to shore. SSC is the replacement for the Landing Craft, Air Cushion, which is approaching the end of its service life. The SSC is designed to deploy in and from Navy amphibious ships that have well decks, such as the LPD 17 class, and will support assault and nonassault operations.

Program Essentials

Milestone decision authority: Navy
Program office: Washington, DC
Prime Contractor: Textron, Inc.
Contract type: FPI (detail design and construction)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Modified Waterfall

Average time of software deliveries (months)

Software percentage of total program cost

Software type

73 percent Off the shelf
2 percent Modified off the shelf
25 percent Custom software

Program officials stated they are not tracking software in their cost reporting system.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (7/2012)	Latest (8/2020)	Percentage change
Development	$653.54	$636.04	-2.7%
Procurement	$3,965.95	$4,342.99	+9.5%
Unit cost	$63.58	$68.44	+7.6%
Acquisition cycle time (months)	135	152	+12.6%
Total quantities	73	73	+0.0%

Total quantities comprise one development quantity and 72 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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

SSC Program

Technology Maturity, Design Stability, and Production Readiness

Both SSC's critical technology—the fire suppression system—and its design are mature. However, the program continues to address its top two technical issues: premature gearbox wear and cracking propeller blades. The program is still completing a third iteration of the craft's gearbox design, intended to reduce wear. The program completed a lab-based, 100-hour test of the redesigned gearbox in July 2020 and completed at-sea testing of the first production craft. According to program documentation, post-testing inspection has not identified any issues with the new gearbox. Officials said that the program is installing the gearbox final design on craft in the production line and will incorporate it into all craft. Of the nine craft already in production, officials told us that one will need to be retrofitted with the final gearbox design.

The program is pursuing two concurrent solutions to address cracking found on 10 of the 12 tested propeller blades when the crafts were loaded with weight as they would be during an amphibious assault. In the interim, the program is externally reinforcing existing blades and making small changes to the control system to support loaded post-delivery testing and trials. Program officials told us that this reinforced design would allow them to continue testing and producing the craft so that the craft can begin to enter service. This interim design is complete; the program began installing the reinforcements in October 2020, and they were successfully tested on one craft in December 2020.

To ensure that the craft can meet long-term requirements, the program is also pursuing a new blade design and control system modifications. For this new design, the program reported that it established new requirements and plans to hold a preliminary design review in May 2021. This updated blade design is scheduled for initial delivery in December 2022. Program officials told us that extended testing of the interim reinforced blade may determine that a new design is not necessary.

The Navy currently plans to start initial operational testing in the first quarter of fiscal year 2022. Since last year, the program delayed initial operational capability and its full-rate decision by 5 months. According to program documentation, these delays stem from late delivery of the initial craft while the contractor worked to address ongoing technical issues. Any additional delays to craft delivery, expected in early calendar year 2021, could further delay the schedule as program officials told us that they need two to three craft to support initial operational testing in the first quarter of fiscal year 2022.

Software and Cybersecurity

According to program officials, the program completed and tested all software when the first two craft completed at-sea testing in February and June 2020.

According to the program office, it plans to satisfy all cybersecurity requirements for authority to operate the systems by the end of the fourth quarter of fiscal year 2021, which it stated will allow successful completion of operational testing and full use by the fleet.

Other Program Issues

According to program documentation, the program awarded the follow-on production contract in April 2020 for the next 15 craft, bringing the total number of craft to 24. Program officials told us that this contract covers the craft funded in fiscal years 2017, 2018, and 2019.

In part because of design and production challenges facing SSC—particularly the gearbox and propeller blades—the program is in the process of updating its acquisition program baseline. In a briefing to Navy senior leadership, the program stated that it is considering reducing the total number of craft from 72 to 50. It is also considering updating the cost baseline, which the program indicated will likely result in a breach of statutory unit cost thresholds. The program is also considering delaying the initial capability by 11 months to December 2022. However, even with this delay, should the Navy discover additional deficiencies during operational testing, the craft may not be fully capable by December 2022. Operational testing, to be completed in July 2022 under the new baseline, is the program's first opportunity to verify in realistic operational conditions that it has fully addressed all known deficiencies before deployment.

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 program has made progress delivering craft and addressing the gearbox and propeller blade technical issues.

Source: General Dynamics NASSCO.

John Lewis Class Fleet Replenishment Oiler (T-AO 205)

The John Lewis Class Fleet Replenishment Oiler (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 plans to procure these ships at a rate of roughly one ship per year until 2036.

CONCEPT
- 2/11 Program initiation

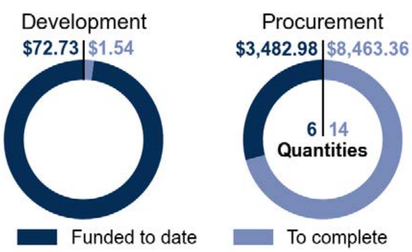
SYSTEM DEVELOPMENT /PRODUCTION
- 9/17 Development/ Production start
- 3/18 Critical design review
- 9/18 Construction start
- 1/21 GAO review
- 6/21 Lead ship delivery
- 1/22 Start operational test
- 3/22 End operational test
- 8/22 Full-rate decision
- 2/23 Initial capability

Program Essentials

Milestone decision authority: Navy
Program office: Washington Navy Yard, DC
Prime Contractor: General Dynamics National Steel and Shipbuilding Company
Contract type: FPI (detail design and construction)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Information not available

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Information not available

Software type

95 percent Off the shelf
5 percent Modified off the shelf
0 percent Custom software

The program is using off-the-shelf software systems and did not collect information on software time frames or cost.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (9/2017)	Latest (8/2020)	Percentage change
Development	$74.49	$74.27	-0.3%
Procurement	$9,339.83	$11,946.34	+27.9%
Unit cost	$553.78	$601.03	+8.5%
Acquisition cycle time (months)	46	65	+41.3%
Total quantities	17	20	+17.6%

Total quantities comprise zero development quantities and 20 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Detail Design Contract Award**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	●	●
Demonstrate all critical technologies in form, fit, and function within a realistic environment	●	●
Complete a system-level preliminary design review	○	●
Product design is stable	**Fabrication Start**	
Complete basic and functional design to include 100 percent of 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

At the 2018 construction start, all Lewis class critical technologies were mature and the design was stable—an approach that typically reduces the risk of cost increase and schedule delays. Over the last 2 years, however, the program experienced challenges with both cost and schedule.

The program projects cost overruns for the first and second ships. In fiscal year 2021, the Navy requested close to $60 million in additional funding to complete construction of these ships and reprogrammed an additional $20 million from other Navy programs. Program officials attributed these overruns to three factors:

- Higher than expected inflation, especially for materials like steel, due to increased tariffs.
- A 2018 incident involving a flooded dry dock delayed and disrupted the shipbuilder's operations. With fewer ships under construction at one time, the shipyard must now allocate the same fixed overhead costs over fewer ships.
- Shipyard and vendor performance issues stemming from more complex work than anticipated.

Program officials stated that the Navy and the shipyard convened a joint working group to identify and implement cost saving efforts. This group is studying a variety of design changes, ranging from smaller modifications, such as switching to a different design for tie-downs on the flight deck, to larger changes like removing a level from the ship's deckhouse. Program officials stated that many of these could be implemented without affecting the Navy's specifications, but some would limit the program's ability to meet its performance requirements and would require higher-level approvals from the Navy.

The program's schedule continues to experience delays due to the events of the last two years. As we reported last year, as a result of events that began with the 2018 flooding of one of the shipbuilder's dry docks, planned delivery of ships two through six slipped by 5 to 12 months. The incident did not affect the lead ship's schedule, but the late delivery of the ship's main engines and certain other components delayed the lead ship's delivery date by 7 months to June 2021. Since our last review, the initial operational capability date, tied to lead ship delivery, was delayed by 6 months to February 2023.

Software and Cybersecurity

The program's software is almost entirely commercial-off-the-shelf, with only a small fraction of that requiring any customization.

The program has an approved cybersecurity strategy involving both tabletop exercises—people talking through how they would respond to simulated scenarios—and security penetration testing.

Other Program Issues

The program issued a revised acquisition program baseline in February 2020, reflecting changes in planned procurement quantities, as well as schedule changes due to delays. The program postponed procurements for fiscal years 2021 and 2022, and its procurement schedule now runs through 2036, rather than 2035, as originally planned.

For the seventh ship, the Navy plans to award a contract modification on a sole-source basis to the current T-AO 205 contractor. The Navy included up to six ships in its original Detailed Design and Construction contract and had planned to purchase future ships through competitively awarded contracts. Navy officials said they wanted to receive detailed production information developed through the first ship's manufacture before competing future procurements. They stated that this information will not be ready in time to include the seventh ship in the competitive award under the current schedule, and making a competitive award without this information could lead to cost duplication that may not be recoverable through competition. While Navy officials reported they have yet to request a proposal for the seventh ship, they stated that the contractor previewed its expected pricing, which was higher than anticipated and reflected a significantly higher unit cost compared to earlier ships.

Program officials stated that they have yet to understand the full effects of COVID-19 on the program but that some effects are already apparent. Officials stated the shipyard was experiencing increased absenteeism and some supply chain issues, including the April 2020 temporary closing of an important sheet metal manufacturer, but the manufacturer has since reopened.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that it continues to adhere to best practices to minimize risks, reduce ship costs, and ensure an affordable design. The program stated that as it encountered cost overruns, it has worked with industry to identify over 150 cost reduction initiatives. These initiatives will be evaluated for implementation based on overall return on investment over the ship's life cycle. The program also stated that the first-in-class ship was launched in January 2021, the second ship is more than halfway complete, and construction commenced on the third ship in December 2020. With the design matured and early lessons incorporated into the construction of follow-on hulls, the program office stated that cost and schedule stability has improved.

Source: USMC.

VH-92A® Presidential Helicopter Replacement Program (VH-92A)

The Navy's VH-92A program provides new helicopters in support of the presidential airlift mission. It supersedes the VH-71 program that DOD canceled due to cost growth, schedule delays, and performance shortfalls. Twenty-three VH-92As—21 in-service and two test aircraft—will replace the current Marine Corps fleet of VH-3D and VH-60N aircraft. The VH-92A is expected to provide improved performance, communications, and survivability capabilities, while offering increased passenger capacity.

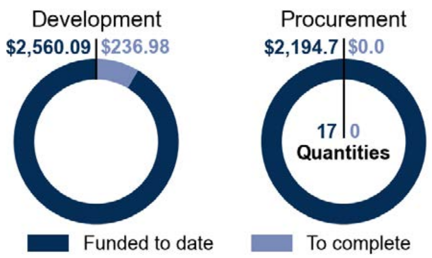
CONCEPT — 3/10 Materiel Development Decision
SYSTEM DEVELOPMENT — 4/14 Development start; 7/16 Critical design review
PRODUCTION — 6/19 Low-rate decision; 1/21 GAO review/Start operational test; 3/21 End operational test; 7/21 Initial capability

Program Essentials

Milestone decision authority: Navy
Program office: Patuxent River, MD
Prime Contractor: Sikorsky Aircraft Corporation, a Lockheed Martin Company
Contract type: FPI (development), FFP (production)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Agile and Waterfall

Average time of software deliveries (months)

Software percentage of total program cost

Information not available

Software type

80 percent Off the shelf
3 percent Modified off the shelf
17 percent Custom software

The program office stated that its overall software costs do not meet the dollar threshold that would require them to be independently tracked.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (4/2014)	Latest (8/2020)	Percentage change
Development	$2,938.11	$2,797.07	-4.8%
Procurement	$2,303.95	$2,194.7	-4.7%
Unit cost	$227.92	$217.03	-4.8%
Acquisition cycle time (months)	75	87	+16.0%
Total quantities	23	23	+0.0%

Total quantities comprise six development quantities and 17 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	NA
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	●
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 critical technologies because, according to the VH-92A program office, the Navy certified VH-92A at development start as not having any.

VH-92A Program

Technology Maturity, Design Stability, and Production Readiness

The contractor has delivered all six developmental helicopters to the Navy. The program office, however, delayed planned initial operational capability (IOC) from January 2021 to July 2021 because they will not have the minimum of four consistently available aircraft to assume the Presidential Lift Mission. The VH-92A program entered production in June 2019 with a stable design. The program reported no critical technologies, though it featured a developmental version of the government-developed mission communications system (MCS) that no other aircraft uses. As we reported last year, the Navy completed an operational assessment in April 2019 and identified MCS-related performance shortfalls, some of which led to inconsistent and unreliable communications.

Program officials stated that they have realigned the initial operational test and evaluation period to the new IOC date—delaying the planned completion of that testing by 6 months, from September 2020 to March 2021. The shift in the testing start date will allow the program to update the MCS software and incorporate an additional revised design for the helicopter's forward door into the test aircraft prior to the start of IOC. This change supports the Navy's new timeline to transition from the current fleet of helicopters to VH-92A helicopters and also allows more time to test the latest MCS software, to incorporate capability enhancements, and to train operators on the aircraft prior to starting operational testing, according to program officials.

According to Navy officials, the program continues to identify one of its landing zone suitability requirements as high-risk. The program has four Landing Zone Suitability requirements: one key performance parameter and three key system attributes. Of these four requirements, the key system attribute for aircraft exhaust damaging the landing zone on a hot day is not fully met. The program reports that heat from the engines with rotors turning continues to damage the lawn under hot environmental conditions.

The program expects to reduce risk to for this requirement with a new auxiliary power unit exhaust deflector, which it reports has demonstrated significant reduction of exhaust directed toward the ground. Fleet-wide introduction of the exhaust deflector is planned for January 2021. Concepts to reduce exhaust damage when the rotors are turning are also under development, with potential solutions expected by April 2021. Because the program entered production while concurrently addressing problems identified during the operational assessment, a design change to address this or other deficiencies discovered in the future may require modifications to units already in production.

Program officials stated that they used a combination of manufacturing readiness assessments and the Federal Aviation Administration certification process to assess VH-92A production readiness. Since our last assessment, the program demonstrated that its manufacturing processes are in control, as recommended by leading acquisition practices. According to Navy officials, the first two low-rate initial production lots are on contract and are on schedule to be delivered between 2021 and 2022. Program requirements and overall design remained stable throughout manufacturing, contributing to declines in program unit costs.

Software and Cybersecurity

According to Navy officials, the program corrected 19 of the 24 MCS-related software issues that affected aircraft reliability in the April 2019 operational assessment, along with the mission and maintenance data computer, which repeatedly sent out false warning alarms. Since completing the operational assessment, the program also identified five new MCS deficiencies that it plans to address through software upgrades or improving networks prior to operational testing.

The program has an approved cybersecurity strategy, and officials stated that they conduct cybersecurity testing on an ongoing basis to identify potential cybersecurity vulnerabilities.

Other Program Issues

In February 2020, the Navy exercised the option for the second low-rate initial production lot for six additional helicopters for planned delivery in 2022. Although COVID-19-related absenteeism slowed the production line, there are no expected effects to the contractual delivery 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.

Source: Huntington Ingalls Industries, Pascagoula, MS.

DDG 51 Arleigh Burke Class Destroyer, Flight III

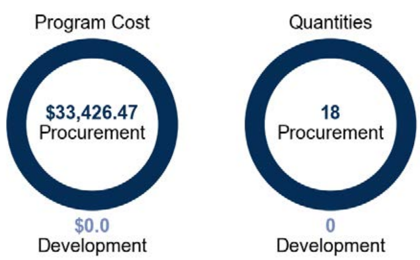
The Navy's DDG 51 Flight III destroyer is planned to be a multimission ship designed to operate against air, surface, and underwater threats. Compared to existing Flight IIA ships of the same class, the Navy expects new Flight III ships to provide the fleet with increased ballistic missile and air defense capabilities. Flight III's changes include replacing the current SPY-1D(V) radar with the Air and Missile Defense Radar (AMDR) program's AN/SPY-6(V)1 radar and upgrading the destroyer's Aegis combat system. The Navy currently plans to procure 18 Flight III ships.

Program Essentials

Milestone decision authority: Navy
Program office: Washington, D.C
Prime contractor: General Dynamics-Bath Iron Works; Huntington Ingalls Industries
Contract type: FPI (construction)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)

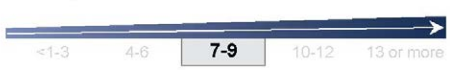


Software Development

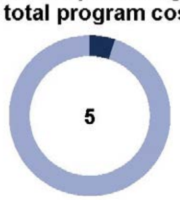
(as of January 2021)

Approach: Agile, Incremental, and DevSecOps

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent Off the shelf

0 percent Modified off the shelf

100 percent Custom software

Current Status

Flight III ships include design changes to incorporate the AN/SPY-6(V)1 radar and an upgraded Aegis combat system, both of which the Navy plans to be integrated and tested at a land-based site prior to on-board activation in 2022. Program officials stated that integration and testing with AN/SPY-6(V)1 and Aegis is underway and is expected to be complete prior to Aegis combat system activation on DDG 125 in 2022. However, Aegis and AN/SPY-6(V)1 will be installed on DDG 125 before land-based testing is complete. This limits opportunities to address any issues prior to Aegis activation in 2022.

The program office, in coordination with the Aegis and AMDR programs, is developing an integrated test and evaluation master plan for the ship, AMDR, and Aegis, but the plan has yet to be approved.

Both shipbuilders—new to building Flight III—may face cost and schedule challenges often associated with lead ships, potentially exacerbated by a labor inefficiencies due to COVID-19. DDG 125 is 43 percent complete, as of October 2020, and has experienced some cost growth, but is expected to deliver on schedule in fiscal year 2023, according to officials. However, this schedule leaves limited time for sea trials and operational testing based on a planned August 2024 initial operational capability. Any issues during sea trials and testing would likely delay DDG 125's operational availability. Construction on the second Flight III ship—DDG 126—began in March 2020. The program reported that a recent labor strike could also affect DDG 126 construction efficiency. Since last year, the program reduced its planned Flight III procurement from 22 to 18 ships to align with the Navy's future large surface combatant ships plan.

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 reports that the DDG 51 program has delivered 68 ships, with another 21 ships under contract, and that both shipyards are in serial production and constructing the initial Flight III ships. It stated the Navy is executing a test program to demonstrate Flight III upgrades prior to shipboard activation. The program anticipates that the first Flight III ship is on track for delivery in fiscal year 2023, and will reach initial operational capability in fiscal year 2024.

Source: U.S. Navy.

LHA(R) Amphibious Assault Ships (LHA 8 and LHA 9)

The Navy's LHA 8 and LHA 9, the third and fourth LHA 6 class ships, will help replace retired LHA 1 Tarawa-class amphibious assault ships. These ships incorporate significant design changes from earlier ships in the LHA 6 class and are intended to provide enhanced aviation capabilities and a well deck that can accommodate two landing craft. The ships are designed to transport about 1,350 Marines and their equipment onto hostile shores. The LHA 8 is scheduled to be delivered in January 2024, and LHA 9 will begin construction in 2024.

Program Essentials

Milestone decision authority: Navy

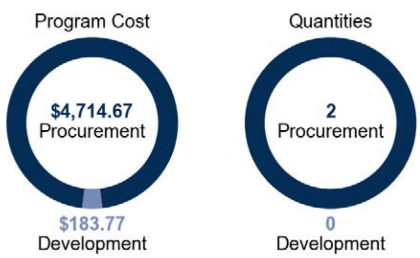
Program office: Washington, DC

Prime contractor: Huntington Ingalls Industries

Contract type: FPI (detail design and construction)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Agile and Mixed

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Information not available

Software type

Information not available

Program officials stated they do not track software work elements.

Current Status

From January 2020 to August 2020, LHA 8 construction progress increased from 5 percent to almost 19 percent complete. LHA 9 is expected to save costs by using the same design as LHA 8. As a result of receiving advanced procurement funding in 2019, the program office stated that it plans to accelerate the contract award of LHA 9 from fiscal year 2024 to late fiscal year 2021.

The Navy is continuing to mitigate risks from the integration of the Enterprise Air Surveillance Radar (EASR), a new rotating radar system for LHA 8 based on the preexisting Air and Missile Defense Radar program. The Navy has completed a design change to adjust the mast and antennas on top of the ship to avoid interference from EASR, according to program officials. However, the program will be limited to laboratory testing the change until EASR is delivered for installation in 2021.

The program is attempting to avoid repeating quality issues, such as issues with the ship's main reduction gears that resulted in delays to LHA 7 delivery. Program officials stated that these quality issues increase schedule risk for LHA 8 but stated that there are currently no delays. Program officials stated that they added contract incentives for better quality control management of the ship's construction, in part to address the quality issues with the ship's main reduction gears, such as poor welds. Program officials also told us the shipbuilder built more covered facilities to protect all equipment, including the gears, from weather.

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 as of January 15, 2021, LHA 8 is roughly 28 percent complete. It also stated that the Navy has continued to work with the contractor to mitigate technical risks to the design changes and address quality issues, and has finalized the new arrangement of the mast and antennas with the contractor.

Source: U.S. Navy.

LPD 17 San Antonio Class Amphibious Transport Dock, Flight II (LPD 17 Flight II)

The Navy's LPD 17 Flight II program 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.

Program Essentials

Milestone decision authority: Navy

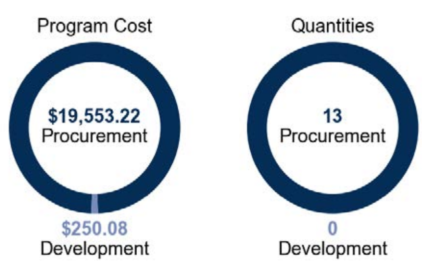
Program office: Washington Navy Yard, DC

Prime contractor: Huntington Ingalls Incorporated

Contract type: FPI (detail design and construction)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Information not available

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Information not available

Software type

Information not available

The program stated it does not track these metrics because software is not a significant element of work.

Current Status

In March 2020, the first Flight II ship construction began on LPD 30. The Navy purchased LPD 31 in April 2020 and plans for construction to start in 2022.

According to the program, the Flight II design is approximately 80 percent complete and includes roughly 200 changes from the Flight I design. The Navy is implementing these changes across three ships, including adding some planned Flight II enhancements to LPD 28 and 29, the last two Flight I ships. For example, LPD 28 includes a new mast design and LPD 29 will be the first LPD ship to include the Navy's new Enterprise Air Surveillance Radar (EASR). Program officials characterized Flight II design changes as more similar to the types of changes expected on a follow-on ship rather than a lead ship. However, risks remain in this approach. For example, EASR is still in testing, so any delays in completing or integrating it could affect LPD 29, the last Flight I ship, which, according to the program office, is approximately 49 percent complete as of February 2021.

Program officials said COVID-19 had some effect on the program although they have yet to develop formal estimates of related cost or schedule changes. Program officials said the number of people working on LPD 30 construction is about half of that planned due to COVID-19-related labor shortages. Consequently, the program expects there may be delays to LPD 30.

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 reported that Flight II will provide increased capability, including improved command and control capabilities, over the ships being replaced. It also stated that the shipbuilder is currently building three LPD 17 ships: LPD 28, LPD 29, and LPD 30.

Source: U.S. Navy.

P-8A Poseidon, Increment 3 (P-8A Increment 3)

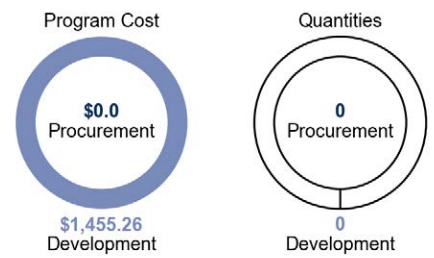
The Navy's P-8A Increment 3 is intended to provide enhanced capabilities to the P-8A aircraft in four sets of improvements. The first two sets include communication, radar, and weapons upgrades that will be incorporated into the existing P-8A architecture. The following sets are to establish a new open systems architecture, improve the combat system's ability to process and display classified information, and enhance the P-8A's search, detection, and targeting capabilities. DOD made Increment 3 part of the P-8A baseline program in 2016.

Program Essentials

Milestone decision authority: Navy
Program office: Patuxent River, MD
Prime contractor: Boeing
Contract type: CPFF (development)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)

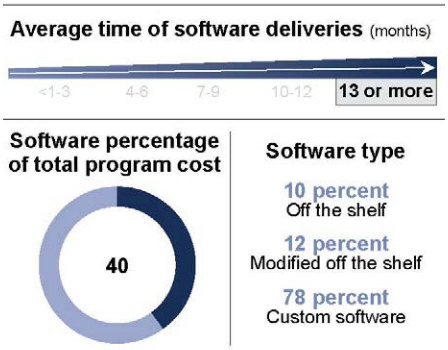


All aircraft, including previously delivered aircraft, will be retrofitted with Increment 3 capabilities. The modification kits are managed as a part of the baseline program.

Software Development

(as of January 2021)

Approach: Agile and DevOps



Current Status

The P-8A program fielded the first of four sets of Increment 3 capability improvements in fiscal year 2018, planned to complete fielding the second set in December 2020, and is developing the third and fourth sets. Since our 2020 assessment, the Increment 3 program experienced a few months' delay on some weapons-related upgrades in the second set of improvements and further extended the rest of the Increment 3 schedule into fiscal year 2025. Program officials attributed the delays and $108 million in cost increases to fiscal year 2019 and prior year funding challenges, as well as software development and integration issues. Program officials stated they were in the process of updating the schedule and further delays were possible due to the ongoing software development issues, which have been exacerbated by COVID-19-related effects.

The Increment 3 software efforts are experiencing delays due to Boeing's understaffed software development efforts and under resourced labs, according to program officials. COVID-19 exacerbated these challenges and affected staff's ability to collaborate on more complex integration efforts. The program officials said that the Navy and Boeing are implementing a strategy to address staffing and lab capacity. In November 2020, the Increment 3 program took over the development and fielding of ground stations to support Increment 3 aircraft. Another program previously managed the effort and was behind schedule. The Increment 3 program expects that assuming responsibility will help alleviate schedule concerns but could shift additional costs to the P-8A program.

Program Office Comments

We sent a draft of this assessment to the program office for comment. It provided technical comments, which we incorporated where appropriate. The joint explanatory statement accompanying the Consolidated Appropriations Act, 2021 identified a portion of the fiscal year 2021 procurement funding DOD requested for the P-8 series as being early to need. According to the program office, receiving less funding than planned, coupled with software development challenges, will delay initial fielding of the third set of capability improvements to late fiscal year 2025.

Source: U.S. Navy photo courtesy of Huntington Ingalls Industries.

SSN 774 Virginia Class Submarine (VCS) Block V

VCS is a class of nuclear-powered attack submarine capable of performing multiple missions, with enhanced capabilities for special operations and intelligence collection and surveillance. The Navy has implemented major upgrades to the class in blocks. The most recent upgrade, Block V, includes enhanced undersea acoustic improvements called acoustic superiority and increases strike capacity for Tomahawk cruise missiles by inserting a new midbody section called the Virginia Payload Module (VPM).

Program Essentials

Milestone decision authority: Navy

Program office: Washington, DC

Prime contractor: General Dynamics Electric Boat

Contract type: FPI (procurement)

Estimated Cost and Quantities (fiscal year 2021 dollars in millions)

Software Development

(as of January 2021)

Approach: Waterfall

Average time of software deliveries (months)

Software percentage of total program cost

Software type

The program office stated it does not track software cost and type because all software has been developed and tested.

Current Status

The Navy modified an existing contract in December 2019 to build nine Block V submarines with options for three more for a $22 billion target price. However, Block V work is already costing more than expected, due in part to the same inefficiencies, such as inadequate staffing levels, affecting earlier blocks. Persistent problems with Block IV construction progress and delays due to COVID-19 on both blocks add risk to Block V's delivery schedule. For example, from February to August 2020, delivery dates for eight of the 10 remaining Block IV submarines were further delayed by 4 months on average, though program officials stated that Block V has schedule margin to absorb some Block IV delays. They stated that the overall increase in submarine workload and resulting increase of inexperienced new hires at both the suppliers and the shipbuilders, along with long-term challenges meeting staffing levels, are driving these unfavorable cost trends for both blocks. The shipbuilders are mitigating these trends by shifting workers and re-allocating work tasks from different sites, and expanding hiring to add capacity. However, the Navy and shipbuilders will need to manage resources across VCS and the Columbia class submarine program, which started construction in late 2020, further stressing labor resources.

By August 2020, work on contract—including the value of materials and labor hours—for the first Block V submarine was 32 percent complete and the second—the first to incorporate the VPM—was 22 percent complete, but higher materials costs and the same inefficient labor performance could result in these submarines costing more than planned if unmitigated. Work on VPM detail design was 75 percent complete when construction started—short of the program's initial goal of 86 percent—which increases risk of cost and schedule growth.

Program Office Comments

We provided a draft 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 has reduced construction time by 2 years from the first submarine. It noted that although efforts to deliver two submarines per year has led to longer construction times, it expects this growth to be offset by reductions in post-delivery activities before the submarines enter service. The program also stated that quality is improving and submarines are delivered within budget.

Source: U.S. Navy.

Large Unmanned Surface Vessel (LUSV)

The LUSV is a planned long-endurance, uncrewed ship capable of conducting warfare operations with varying levels of autonomy. It is expected to integrate antiship and land-attack capabilities onto a modified commercial ship at least 200 feet long. The LUSV is planned to autonomously execute some capabilities, but it is expected to need a crew for certain operations and will not autonomously employ lethal payloads. The Navy plans to deploy the LUSV independently or with other surface combatant ships.

CONCEPT
- 9/20 Conceptual design contract award
- 1/21 GAO review

SYSTEM DEVELOPMENT
- TBD Request for proposal release
- TBD Prototype detail design and construction contract award
- TBD Prototype critical design review
- TBD Modified detail design and construction options award

PRODUCTION
- TBD Start of lead ship fabrication
- TBD Start operational test
- TBD Initial capability

Program Essentials

Milestone decision authority: Navy

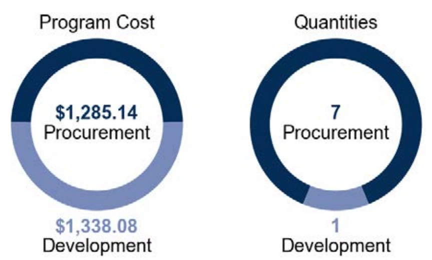
Program office: Washington Navy Yard, DC

Prime contractors: Huntington Ingalls Incorporated; Austal USA; Marinette Marine Corp.; Bollinger Shipyards; Lockheed Martin; Gibbs & Cox

Contract type: FFP (conceptual design)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Agile, Incremental, DevOps, and DevSecOps

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Information not available

Software type

Information not available

The program said it has started initial code modification in support of platform systems but has yet to determine total software costs or types.

Current Status

In September 2020, the Navy awarded six contracts for design, development, and production planning activities to help refine and develop ship specifications and requirements. According to its fiscal year 2021 plans, the Navy anticipated awarding an LUSV prototype contract in 2022 and modified design and construction contract options beginning in 2023 for up to seven fully operational ships. However, the program reported that its award plans are being updated. The Navy has yet to determine LUSV's acquisition strategy because it is currently working on a plan to develop and deliver LUSVs in support of the recently completed Future Naval Force Study.

According to fiscal year 2021 program documents, the program plans to award the first two operational ships in 2023 before LUSV prototype testing starts in 2025, limiting its ability to inform development of the lead ships. However, the program is leveraging other DOD prototyping efforts and Navy uncrewed surface vessel (USV) programs to improve endurance and further develop combat systems, sensors, and autonomy. Its prototyping schedule includes events such as autonomous transit and self-defense maneuvers. Program officials stated they need to find the right balance between sea-based and land-based prototype testing, and the Navy also plans to demonstrate other experimental USVs' enabling capabilities through 2022, such as command and control of remote launch capabilities.

Attainment of Technology Maturation Knowledge (as of January 2021)

Conduct competitive prototyping	...	**Complete independent technical risk assessment**	...
Validate requirements	...	**Complete preliminary design review**	...

● Knowledge attained, ◐ Knowledge planned, ○ Knowledge not attained,
... Information not available, NA Not applicable

We did not assess LUSV technology maturation knowledge metrics because the program office stated that it had not determined the dates for the associated events.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provide technical comments, which we incorporated where appropriate. The program office stated that the Navy is updating LUSV program plans in response to the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 and the Consolidated Appropriations Act, 2021.

Source: AVIAN CSS.

Next Generation Jammer Low-Band (NGJ LB)

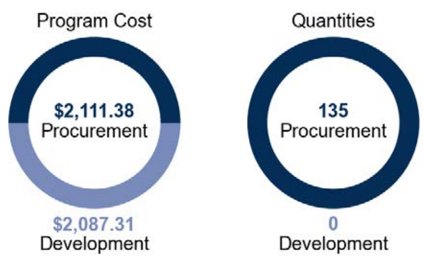
The Navy's NGJ LB, an external jamming pod system the Navy plans to integrate on EA-18G Growler aircraft, will augment, then replace, the ALQ-99 jamming system in the low-band frequency range. It will provide enhanced airborne electronic attack capabilities to disrupt adversaries' use of the electromagnetic spectrum for radar detection, among other purposes. The Navy plans to field the low-band system in 2029. The Navy also has a mid-band frequency program and will start a high-band program at a later date. We assessed the low-band program.

Program Essentials

Milestone decision authority: Navy
Program office: Patuxent River, MD
Prime contractor: L3 Technologies Inc.
Contract type: CPIF

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Information not available

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Information not available

Software type

Information not available

The program reported that software approach, cost, and type will not be available until after contract award.

Current Status

In December 2020, the NGJ LB program entered system development. According to program officials, they made a risk-based decision to proceed as an MDAP—rather than an MTA effort—in part due to the expectation in DOD guidance that programs using the MTA pathway not be planned to exceed 5 years to completion. According to the acquisition program baseline, the NGJ LB program now plans to begin production and field an initial capability almost 2 years later than we reported last year.

The program office completed its technology maturation efforts in August 2020 in preparation for system development. In October 2018, the Navy awarded contracts to two contractors to provide prototypes and demonstrate technology maturity in a relevant test environment. An independent Navy team conducted a July 2019 technology maturity assessment of the prototype designs and determined they were either based on mature technology or would be demonstrated in a relevant environment during the planned demonstrations. Program officials noted the technology demonstration contracts successfully achieved their intended purpose.

Attainment of Technology Maturation Knowledge (as of January 2021)

Conduct competitive prototyping	●	Complete independent technical risk assessment	●
Validate requirements	●	Complete preliminary design review	●

● Knowledge attained, ◐ Knowledge planned, ○ Knowledge not attained,
… Information not available, NA Not applicable

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. In its comments, the program office stated that a bid protest was filed on the program's development contract award on February 1, 2021 and that program officials were assessing the impact of this protest. This protest was subsequently dismissed by GAO in March 2021.

Source: U.S. Navy.

Conventional Prompt Strike (CPS)

The Navy's CPS program plans to develop a submarine-launched, intermediate-range, hypersonic missile via multiple middle-tier efforts, to demonstrate land-based canister launch by 2023, submarine launch by 2025, and initial operational capability on Virginia-class submarines by 2028. The Navy and Army are collaborating on CPS, with the Army leading warhead glide body production and the Navy leading remaining work. We evaluated the first effort—to demonstrate a canister launch. At the conclusion of our review, the program began realigning its acquisition plans due to funding cuts.

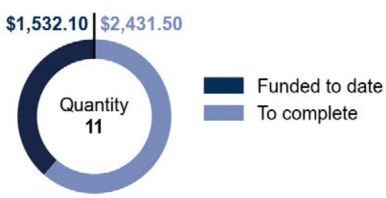
8/19	10/19	3/20	1/21	3/23	4-6/23	10/24
MTA initiation	MTA funds obligated	Interim program review	GAO review	First demonstration	Expected MTA completion	5 years since MTA funds obligated

Program Essentials

Decision authority: Navy
Program office: Washington, DC
Prime contractor: Lockheed Martin
MTA Pathway: Rapid Prototyping
Contract type: CPIF

Estimated Middle-Tier Program Cost and Quantities

(fiscal year 2021 dollars in millions)



Program officials said the first stage consumes prototype assets vice delivering production assets.

Software Development

(as of January 2021)

Approach: Agile, Waterfall, Incremental, and DevSecOps

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Software type

0 percent Off the shelf
0 percent Modified off the shelf
100 percent Custom software

The program office stated that it plans to track software costs and associated development data once the contract dealing with software is finalized.

Program Background and Transition Plan

The Navy initiated the CPS program in August 2019 based on a technology development effort started in the Office of the Secretary of Defense in 2009. Development under the first MTA effort—a rapid prototyping effort—is occurring in several stages to demonstrate a land-based canister launch by 2023. In March 2020, the Navy successfully flight tested its glide body using a surrogate missile booster. In the first quarter of fiscal year 2022, CPS plans to launch the glide body using a CPS-designed booster. Finally, the Navy plans to complete this rapid prototyping effort in the third quarter of fiscal year 2023 after test launching the CPS missile from a canister, also referred to as a missile enclosure, in the prior quarter.

Transition Plan: Transition to a follow-on rapid prototyping effort.

Attainment of Middle-Tier Acquisition Knowledge (as of January 2021)

Key Elements of a Business Case	Status at Initiation	Current Status
Approved requirements document	○	●
Approved middle-tier 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

Planned Knowledge by MTA Transition			
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	NA	Demonstrate all critical technologies in form, fit, and function within a realistic environment	NA
Complete system-level preliminary design review	NA	Release at least 90 percent of design drawings	NA
Test a system-level integrated prototype	NA	Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA
Demonstrate critical processes on a pilot production line	NA	Test a production-representative prototype in its intended environment	NA

● Knowledge attained, ◐ Knowledge planned, ⊗ Knowledge not planned,
… Information not available, NA Not applicable

We did not assess CPS's planned knowledge by MTA transition because the program plans to transition to another middle-tier rapid prototyping effort.

CPS Program

Key Elements of Program Business Case

While CPS had an approved acquisition strategy at program initiation, it did not have several other key business case elements—including top level requirements, a cost assessment based on an independent assessment, or formal technology and schedule risk assessments—approved at that time. Our prior work shows that this type of information helps decision makers make well-informed choices about MTA initiation, including the likelihood the program will meet the statute-based objective of fielding a prototype that can be demonstrated in an operational environment and can provide a residual operational capability within 5 years of an approved requirement.

Since initiation, the program finalized its requirements and DOD's Office of Cost Assessment and Program Evaluation (CAPE) conducted a preliminary cost estimate. The Senate Committee on Appropriations—in a 2019 report accompanying a bill for the DOD Appropriations Act, 2020—expressed concern that the Navy was accelerating the CPS program in a near-sole source environment without a clear understanding of technology and schedule risks, as well as costs. In response, CAPE completed a preliminary cost estimate in June 2020, predicting a $400 million shortfall over fiscal years 2022 and 2023.

Interdependency between CPS and other acquisition programs can also increase schedule risk. For example, CPS officials reported that a delay in supplier parts for the Army's version of the weapon left little margin for CPS's program schedule. CPS plans to conduct formal assessments of schedule and technology risk by June 2021, nearly 2 years after program initiation.

Technology

CPS identified four critical technologies for the first MTA effort, none of which are currently mature. These technologies include the warhead glide body, glide body and missile booster integration, early weapon control capability, and a canister launcher. The program plans to mature all technologies sequentially by the time of the first missile demonstration launch from a canister in the second quarter of 2023.

Software Development and Cybersecurity

The program's software development plan was approved in August 2019. CPS uses a mixture of software development approaches—including Agile, incremental, waterfall, and DevSecOps—to deliver custom software on a mixture of commercial and custom hardware at the component level. The CPS program office stated it plans continuous improvement in software through periodic deliveries. The program office also stated that it tracks software risk due to challenges integrating the component software found in the glide body, missile body, weapons control, and other subcomponents into one software package for the overall system. Its reliance on the prime contractor to design and integrate all software and cybersecurity interfaces mitigates its software integration risk, according to the program office.

The program's cybersecurity strategy was approved in March 2020.The program office stated that its cybersecurity team completed several tabletop exercises, which bring people together to discuss alternatives for responding to simulated scenarios. The program office noted that it has identified known cyber vulnerabilities and that a team of program officials and contractors use guidance from the program's cybersecurity strategy, including a mission-based assessment process, to reduce cybersecurity vulnerabilities.

Transition Plan

The program expects to conclude its first rapid prototyping phase in the third quarter of fiscal year 2023 once the CPS weapon system is successfully tested in a canister launcher. The CPS program will then turn its full focus to its second rapid prototyping effort, with a planned start in fiscal year 2022, to further develop capabilities for underwater test launch from a nuclear-powered guided missile submarine by fiscal year 2025.

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 was in the process of realigning its acquisition approach to prepare for reduced funding in fiscal year 2021. Consequently, the program office stated that this assessment reflects CPS plans prior to the anticipated funding reduction, but added that key flight tests and capability dates in the schedule are not expected to change.

Source: Department of Defense.

F-35 Lightning II (F-35)

DOD is developing and fielding three strike fighter aircraft variants integrating stealth technologies, advanced sensors, and computer networking for the U.S. Air Force, Marine Corps, and Navy; international partners; and foreign military sales customers. The Air Force's F-35A variant will complement its F-22A fleet and 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 variant will complement its F/A-18E/F aircraft.

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

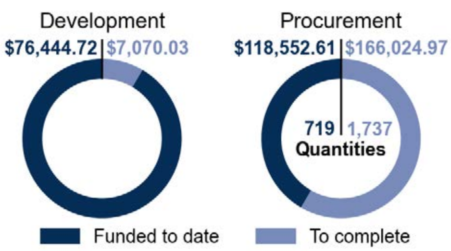
- **10/01** Development start
- **2/06 and 6/07** Critical design review
- **6/07** Production decision
- **3/12** Milestone recertification
- **7/15 and 8/16** Initial capability USMC and USAF
- **12/18** Start operational test
- **2/19** Initial capability USN
- **1/21** GAO review
- **TBD** End operational test/Full rate production

Program Essentials

Milestone decision authority: Under Secretary of Defense, Acquisition and Sustainment
Program office: Arlington, VA
Prime Contractor: Lockheed Martin, Pratt & Whitney
Contract type: CPIF (procurement, development), FPI (procurement)

Estimated Cost and Quantities

(fiscal year 2021 dollars in millions)



Software Development

(as of January 2021)

Approach: Agile and Waterfall

Average time of software deliveries (months)

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

Software percentage of total program cost

Information not available

Software type

0 percent Off the shelf
0 percent Modified off the shelf
100 percent Custom software

GAO recently reported that actual software delivery times varied from 6 months to over 1 year for the program's most recent software drop.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (10/2001)	Latest (9/2020)	Percentage change
Development	$45,763.67	$83,514.75	+82.5%
Procurement	$203,032.02	$284,577.58	+40.2%
Unit cost	$87.55	$151.15	+72.6%
Acquisition cycle time (months)	175	237	+35.4%
Total quantities	2,866	2,470	-13.8%

Total quantities comprise 14 development quantities and 2,456 procurement quantities.

Attainment of Product Knowledge (as of January 2021)

	Status at	Current Status
Resources and requirements match	**Development Start**	
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit, and function within 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 Manufacturing Readiness Level of at least 9, or critical processes are in statistical control	○	○
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

The F-35 program is conducting ongoing operational testing to evaluate the air vehicle's baseline capabilities. As of November 2020, challenges completing the joint simulation environment—used to conduct virtual tests unreproducible in a real flight—delayed the program's remaining 64 simulated flight tests until spring 2021.The program cannot make the full-rate production decision until it completes this testing and therefore postponed the decision to an unknown date.

While the program closed performance deficiencies in the past year, the total number increased due to additional deficiencies found during operational testing. As of November 2020, 11 open category 1 deficiencies remain that could jeopardize safety or security, and 861 open category 2 deficiencies remain that could impede mission success. The program office plans to resolve seven category 1 deficiencies prior to the completion of operational testing. The remaining four category 1 deficiencies will remain open until the program completes software improvements currently scheduled for delivery in 2021. This will not occur until after the full-rate production decision, which could lead to additional retrofit costs to existing aircraft.

The airframe contractor continues to deliver aircraft late due to long-standing production challenges and ongoing COVID-19-related manufacturing issues and work restrictions. Of the 94 contracted aircraft delivered as of November 2020, the airframe contractor delivered 65 late—40 more than the number of aircraft delivered late in 2019. Defense Contract Management Agency officials attribute these delays to production issues we have previously reported on, including fastener issues and fuel tube damage. They explained that COVID-19-related work restrictions exacerbated these delays but noted that the contractor is taking actions to address each issue.

The program reported that it has yet to achieve statistical control of critical production processes, in contrast to leading practices. Improvement in reliability and maintainability continues to be slow, with some metrics not meeting program goals.

As the program continues to reallocate Turkish parts from the supply chain following Turkey's suspension from the F-35 program, DOD authorized contractors to continue using Turkish parts through 2022, helping to alleviate concerns that removing Turkish suppliers will cause delays to aircraft deliveries. Program officials report they identified alternative suppliers for all 1,005 affected parts.

Software and Cybersecurity

While the program developed baseline capabilities using a waterfall approach, it is now into its third year of transitioning to an Agile software development approach. The program completed all planned cybersecurity testing in 2020. According to officials, the logistics system-related testing was completed in October 2020.

Other Program Issues

Since our last assessment, the total program cost decreased by $28.6 billion, primarily due to a reduction in negotiated unit costs, including reduced labor rates. Costs for the F-35's modernization effort, known as Block 4, increased. Total Block 4 development costs—included in the Program Performance table—grew from $12.1 billion last year to $14.4 billion this year, in part due to the additional costs for flight test activities and an additional year of development.

The program continues to deliver Block 4 capabilities late because of its overly optimistic schedule. As of October 2020, the contractor had delivered only eight of 20 capabilities planned to-date, including some that were delivered earlier than originally planned. Further, Block 4 capabilities enabled by software are frequently delivered late to flight testers, and software defects continue to be a problem. Our prior work found that using historical data to analyze software development timelines would inform a more realistic delivery schedule.

In 2020, we reported that the program had yet to conduct a technology readiness assessment for Block 4, increasing the risk of not meeting schedule and cost goals. In 2020, the program created a plan for conducting incremental technology readiness assessments for Block 4 capabilities, aligned with future software releases. The program plans for the first assessment to be completed in April 2021, 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. In addition, the program office stated that officials are currently implementing recommendations from a November 2020 software independent review team that highlighted areas for improvement. The program office also noted that, subsequent to our review, it had recategorized 178 of the 861 category 2 deficiencies as enhancements.

Appendix II: Objectives, Scope, and Methodology

This report assesses (1) the characteristics of the portfolio of 107 of the Department of Defense's most costly weapon programs we reviewed and how these programs have performed according to selected cost and schedule measures; (2) how these programs implemented or planned for knowledge-based acquisition practices; (3) how these programs have implemented modern software development approaches and recommended cybersecurity practices; and (4) the extent to which DOD has planned for the potential program execution and oversight implications of DOD's changes to its foundational acquisition instruction. This report also presents individual knowledge-based assessments of 64 Major Defense Acquisition Programs (MDAP), future MDAPs, and middle-tier acquisition (MTA) programs.

Program Selection

To identify DOD's most expensive weapon programs, we retrieved DOD's list of MDAPs from the Defense Acquisition Management Information Retrieval (DAMIR) system.[89] We selected the programs that issued an unclassified December 2019 Selected Acquisition Report and determined these to be the number of MDAPs in the 2020 portfolio. To identify MDAPs for individual knowledge-based assessments, we narrowed our overall list of MDAPs to those that were either between the start of development and the early stages of production or well into production but introducing new increments of capability or significant changes expected to exceed the cost threshold for designation as an MDAP.

To identify future MDAPs, we used the list of future MDAPs from DOD's DAMIR system that were identified by DOD as pre-MDAPs and one program we identified based on budget documentation, all of which were not considered sensitive and expected to conduct a milestone decision

[89]The Defense Acquisition Management Information Retrieval (DAMIR) is a DOD repository for program data.

event within the next 2 fiscal years.[90] We then reviewed budget materials and DOD documentation to identify planned milestone dates for these future MDAPs. We selected six systems that planned to conduct a major milestone event within the next 2 years.[91]

To identify MTA programs, we used a similar list from DOD's Defense Acquisition Visibility Environment to select programs using the MTA rapid prototyping or rapid fielding pathway that were reported by the military departments, as of March 2020, as 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). We assessed current rapid prototyping or rapid fielding efforts conducted by 17 programs using the MTA pathway—11 Air Force programs, five Army programs, and one Navy program. In some instances, current MTA efforts represent one of multiple planned efforts using the MTA or another pathway that are planned as part of a program's overall acquisition strategy. Our assessment focused on the current MTA effort, not the program's planned future efforts.

We excluded the Missile Defense Agency's Ballistic Missile Defense System and its elements from all analyses due to the lack of an integrated long-term baseline. We also excluded classified programs from our analyses.

To make DOD's acquisition terminology consistent across programs we reviewed, we standardized the terminology for key program events.

- For most individual MDAPs and future MDAPs 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 on the major capability acquisition pathway. A few MDAPs or future MDAPs in our assessment have a separate

[90]Historically, DOD guidance stated that future MDAPs should be registered in a DOD database once a program completed its first program decision. DOD maintained this list of programs that were not formally designated as MDAPs but that planned to enter system development, or bypass development and begin production, at which point DOD would likely designate them as MDAPs. For this year's report, we refer to programs we have historically reported on from this list as future MDAPs, with the exception of Large Unmanned Surface Vehicle, which has yet to determine its acquisition pathway and has not been included on DOD's list of future MDAPs.

[91]Due to the implementation of the Adaptive Acquisition Framework, some of these programs may transition to pathways other than the major capability acquisition pathway.

"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 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, which generally coincides with milestone C for non-shipbuilding programs on the major capability acquisition pathway. The "initial capability" refers to the initial operational capability—sometimes called 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 is 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 of funds first obligated. Programs using the MTA pathway also develop "transition" plans, which refers to the point at which the program begins another effort using the MTA pathway or another acquisition pathway. DOD guidance directs these programs to develop a process for transitioning successful prototypes to new or existing acquisition programs for production, fielding, and operations and sustainment.[92]

Data Collection and Reliability

To determine the total acquisition cost and schedule for MDAPs and MTA programs in the 2020 portfolio, we collected and analyzed data from the Office of the Under Secretary of Defense for Acquisition and Sustainment.

- For MDAPs, we obtained and analyzed cost data from each program's December 2019 Selected Acquisition Report. We compared the 2020 portfolio with the programs that issued Selected

[92]DOD Instruction 5000.80, *Operation of the Middle Tier of Acquisition (MTA)* (Dec. 30, 2019).

Acquisition Reports in December 2018 (i.e., the 2019 portfolio) to identify the programs that exited and entered the 2020 portfolio, and the total cost and number of programs in the 2020 portfolio compared to DOD's MDAP portfolios for previous years. Programs enter the portfolio when they start Selected Acquisition Report reporting, which typically occurs at milestone B. Programs exit the portfolio when Selected Acquisition Report reporting ends, which typically occurs when the program has expended 90 percent of total estimated program cost. Where we had historical information on prior portfolios, we compared total cost estimates for the most recent portfolio against the last 10 portfolio years.

- For MTA programs, we obtained and analyzed MTA program identification data as well as data from each MTA effort's fiscal year 2020 program status submission reports to the Office of the Under Secretary of Defense for Acquisition and Sustainment.

We also distributed a questionnaire to 65 selected program offices—35 MDAPs in development or early production, seven MDAPs that are well into production, but introducing new increments of capability or significant changes, and all six future MDAPs and 17 MTA programs we selected. For future MDAPS and MTA programs, we used the questionnaire to determine acquisition cost and to obtain additional verification of MTA program cost data, among other program information. In addition, we used the questionnaire to assess the Coronavirus Disease 2019 (COIVD-19) effects on program cost and schedule. We received responses from our questionnaires from July 2020 through September 2020. To 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 for the MDAP, future MDAP, and MTA program questionnaires prior to distribution to ensure our questions were clear, unbiased, and consistently interpreted. Our pretests of new questions covered each military department, to better ensure the questionnaire could be understood by officials in all departments.

For programs that we sent questionnaires to, we also collected and analyzed 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 interviewed or received written responses from program officials to supplement and clarify this information.

For all programs we reviewed, we converted all cost information to fiscal year 2021 dollars using conversion factors from DOD Comptroller's National Defense Budget Estimates for Fiscal Year 2021.[93]

To assess the reliability of the DAMIR system and Selected Acquisition Report data, we conducted electronic testing for missing data, outliers, and obvious errors. In addition, we relied on a full assessment of DAMIR conducted in June 2019. In June 2019, we sent three questionnaires to DOD officials with numerous questions related to their management information systems, the data in those systems, and the custodians of the data. To assess the reliability of MTA cost data, we interviewed knowledgeable agency officials from the Office of Director, Cost Assessment and Program Evaluation on MTA program cost reporting requirements, and issued a supplemental data collection instrument to each MTA program to cross-check data and solicit any updates to the numbers, with explanation. Based on these efforts, we determined that the Selected Acquisition Report data retrieved from DAMIR and MTA 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 2020 portfolio includes comparisons of cost and schedule changes over the past year (one-year change) and from baseline estimates (first full estimates) that utilize Selected Acquisition Report data from December 2019, December 2018, and from the programs' initial Selected Acquisition Report submissions. We compared the 2020 portfolio with total cost and number of programs in the current portfolio to previous years (2011-2020 portfolios). To analyze cost changes over the past year, we compared the individual and combined procurement, RDT&E, military construction, and operations and maintenance, and total acquisition costs from December 2019 to those individual and combined costs reported in December 2018 Selected

[93]Department of Defense, Undersecretary of Defense (Comptroller), *National Defense Budget Estimates for Fiscal Year 2021*, Green Book Table 5-9 (Washington, D.C.: April 2020), 68.

Acquisition Reports. We calculated the one-year cost changes of the 2020 portfolio both including and excluding the portfolio's costliest program, the F-35 Lightning II. We also calculated the total one-year cost changes of each MDAP in the 2020 portfolio that were both attributable and not attributable to quantity changes (increases or decreases in total quantity).

To further identify the top reasons for one-year cost changes that were not attributable to quantity change in the 2020 portfolio, we separated MDAPs into two groups: (1) 42 programs with increases in total cost, and (2) 42 programs with decreases in total cost between their December 2018 Selected Acquisition Report and their December 2019 Selected Acquisition Report. From programs with increases in total cost, we then selected the five programs with the greatest cost increase not attributable to quantity change. From the programs with decreases in total cost, we selected the five programs with the greatest cost decrease not attributable to quantity change. We reviewed each of these 10 program's December 2019 Selected Acquisition Report to identify the contributing factors attributed to the highest cost increases or highest cost decreases for each funding type—RDT&E, military construction and operations and maintenance, and procurement. We excluded cost increases or decreases due to quantity increase or decrease, inflation, or funding transfers within a program. For each program, we then summarized the top three contributing factors associated with the highest cost increase or decrease across funding types. Using this analysis, we identified the top three factors contributing to highest cost increase not attributable to quantity change and the top three factors contributing to highest cost decrease not attributable to quantity change across all five programs and across all funding types.

To analyze cost changes from program baseline estimates (also referred to in this report as first full estimates), we compared the procurement, RDT&E, military construction and operations and maintenance, and total acquisition costs of the 2020 portfolio to the corresponding costs of the programs' initial Selected Acquisition Report submissions. We calculated the cost changes of the 2020 portfolio to the initial program estimates. We calculated the total costs changes of each MDAP in the 2020 portfolio since their first full estimate that are both attributable and not attributable to quantity changes.

Additionally, to assess cost changes to the MDAP portfolio over the last 15 fiscal years, we compiled and compared the yearly MDAP portfolio cost data reported in the prior annual weapon system assessment reviews from 2011 to 2020. The data included yearly RDT&E and procurement costs as well as costs associated with quantity and non-quantity changes. We compared the yearly portfolio costs to determine annual cost change. To compare portfolio costs prior to 2011, we analyzed the cost performance of the MDAP portfolio by assessing the reported portfolio cost to the first full estimate cost of the programs in the portfolio. We used this approach to reflect different methodologies used to calculate MDAP portfolio cost performance prior to the 2010 portfolio.[94]

To analyze MDAP schedule performance, we identified 35 MDAPs in the 2020 portfolio that had yet to declare initial operational capability as of their December 2019 Selected Acquisition Reports. We compared the 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, to the cycle time of 44 programs that achieved initial operational capability as of their December 2019 Selected Acquisition Reports. Five MDAPs did not have initial operational capability data available and were excluded from this analysis. We also calculated the one-year cycle time changes for each program in the 2020 portfolio by comparing cycle times reported in their December 2019 Selected Acquisition Reports to those reported in December 2018 Selected Acquisition Reports. For 16 programs with increased cycle times, we reviewed their December 2019 Selected Acquisition Reports to identify factors that contributed to schedule change. We summarized these factors into high-level categories and further reported program-specific details based on program Selected Acquisition Report descriptions.

Analysis of MDAP Adherence to Knowledge-Based Acquisition Practices

Our analysis of how well MDAPs are adhering to a knowledge-based acquisition approach focuses on knowledge attained by key decision points (system development start or detail design contract award for shipbuilding programs, critical design review or lead ship fabrication start for shipbuilding programs, and production start). Factors we analyze at each key decision point include those that we have previously identified as underpinning a knowledge-based acquisition approach, including holding early systems engineering reviews, testing an integrated

[94]We assessed the 2010 portfolio costs against the 2008 portfolio because DOD did not issue complete Selected Acquisition Reports for MDAPs in 2009, which precluded an analysis of the overall cost and schedule performance of DOD's portfolio in that year's assessment.

prototype prior to the design review, planning for manufacturing, and testing a production-representative prototype prior to making a production decision. Additional information on how we collect these data is found in the knowledge assessment section of this appendix. See also appendix III for 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.[95] We also used our questionnaire to collect data on the knowledge that six future MDAPs expect to obtain before starting development. We did not verify the data provided by the program offices, but 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 at knowledge points they had previously reached in cases where the information underpinning the attainment of knowledge had since changed. For example, if the number of a program's design drawings released to manufacturing increased to the extent that the number completed at design review was no longer at least 90 percent of the total drawings, we assessed that knowledge was not attained at design review based on the growth.

For the fourth consecutive year, we performed a statistical analysis that examined our identified knowledge-based acquisition practices and select programs' cost and schedule changes. We focused the analysis on the 24 non-shipbuilding MDAPs that, prior to this assessment, completed each of the three knowledge points within the acquisition process (i.e., completed development, held a critical design review, and started production). Our statistical analysis compared average cost and schedule changes for those programs that had implemented eight key knowledge-based acquisition practices by the time they reached knowledge points 1 through 3, compared to those programs that did not complete the leading practices at each knowledge point. To ensure a reliable estimate of the average in each group, we limited our analysis to those knowledge-based acquisition practices for which at least three programs had engaged in the

[95]We removed Joint Precision Approach and Landing System from the scope of our individual assessments because it attained operational capability.

practice and at least three opted not to engage in the practice. MDAP data were sufficient to meet minimum sample size requirements for six of the eight leading practices. We did not have sufficient data to analyze the remaining two leading practices.[96] We assessed the statistical significance of the observed differences between the groups at the 90 percent confidence level.[97] With such a small sample of MDAPs, our estimates are fairly imprecise and do not meet normality assumptions.

Assessment of MTA Programs on Selected Cost and Schedule Performance Measures, Critical Technologies and Knowledge-Based Acquisition Practices

MTA Cost and Schedule Performance

To determine the planned costs for current MTA efforts, we analyzed cost data reported in the program submission forms that the military departments submitted to the Office of the Secretary of Defense in the second and fourth quarters of fiscal year 2020. To assess the accuracy and supplement the cost data, we provided data collection instruments for the program offices to provide updated cost data for MTA efforts. To assess the schedules of MTA programs, we analyzed data from the same program submission forms, including program start and planned end dates. We also reviewed the specific schedule events that MTA programs reported in the questionnaire and compared those to the type of schedule events used by more traditional acquisition programs.

MTA Critical Technologies

To assess the maturity of MTAs' critical technologies, we asked MTA programs to identify their critical technology elements in our

[96]MDAP data were sufficient to meet minimum sample size requirements for the following best six leading practices: Demonstrates all critical technologies are very close to final form, fit, and function within a relevant environment; completed preliminary design review before system development start; release at least 90 percent of drawings by critical design review; test an early system-level integrated prototype; demonstrate critical processes on a pilot production line; and test a production-representative prototype in its intended environment. MDAP data were not sufficient to meet minimum sample size requirements for two leading practices: demonstrate all critical technologies are in form, fit, and function within an operational environment; and demonstrate manufacturing process capabilities are in control.

[97]Statistical significance at the 90 percent confidence level indicates that the chances of observing a statistical difference as large or larger as observed by chance, if no difference existed, is less than 10 percent.

questionnaire. We also asked the programs to identify the technology readiness levels (TRL) for each critical technology, including projections for the technologies' maturity levels at completion of the current MTA effort. If a program indicated that it planned to transition to a rapid fielding effort or major capability acquisition pathway at system development or production, we assessed the program's planned critical technology maturity levels at those respective future points against leading acquisition practices. Those practices call for a program to have demonstrated maturity of its critical technologies in a realistic environment at development start to mitigate risk of costly and time-intensive rework if a technology fails to perform as expected once the program is in production. In cases where a program attained technology-related knowledge before it reached the transition point, we acknowledge this attainment.

Analysis of MTA Plans to Attain Product Knowledge and Progress in Development of Business Case Documentation

To assess the extent to which selected MTA programs plan to attain relevant product knowledge prior to their planned transition to the major capability acquisition pathway or to an MTA rapid fielding effort, we asked MTA programs in our questionnaire about their planned next steps after the conclusion of the current MTA effort. We determined based on programs' responses that our knowledge-based acquisition practices applied to 11 of the 17 MTA programs we reviewed: three programs that plan to transition to the major capability acquisition pathway with entry at system development and eight programs that plan to transition to the major capability acquisition pathway with entry at production or that plan to transition to an MTA rapid fielding effort.[98] We analyzed the extent to which all 11 programs planned to attain knowledge associated with knowledge point 1 by the end of the current MTA effort. In addition, for the eight programs that plan to transition to either a rapid fielding effort or the major capability acquisition pathway at production, we also analyzed the extent to which the programs plan to demonstrate knowledge associated with knowledge points 2 and 3 by the end of the current MTA effort.

[98]We determined in certain cases that our knowledge-based criteria did not apply to some programs. For example, we did not assess Optionally Manned Fighting Vehicle Increment 1 critical technologies because the program has yet to identify them. We did not assess Evolved Strategic SATCOM for test of a production-representative prototype in its intended environment because the program will not demonstrate the prototype in space.

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, including cost estimates based on an independent assessment, requirements, acquisition strategies, and formal schedule and technology risk assessments.[99] Our decision to use the program initiation date as a key knowledge point was based on prior work on business cases that demonstrated that the biggest point of leverage for a decision maker is before the decision to start a program.[100] In our questionnaire, we asked the program office whether it had the elements in place. We used program responses to determine the status of the program's business case at program initiation. Specifically, we 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 element prior to initiation or afterwards.[101] For current status, we assessed whether or not the program had completed the above five elements as of January 2021, the end of our review period. We clarified the program's status of business case elements where the program reported information that raised questions.

Assessment of MDAP and MTA Program Implementation of Software Development Approaches and Cybersecurity Practices

To assess MDAP and MTA programs' software development approaches and cybersecurity practices and the extent to which those approaches and practices are consistent with leading software practices and cybersecurity guidance, we included a number of software- and

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

[100]GAO-19-439; and GAO, *Defense Acquisitions: Joint Action Needed by DOD and Congress to Improve Outcomes*, GAO-16-187T (Washington, D.C.: Oct. 27, 2015).

[101]For status at initiation, if a program stated it had conducted any of the five activities above within 30 days of initiation, we considered that as having achieved the knowledge for that metric.

cybersecurity-related questions in our questionnaire.[102] We reviewed several related reports, including our *Agile Assessment Guide* that identifies leading practices for Agile adoption and implementation, a May 2019 Defense Innovation Board report that recommended DOD's weapon acquisition programs utilize leading commercial software development approaches that would include iterative software development approaches and a stronger emphasis on delivery times, and a February 2018 Defense Science Board report that recommended modern software practices, such as implementation of a software factory and training for program managers. We also reviewed DOD guidance, including DOD Instruction 5000.87, *Operation of the Software Acquisition Pathway*, which establishes policies and procedures for programs using the software pathway, as well as DOD's Agile Software Acquisition Guidebook, which presents lessons learned from the department's Agile pilot programs that began in fiscal year 2018.

To report on software development-related challenges, we used our questionnaire data to identify programs that reported their software as a risk item and then aggregated the reasons they provided for identifying software as a risk. To report on the type of software being developed, we asked programs to categorize software as either commercial or government off-the-shelf, modified commercial or government off-the-shelf, or custom.

To report on programs' software development approaches and delivery times, we tallied questionnaire responses for the number of programs utilizing various software development approaches. We then identified the reported software delivery times for programs using those different approaches. We focused specifically on programs that reported using Agile development and compared those delivery rates with those of leading commercial companies, as recommended by the Defense Innovation Board, National Defense Industrial Association, International Standards Organization, and other industry studies.[103] We also tallied

[102]We also surveyed future MDAPs on software approach, software type, and average length of time between software deliveries to end users. We did not include aggregate future MDAP software data in our analysis because programs reported this information was largely unavailable, in part because programs were early in their life cycles.

[103]ISO/IEC JTC1/SC7, *DevOps & Agile Study Group Report, Version 1.0* (May 2017 to April 2018); National Defense Industrial Association, *An Industry Practice Guide for Agile on Earned Value Management Programs* (Arlington, VA: Mar. 31, 2017).

responses from programs that identified whether they did or did not implement certain recommended Defense Science Board practices.

We followed up with program offices to verify answers as needed and aggregated the responses into figures that consolidated MDAP and MTA program data, as well as figures for each individual one- or two-page assessment.

To determine the extent to which programs' cybersecurity practices aligned with DOD's established cybersecurity policies, we identified specific DOD 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 February 2020. We included a number of cybersecurity-related questions in our questionnaire, including whether programs had approved cybersecurity strategies, including cybersecurity in requirements planning, and had conducted various cybersecurity assessments. We then summarized programs' responses and compared them to the DOD guidance as appropriate based on programs' phases in the acquisition life cycle.

Assessment of DOD's Oversight Plans for the Adaptive Acquisition Framework

To analyze the extent to which DOD has planned for potential program execution and oversight implications of changes to its foundational acquisition instruction, we requested and reviewed DOD documents published between December 2019 and December 2020 from the Office of the Under Secretary of Defense for Acquisition and Sustainment and other offices that provide instruction and guidance for the Adaptive Acquisition Framework.[104] We also reviewed the Secretary of Defense's plan to assess the effects of recent acquisition reforms, the Under Secretary of Defense for Acquisition and Sustainment Memo on Data

[104]DOD Instruction 5000.02, *Operation of the Adaptive Acquisition Framework* (Jan. 23, 2020); DOD Directive 5000.01, *The Defense Acquisition System* (Sept. 9, 2020); DOD Instruction 5000.85, *Major Capability Acquisition* (Aug. 6, 2020); DOD Instruction 5000.80, *Operation of the Middle Tier of Acquisition (MTA)* (Dec. 30, 2019); DOD Instruction 5000.87, *Operation of the Software Acquisition Pathway* (Oct. 2, 2020); DOD Instruction 5000.73, *Cost Analysis Guidance and Procedures* (Mar. 13, 2020); DOD Instruction 5000.89, *Test and Evaluation* (Nov. 19, 2020); DOD Instruction 5000.90, *Cybersecurity for Acquisition Decision Authorities and Program Managers* (Dec. 31, 2020).

Transparency to Enable Acquisition Pathways, published in June 2020, and DOD's Data Strategy, published in September 2020.

We assessed DOD's policies for collecting and communicating quality information as a part of the Adaptive Acquisition Framework. We also obtained information from programs using various acquisition pathways and analyzed the data to identify consistency in programs within the same pathway. We also collected and reviewed additional information such as acquisition decision memorandums, acquisition strategies, and program cost and schedule data from programs using different pathways. We reviewed DOD's implementation guidance for acquisition and sustainment data and analytics.[105] We also compared DOD policy with our past work on reform efforts and portfolio management.[106]

Additionally, we reviewed legislation, policy and guidance that outlined roles and responsibilities for the Office of the Secretary of Defense with regard to acquisition oversight, such as roles and responsibilities for the Under Secretary of Defense for Acquisition and Sustainment and the Under Secretary of Defense for Research and Engineering, as well as responsibilities for test and evaluation and cost estimation.

We also conducted interviews with officials from the Office of the Under Secretary of Defense for Acquisition and Sustainment; Office of the Director, Cost Assessment and Program Evaluation; and Office of the Director, Operational Test and Evaluation, to obtain additional insight into policy, legislative, and organizational changes, including:

- Data reporting requirements for individual Adaptive Acquisition Framework pathways and for programs using multiple pathways.
- Oversight roles and responsibilities under the Adaptive Acquisition Framework, as well as provisions and other issues DOD officials

[105]Department of Defense, Office of Acquisition Enablers, *Acquisition and Sustainment Data and Analytics Strategic Implementation Plan* (December 2020).

[106]GAO, *Agile Software Development: DHS Has Made Significant Progress in Implementing Leading Practices, but Needs to Take Additional Actions,* GAO-20-213 (Washington, D.C.: June 1, 2020); *Government Reorganization: Key Questions to Assess Agency Reform Efforts,* GAO-18-427 (Washington, D.C.: July 13, 2018); *IT Workforce: Key Practices Help Ensure Strong Integrated Program Teams; Selected Departments Need to Assess Skill Gaps,* GAO-17-8 (Washington, D.C.: Nov. 30, 2016); and *Weapon System Acquisitions: Opportunities Exist to Improve the Department of Defense's Portfolio Management,* GAO-15-466 (Washington, D.C.: Aug. 27, 2015).

considered to be relevant to defense acquisition execution and oversight.

Individual Assessments of Weapon Programs

This report presents individual knowledge-based assessments of 64 current and future weapon programs. Appendix VI contains a list of these assessments. Of the 64 assessments:

- Thirty-four 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.
- Thirteen assess future or current MDAPs in a one-page format that describes the program's current status. Those one-page assessments include (1) six future MDAPs not yet in development, and (2) seven MDAPs that are well into production, but introducing new increments of capability or significant changes.[107]
- Seventeen assess MTA programs in a two-page format discussing each program's completion of business case elements or updates to the program's business case; plans to acquire knowledge about technology and design during the current MTA effort; software development and cybersecurity; transition plan; and other program issues.

For presentation purposes, we grouped the individual assessments by lead service—Air Force and Space Force, Army, Navy and Marine Corps, and DOD-wide. We included separator pages for the Air Force, Army, and Navy at the start of each departmental grouping. These three separator pages present aggregated information about selected programs' acquisition phases, knowledge attainment, cost and schedule performance, software characteristics, cybersecurity testing, and business case activities. We obtained data on these pages primarily from the September 2020 Defense Acquisition Executive Summary (DAES) and supplemented them with program office responses to our questionnaires.

[107]One of the 13 one-page assessments for a future MDAP—the Navy's Next Generation Jammer-Low Band (NGJ-LB)—is scheduled to become an MDAP in advance of our publication date, but key program documentation was not finalized in time for us to assess it as an MDAP. We plan to assess this program as an MDAP in our next report.

For all assessments, we obtained the information presented in the Program Essentials section from sources including DOD's Selected Acquisition Reports and program office questionnaire responses. 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 MDAP and MTA program individual assessments from program office responses to a questionnaire, program office documents, and communications with program officials. In their questionnaire responses, program offices self-identified the type of software used based on definitions from the Defense Innovation Board, the frequency of software releases based on definitions from the Office of the Secretary of Defense Cost Assessment and Program Evaluation, and the types of software development approaches the program is employing.

Individual Assessments of MDAP and Future MDAP Programs

For each MDAP we assessed in a two-page format, we present cost, schedule, and quantity data at the program's first full estimate as well as an estimate from the September 2020 DAES report reflecting 2020 data, except in cases where the program did not submit a DAES report, or had a major development following that submission.[108] 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 at that milestone or decision point, such as development start estimate of cost and quantities. For MDAPs and future MDAPs assessed in a one-page format, we present the latest available estimate of cost and quantity from the program office.

[108] Specifically, we used initial Selected Acquisition Reports for Weather System Follow-On (WSF) and Guided Missile Frigate (FFG(X)), and an updated program cost estimate for F-15 Eagle Passive Active Warning Survivability System (F-15 EPAWSS) and Amphibious Combat Vehicle (ACV).

For the program performance table on 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. These costs are often referred to as program acquisition unit costs. In some instances, the data were not applicable, for example, because there are multiple different units being developed and fielded under a single program. We annotate this designation by using the term "not applicable (NA)."
- The quantities listed refer to total quantities, including both procurement and development quantities.
- The schedule assessment is based on acquisition cycle time, defined as the number of months between program start and the achievement of initial operational capability or an equivalent fielding date. In some instances the data were not yet available, and we annotate this by using the term "NA." In some cases, initial operational capability dates were updated from questionnaire data to reflect updates provided in program office comments.

The information presented in the current and future MDAP "Funding and Quantities" figures is drawn from funding stream information from DAES reports (for MDAPs) or on data from the program office (for future MDAPs). For MDAPs, we define "funded to date" as all funding that has been provided to the program through fiscal year 2021. "To complete" funding is from fiscal year 2022 through completion of the program. This graphic covers the total procurement quantities planned and funded to date.

Planned or Actual Attainment of Product Development Knowledge

As discussed above, we assessed the product development knowledge planned or attained at key points by reviewing program offices' responses to our questionnaire. However, not every program had a response to each element of the questionnaire for reasons such as: not yet reaching a key knowledge point (in the case of MDAPs); knowledge metric not applicable; or MTA programs planning to transition to a subsequent MTA rapid prototyping effort, to which our knowledge points would not apply. We also reviewed pertinent program documentation and discussed the information presented on the questionnaire with program officials as necessary. In most cases, we did not validate the information provided by the program office, although we clarified information that indicated significant deviations from prior data or was otherwise contradicted.

MDAPs

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.

For each of the three key knowledge points assessed in our MDAP knowledge graphics, we took the following steps:

- To assess whether a program's requirements and resources match, we asked program officials to report TRLs for their program's critical technologies. See Appendix IV for TRL definitions. Our knowledge-based acquisition practices work has shown 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 risk for starting a product development program.[109] For shipbuilding programs, we have recommended that this level of

[109]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.: January 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 has shown that a TRL 7 is the level of technology maturity that constitutes a low risk for starting development, DOD's guidance permits development to start at TRL 6. DOD's guidance is based on a statute that generally prohibits a major defense acquisition program 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. § 2366b(a)(2).

maturity be achieved by the contract award for detailed design.[110] 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. Satellite technologies that have achieved TRL 6 are assessed as fully mature due to the difficulty of demonstrating maturity in a realistic environment—space. In addition, we asked program officials to provide the date of the system-level preliminary design review. We compared this date to the system development start date. Where practicable, we compared technology assessments provided by the program office to Independent Technology Risk Assessments or assessments from the Office of the Under Secretary of Defense for Research and Engineering.

- To assess 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 program officials to provide the percentage of the three-dimensional product model that had been completed by the start of lead ship fabrication, and as of our current assessment. To gain greater insights into design stability, we also asked program officials 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 to the date of the critical design review. We did not assess whether shipbuilding programs had completed integrated prototypes.
- To assess production maturity, as a part of our questionnaire we asked program officials for their Manufacturing Readiness Level (MRL) for the process capability and control sub-thread.[111] We assessed programs as having mature manufacturing processes if they reported an MRL 9 for that sub-thread—meaning that manufacturing processes are stable, adequately controlled, and capable. To gain

[110] 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).

[111] We also gave MDAPs the opportunity to identify the number of critical manufacturing processes and quantify the extent of statistical control achieved for those processes as a measure of manufacturing maturity. Two programs responded that they used this metric but neither met our criteria for manufacturing readiness levels.

further insights into production maturity, we asked program officials whether the program 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 to 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.

Future MDAPs

For future MDAPs, we included a table indicating whether the programs had attained or planned to attain key knowledge prior to starting development. We selected key activities programs should conduct prior to entering system development, based on DOD Instruction 5000.85 and on earlier guidance for MDAPs: conduct competitive prototyping, validate requirements, conduct an independent technical risk assessment, and complete a preliminary design review. These are not the only activities suggested at this stage, but the table is intended to provide insight into the extent to which a program has gained or plans to gain critical knowledge before development start. To determine whether programs had conducted or planned to conduct these activities, we obtained information through our questionnaire and clarified responses with program officials, as needed.

MTA Programs

For MTA programs, we used the approach described earlier in this section to assess the attainment of knowledge for 11 MTA programs, completion of business case documents for 17 MTA programs, and to summarize cost and quantity data for 17 MTA programs. We reported costs for the current MTA effort only, as reported by the programs in our data collection instrument.

We conducted this performance audit from May 2020 to June 2021, 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: Knowledge-Based Acquisition Practices

Our prior work on best product development practices found that successful programs take steps to gather knowledge that confirms their technologies are mature, their designs stable, and that their production processes are in control. Successful product developers 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 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 6 summarizes these knowledge points and associated practices.

Table 6: Best Practices for Knowledge-based Acquisitions

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 fully funded (programmed in anticipation of milestone)
Align program manager tenure to complete development phase
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-21-222

[a]Department of Defense guidance permits development to start at a technology maturity level commensurate with Technology Readiness Level 6—demonstration of program technology in a relevant environment. Therefore, we have assessed programs against this measure as well.

Appendix IV: Technology Readiness Levels

Table 7: 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 paper studies.
3.	Analytical and experimental function and/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 and/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 and/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, in a vehicle, or in space).
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-21-222

Appendix V: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

Ms. Shelby Oakley
Defense Capabilities and Management
U.S. Government Accountability Office
441 G St NW
Washington, DC 20548

Dear Ms. Oakley,

This is the Department of Defense (DoD) response to the GAO Draft Report, GAO-21-222, "WEAPONS SYSTEM ANNUAL ASSESSMENT: Updated Program Oversight Approach Needed," dated March 31, 2021 (GAO Code 103420).

The Department concurs that the Under Secretary for Acquisition and Sustainment should ensure that the internal and external reporting for capabilities developed using multiple efforts or pathways provides information on each individual effort as well as the overall planned cost and schedule required to deliver the eventual capability.

The Department remains committed to acquisition reform and implementing the six pathways that make up the Adaptive Acquisition Framework (AAF). DoD agrees that the AAF introduces new considerations to program oversight with respect to overarching data collection and the reporting strategy for programs transitioning between pathways or conducting multiple efforts using the same pathway. DoD is committed to evaluating the metrics on the AAF pathways as part of the overarching data collection efforts and developing the proper data oversight.

The Department is providing official written comments for inclusion in the report.

The Department appreciates the opportunity to comment on the Draft Final Report. My point of contact for this effort is Ms. Katharine Edgerton, 571-256-1528.

Sincerely,

David S. Cadman
Acting Deputy Assistant Secretary of Defense (Acquisition Enablers)

Attachment

Text of Appendix V: Comments from the Department of Defense

Ms. Shelby Oakley

Defense Capabilities and Management

U.S. Government Accountability Office

441 G St NW

Washington, DC 20548

Dear Ms. Oakley,

This is the Department of Defense (DoD) response to the GAO Draft Report, GAO-21-222, 'WEAPONS SYSTEM ANNUAL ASSESSMENT: Updated Program Oversight Approach Needed,' dated March 30, 2021 (GAO Code 103420).

The Department concurs that the Under Secretary for Acquisition and Sustainment should ensure that the internal and external reporting for capabilities developed using multiple efforts or pathways provides information on each individual effort as well as the overall planned cost and schedule required to deliver the eventual capability.

The Department remains committed to acquisition reform and implementing the six pathways that make up the Adaptive Acquisition Framework (AAF). DoD agrees that the AAF introduces new considerations to program oversight with respect to overarching data collection and the reporting strategy for programs transitioning between pathways or conducting multiple efforts using the same pathway. DoD is committed to evaluating the metrics on the AAF pathways as part of the overarching data collection efforts and developing the proper data oversight.

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Sincerely,

David S. Cadman

Acting Deputy Assistant Secretary of Defense (Acquisition Enablers)

Attachment

Appendix VI: GAO Contact and Staff Acknowledgments

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Staff Acknowledgments

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Table 8 lists the staff responsible for individual program assessments.

Table 8: GAO Staff Responsible for Individual Program Assessments

	Program Name	Primary Staff
Army Programs	Armored Multi-Purpose Vehicle (AMPV)	Charlie Shivers, Amos Mwesigwa
	CH-47F Modernized Cargo Helicopter (CH-47F Block II)	Wendy P. Smythe, Jasmina Clyburn
	Extended Range Cannon Artillery Increment IC (ERCA)	Leslie Ashton, Robert Bullock
	Future Long-Range Assault Aircraft (FLRAA)	Sean Merrill, Joe E. Hunter
	Handheld, Manpack, and Small Form Fit Radios (HMS)	Jenny Shinn, Sierra Hicks, Zamir Ruli
	Improved Turbine Engine Program (ITEP)	Jasmina Clyburn, Wendy P. Smythe
	Indirect Fire Protection Capability Increment 2 (IFPC Inc 2-I)	Brian Smith, Brian Tittle

	Program Name	Primary Staff
	Integrated Air and Missile Defense (IAMD)	Julie Clark, Anh Nguyen
	Integrated Visual Augmentation System (IVAS)	Beth Reed Fritts, Betsy Gregory-Hosler
	Lower Tier Air and Missile Defense Sensor (LTAMDS)	John Rastler-Cross, Michael H. Moran
	Mobile Protected Firepower (MPF)	Jessica Berkholtz, Scott Purdy
	Optionally Manned Fighting Vehicle (OMFV)	Scott Purdy, Joy J. Kim
	Precision Strike Missile (PrSM)	TyAnn Lee, Andrew H. Burton
Navy and Marine Corps Programs	Advanced Anti-Radiation Guided Missile – Extended Range (AARGM-ER)	Marcus C. Ferguson, Adriana Aldgate
	Air and Missile Defense Radar (AMDR)	Nathan P. Foster, Kathryn B. Lenart
	Amphibious Combat Vehicle (ACV)	Matthew M. Shaffer, Monique Nasrallah
	CH-53K Heavy Replacement Helicopter (CH-53K)	Victoria Klepacz, Christopher Woika
	Constellation Class Frigate (FFG 62)	Chad Johnson, Sean Merrill
	Conventional Prompt Strike (CPS)	Matthew L. McKnight, Lisa Fisher
	CVN 78 Gerald R. Ford Class Nuclear Aircraft Carrier (CVN 78)	Jessica Karnis, Burns C. Eckert, Kimberly Schuster
	DDG 1000 Zumwalt Class Destroyer (DDG 1000)	Laurier Fish, Timothy Moss
	DDG 51 Arleigh Burke Class Guided Missile Destroyer - Flight III (DDG 51 Flight III)	Nathan P. Foster, Anh Nguyen
	F/A-18E/F Infrared Search and Track (IRST)	Erin Stockdale, Nicole Warder
	John Lewis Class Fleet Replenishment Oiler (T-AO 205)	Matthew J. Ambrose, William Reed
	Large Unmanned Surface Vessel (LUSV)	Kya Palomaki, Brendan K. Orino
	LHA(R) Amphibious Assault Ships (LHA 8 and LHA 9)	Cale Jones, Miranda J. Wickham
	Littoral Combat Ship Mission Modules (LCS Packages)	Brendan K. Orino, Monique Nasrallah
	LPD 17 San Antonio Class Amphibious Transport Dock, Flight II (LPD 17 Flight II)	Brandon Booth, Holly Williams
	MQ-25 Unmanned Aircraft System (MQ-25 Stingray)	Sophia Payind, James Kim
	MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)	Tana M. Davis, Laura T. Abendroth
	Next Generation Jammer Low Band (NGJ Low-Band)	Daniel Glickstein, Carmen Yeung
	Next Generation Jammer Mid-Band (NGJ Mid-Band)	Claire Li, Daniel Glickstein, Ryan Braun
	P-8A Poseidon, Increment 3 (P-8A Increment 3)	Heather Barker Miller, Andrew Powell
	Ship to Shore Connector Amphibious Craft (SSC)	Kristin VanWychen, Jeffrey L. Hartnett, Sara M. Younes
	SSBN 826 Columbia Class Ballistic Missile Submarine (SSBN 826)	Lindsay Cross, Nathaniel Vaught
	SSN 774 Virginia Class Submarine Block V (VCS Block V)	Nathaniel Vaught, Laurier Fish
	VH-92A® Presidential Helicopter Replacement Program (VH-92A)	Marvin Bonner, Andrew Powell, Wendy Smythe
Air Force Programs	Air Operations Center Weapon System Modifications (AOC WS MODS)	Desiree E. Cunningham, Laura D. Hook
	Air Launched Rapid Response Weapon (ARRW)	Patrick Breiding, Matthew McKnight

	Program Name	Primary Staff
	B-52 Commercial Engine Replacement Program Rapid Virtual Prototype (B-52 CERP RVP)	Megan Setser, Don Springman
	B-52 Radar Modernization Program (B-52 RMP)	Don Springman, Rachel A. Steiner-Dillon
	Enhanced Polar System - Recapitalization (EPS-R)	Erin Carson, Jennifer Dougherty
	Evolved Strategic SATCOM (ESS)	Laura D. Hook, Mary Diop, Margaret Fisher
	F-15 Eagle Passive Active Warning Survivability System (F-15 EPAWSS)	Matthew Drerup, Adrianne Lewis
	F-15 EX (F-15 EX)	Amos Mwesigwa , Megan Setser
	F-22 Capability Pipeline	Dennis A. Antonio, Sean Seales
	Future Operationally Resilient Ground Evolution (FORGE)	Tanya Waller, Erin R. Cohen
	Global Positioning System III (GPS III)	Jonathan Mulcare, Kelsey M. Carpenter
	Global Positioning System III Follow-On (GPS IIIF)	Jonathan Mulcare, Andrew Redd, Ryan Braun
	HH-60W Jolly Green (HH-60W)	Sean Seales, Daniel R. Singleton
	KC-46A Tanker Modernization (KC-46A)	Katheryn Hubbell, Jean Lee
	Military Global Positioning System (GPS) User Equipment Increment 1 (MGUE Inc 1)	Andrew Redd, Erin Carson
	Military Global Positioning System (GPS) User Equipment Increment 2 (MGUE Inc 2)	Andrew Redd, Erin Carson
	Multi-Mission Helicopter (MH-139A)	Ashley Rawson, Gina Flacco
	National Security Space Launch (NSSL)	Erin R. Cohen, Tanya Waller
	Next Generation Operational Control System (OCX)	Jonathan Mulcare , Andrew Redd
	Next Generation Overhead Persistent Infrared (Next Gen OPIR)	Claire Buck, Brenna Derritt
	Protected Tactical Enterprise Service (PTES)	Brian D. Fersch, Lucas Smith
	Protected Tactical SATCOM (PTS)	Mary Diop, Andrew Berglund
	Small Diameter Bomb Increment II (SDB II)	Sarah B. Tempel, John W. Crawford
	T-7A Red Hawk (T-7A)	Adrianne Lewis, Marvin Bonner
	VC-25B Presidential Aircraft Recapitalization (VC-25B)	LeAnna Parkey, Jenny Shinn
	Weather System Follow-On (WSF)	Nicole Warder, Brenna Derritt
Joint Department of Defense Programs	F-35 Lightning II (F-35)	Erika M. Cubilo, Jillena Roberts

Source: GAO. | GAO-21-222

Related GAO Products

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