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Report to Congressional Committees

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DEFENSE ACQUISITIONS ANNUAL ASSESSMENT

Drive to Deliver Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight

GAO-20-439

GAO Highlights

Highlights of GAO-20-439.

A Report to Congressional Committees — June 2020

Defense Acquisitions Annual Assessment

Drive to Deliver Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight

This is GAO's 18th annual assessment of DOD acquisition programs. GAO's prior assessments covered major defense acquisition programs. This year's assessment expands to include selected major IT systems and rapid prototyping and rapid fielding programs, in response to a provision in the National Defense Authorization Act for Fiscal Year 2019.

This report (1) summarizes the characteristics of 121 weapon and IT programs, (2) examines cost and schedule measures and other topics for these same programs, and (3) summarizes selected organizational and legislative changes. GAO identified the 121 programs for review based on their cost and acquisition status. GAO selected organizational and legislative changes that it determined related to the execution and oversight of the 121 programs. GAO reviewed relevant legislation and DOD reports, collected data from program offices through a questionnaire, and interviewed DOD officials.

Additional analyses and assessments of major IT programs are included in a companion report to be issued later this year.

The Department of Defense (DOD) currently plans to invest over $1.8 trillion to acquire new major weapon systems such as aircraft, ships, and satellites. At the same time, the department is investing billions more in information technology (IT) systems and capabilities that it expects to either prototype or field rapidly through a new middle-tier acquisition pathway. (See table.)

Department of Defense Planned Investments in Selected Acquisition Programs GAO Reviewed (Fiscal Year 2020 Dollars in Billions)

Type of program	Number of programs reviewed	Total investment
Major defense acquisition programs (current and future)	93	$1823.8
Major information technology programs	15	$15.1
Middle-tier acquisition programs	13	$19.5
Total	**121**	**$1858.4**

Source: GAO analysis of Department of Defense data. | GAO-20-439

Note: Cost estimates for some future major defense acquisition programs and middle-tier acquisition programs do not represent DOD's full level of planned investment.

In recent years, Congress enacted reforms that could help streamline acquisition oversight and deliver capabilities faster. In January 2020, in part to improve the speed of the acquisition system, DOD reissued its foundational acquisition guidance. The new guidance includes six acquisition pathways based on the characteristics and risk profile of the system being acquired, including three that relate to the three types of programs GAO reviewed: 1) major capability acquisition, used to acquire major defense acquisition programs (MDAP); 2) middle-tier acquisition (MTA), used for rapid prototyping and rapid fielding efforts; and 3) defense business systems, used to acquire certain major IT programs. GAO's observations on MDAPs and MTA programs are discussed below.

Major Defense Acquisition Programs

MDAPs are generally programs designated by the Secretary of Defense as such or that are estimated to require eventual total expenditure for research, development, test, and evaluation of more than $480 million, or for procurement of more than $2.79 billion, in fiscal year 2014 constant dollars.

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MDAPs have generally stabilized non-quantity-related cost growth and schedule growth but continue to proceed with limited knowledge and inconsistent software development approaches and cybersecurity practices. Between 2018 and 2019, total acquisition cost estimates for DOD's 85 current MDAPs grew by a combined $64 billion (a 4 percent increase), growth that was driven by decisions to increase planned quantities of some weapon systems. For example, DOD more than doubled in the past year the total number of missiles it plans to acquire through the Air Force's Joint Air-to-Surface Standoff Missile program. Also between 2018 and 2019, capability delivery schedules for MDAPs increased, on average, by just over 1 month (a 1 percent increase). However, MDAPs' cost and schedule performance is less encouraging as measured against their original approved program baselines. MDAPs have accumulated over $628 billion (or 54 percent) in total cost growth since program start, most of which is unrelated to the increase in quantities purchased. Additionally, over the same time period, time required to deliver initial capabilities has increased by 30 percent, resulting in an average delay of more than 2 years.

MDAP Adherence to Knowledge-Based Practices

Many MDAPs continue to move forward without the benefit of knowledge at key acquisition points. GAO has found a correlation between implementation of certain practices and improved cost and schedule performance (see table).

Statistically Significant Knowledge-Based Acquisition Practices and Their Corresponding Unit Cost and Schedule Outcomes

Knowledge practice	Programs that implemented the practice	Programs that did not implement the practice	Net performance difference
Complete a system-level preliminary design review prior to system development	• -13.1% unit cost growth • 11.6% schedule growth	• 33.6% unit cost growth • 46.3% schedule growth	• 46.7% less unit cost growth • 34.7% less schedule growth
Release at least 90 percent of design drawings by critical design review	• -5.5% unit cost growth • 10.3% schedule growth	• 45.1% unit cost growth • 50.3% schedule growth	• 50.6% less unit cost growth • 40.0% less schedule growth
Test a system-level integrated prototype by critical design review	• 13.3% schedule growth	• 43.2% schedule growth	• 29.9% less schedule growth

Source: GAO analysis of Department of Defense data. | GAO-20-439

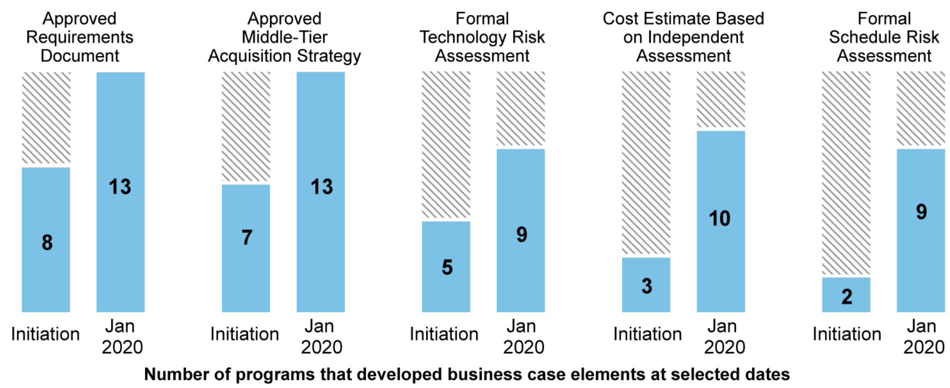
GAO also found inconsistent implementation of leading software practices and cybersecurity measures among MDAPs. This included longer-than-expected delivery times for software and delays completing cybersecurity assessments—outcomes disruptive to DOD's efforts to keep pace with warfighters' needs for enhanced, software-dependent capabilities and protect weapon systems from increasingly sophisticated cybersecurity threats.

Middle-Tier Acquisition Programs

Statute required DOD to establish guidance for rapid prototyping and rapid fielding pathways. These pathways are to provide a streamlined acquisition process for programs intended to field capabilities within 2 to 5 years. MTA programs are generally exempt from DOD's traditional acquisition and requirements development processes.

DOD has taken steps to improve oversight of its costliest MTA programs, but challenges remain to tracking cost and schedule performance. The 13 programs GAO reviewed were expected to last about 4 years on average, although most planned follow-on efforts. For example, the Army's Extended Range Cannon Artillery program plans two rapid prototyping spirals, followed by fielding. DOD issued guidance in December 2019 that increased oversight for MTA programs, including requiring certain business case documentation to help assess whether programs are well-positioned to field capabilities within 5 years. These document requirements were consistent with a June 2019 GAO recommendation. GAO found that while most MTA programs it reviewed were lacking some or all of these documents at program initiation, they had made significant progress in receiving approval of these documents by the time of this review (see figure).

MTA Program Completion of Key Program Business Case Documentation



Source: GAO analysis of Department of Defense acquisition programs' responses to GAO questionnaire. | GAO-20-439

GAO observed inconsistent cost reporting and wide variation in schedule metrics across MTA programs, which pose oversight challenges for Office of the Secretary of Defense and military department leaders trying to assess performance of these programs. According to DOD officials, the department is in the process of improving MTA program data.

Contents

Tables

Figures

Abbreviations

AA	adversarial assessment
APB	acquisition program baseline
APUC	average procurement unit cost
BMDS	Ballistic Missile Defense System
CAPE	Cost Analysis and Program Evaluation
COTS	commercial-off-the-shelf
CVPA	cooperative vulnerability and penetration assessment
DAES	Defense Acquisition Executive Summary
DAMIR	Defense Acquisition Management Information Retrieval
DOD	Department of Defense
FY	fiscal year
IT	information technology
KPP	key performance parameter
KSA	key system attribute
MAIS	major automated information system
MDA	Missile Defense Agency
MDAP	major defense acquisition program
MRL	manufacturing readiness level
MTA	middle-tier acquisition
NA	not applicable
NDAA	National Defense Authorization Act
OSD	Office of the Secretary of Defense
OUSD(A&S)	Office of the Under Secretary of Defense (Acquisition and Sustainment)
OUSD(R&E)	Office of the Under Secretary of Defense (Research and Engineering)
RDT&E	research, development, test, and evaluation
SAR	Selected Acquisition Report
SRDR	Software Resource Data Report
TBD	to be determined
TRL	technology readiness level
WSARA	Weapon Systems Acquisition Reform Act

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**Comptroller General
of the United States**

June 3, 2020

Congressional Committees

I am pleased to present our annual assessment of Department of Defense (DOD) acquisition programs. This assessment, now in its 18th year, examines DOD's most expensive weapon system acquisition programs—an area on GAO's High Risk List since 1990—and information technology (IT) acquisition programs.[1] DOD relies on both of these types of acquisition programs to achieve its warfighting mission, and this is our first annual assessment that examines them together.

Altogether, this report covers 121 acquisition programs, which DOD expects to cost over $1.8 trillion in total.[2] This significant financial investment demands keen oversight, particularly as DOD changes how it manages these programs under its acquisition policy, revised in January 2020.[3] Among other things, DOD has issued an updated policy that includes the use of sound business practices and indicates additional policies related to acquisitions currently are being developed. Our prior work has shown that knowledge-based acquisition practices, which we have recommended DOD adopt, provide a sound foundation for programs to meet their users' needs. Nonetheless, we continue to find that these practices lack consistent application within the department.

DOD's revisions to its acquisition policy also reflect new pathways for managing acquisition programs. DOD has begun to use a new middle-tier

[1]GAO, *High-Risk Series: Substantial Efforts Needed to Achieve Greater Progress on High-Risk Areas*, GAO-19-157SP (Washington, D.C.: Mar. 6, 2019).

[2]Our assessment does not include the cost of the Missile Defense Agency's (MDA) Ballistic Missile Defense System (BMDS) as this major defense acquisition program and its elements lack acquisition program baselines needed to support our analyses of cost and schedule changes. Although 10 U.S.C. § 225 requires the MDA to establish and maintain an acquisition baseline for certain elements of the BMDS, these baselines are not the same as the acquisition program baselines developed pursuant to 10 U.S.C. § 2435 and DOD acquisition policies; subsequently they do not provide all the data we need to analyze cost and schedule changes. For more information on BMDS and its elements, see GAO, *Missile Defense: Delivery Delays Provide Opportunity for Increased Testing to Better Understand Capability*, GAO-19-387 (Washington, D.C.: June 6, 2019).

[3]Department of Defense Instruction 5000.80, *Operation of the Middle Tier of Acquisition (MTA)* (December 30, 2019); Department of Defense Instruction 5000.02, *Operation of the Adaptive Acquisition Framework* (January 2020); Department of Defense Instruction 5000.75, *Business Systems Requirements and Acquisition* (February 2017 [incorporating change 2 (Jan. 2020)]).

acquisition (MTA) pathway in an effort to speed the pace of weapons acquisition and deliver capability to users more quickly. Congress provided DOD with the authority for this pathway in November 2015. These MTA programs tailor reviews, assessments, and documentation requirements to their unique needs with the intention of fielding capabilities within 5 years of program start. MTA programs have increasingly taken root across the military departments, including for large, expensive programs critical to DOD's mission needs. Further, while the vast majority of DOD's acquisition investments continue to be focused toward weapon systems, investments in major business and nonbusiness IT programs, acquired under a defense business systems pathway, among other pathways, have also grown.

At the same time, DOD acquisition programs are more software-driven than ever before. Timely development and delivery of software capability is now often paramount to a program's success. Nonetheless, we found that software development continues to be a stumbling block in many programs, as DOD often departs from the proven practices on which commercial industry relies. These challenges also occur in an environment where DOD faces global cybersecurity threats to its weapon and IT systems, but has made only limited progress to date in identifying and eliminating its vulnerabilities.

DOD continues to look for ways to deliver systems as fast as possible. The confluence of these two factors—namely, the desire to deliver capabilities faster and at the same time field more software-intensive and secure systems—further underscores the importance of having requisite knowledge at key acquisition points. Our prior work has found that having such knowledge is what enables leading industry to develop, manufacture, and bring to market innovative products under a more predictable and controllable schedule. Further, for the third year in a row, we completed an exploratory statistical analysis that reaffirms a linkage between the attainment of knowledge and the real-life cost and schedule outcomes that weapons programs deliver. This year, we expanded our data set by four programs to a total of 21, each of which has entered production. Over the past 3 years, our analyses show that, consistent with the knowledge-based acquisition practices we have recommended, programs that attained certain knowledge at key points had lower cost and schedule growth than other programs.

Consequently, delivering secure, functional capabilities that keep pace with the evolving threats and attaining knowledge in programs go hand in hand—namely, in order for DOD to achieve the former, it must first achieve the latter. Therefore, it is troubling to see programs, including MTA programs, embark on ambitious plans for delivering capabilities without having established fundamental knowledge, such as key business case elements related to technologies and cost. Until DOD can reconcile gaps in the ambitious schedules that programs promise with the incomplete knowledge they have attained, its ability to accelerate the speed at which it delivers capabilities remains in jeopardy.

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June 3, 2020

Congressional Committees

In response to section 833 of the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2019, this report provides insight into 121 of the Department of Defense's (DOD) most costly weapon and information technology (IT) acquisition programs.[1] Specifically, this report covers the following four sets of programs:

- 85 major defense acquisition programs (MDAP),
- 8 future MDAPs,
- 13 middle-tier acquisition (MTA) programs, and
- 15 major IT programs.[2]

This report (1) summarizes the characteristics of the 121 programs we reviewed; (2) assesses the four sets of programs we reviewed on selected cost and schedule measures and other topics uniquely applicable to each of them, such as implementation of knowledge-based acquisition practices, software development approaches, and cybersecurity practices; and (3) summarizes recent organizational and legislative changes that have potential implications for execution and oversight of the programs we reviewed.

To identify the characteristics of the programs we reviewed, we collected and analyzed data on the number of programs and program cost estimates, when available, for the four sets of programs in our review. For MDAPs, we included programs that issued an unclassified Selected Acquisition Report (SAR) in December 2018.[3] We obtained cost data from those SARs. For future MDAPs, we included programs that were

[1]John S. McCain National Defense Authorization Act for Fiscal Year 2019, Pub. L. No. 115-232, § 833(a) (2018) (codified at 10 U.S.C. § 2229b).

[2]Additional information on the performance of major IT programs and one-page summaries of 15 major IT programs are included in a separate report, which we also prepared in response to section 833 of the NDAA for FY 2019 and will issue later this year. See app. 1 for a listing of the 15 programs we include in our assessment.

[3]Major defense acquisition programs (MDAP) generally are those 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 $480 million, or for procurement of more than $2.79 billion, in fiscal year 2014 constant dollars.

identified by DOD as pre-MDAPs and that were expected to conduct a milestone decision event within the next two fiscal years.[4] To collect cost data for these programs, we provided a questionnaire to program offices. For MTA programs, we included programs initiated as of July 2019 that were identified by DOD as equivalent to an MDAP in terms of cost, either because the current MTA effort had estimated costs equivalent to the MDAP cost threshold, or because the military department planned multiple MTA efforts that had total estimated costs equivalent to the MDAP cost threshold.[5] We collected program budget information from MTA program identification data forms submitted by the military departments to the Office of the Secretary of Defense (OSD) in July or August and October 2019 and worked with the program offices to update these figures as necessary.[6] For major IT programs, we used DOD's official list of 29 major IT programs as of April 10, 2019 to establish a basis for selecting programs. From this list, we selected the 15 major IT programs identified by DOD that: (1) had an initial acquisition program baseline (APB) that we could use as a reference point for evaluating cost, schedule, and technical performance characteristics; and (2) were not fully deployed as of December 31, 2019. We then obtained the latest cost estimates for each program as of December 2019.[7]

To assess the performance of the four sets of programs we reviewed, we took the following steps:

[4]DOD maintains a list of programs designated as future MDAPs. These programs have not formally been designated as MDAPs; however, DOD plans for these programs to enter system development, or bypass development and begin production, at which point DOD will likely designate them as MDAPs. We refer to these programs as future or pre-MDAPs throughout this report.

[5]Section 804 of the National Defense Authorization Act for Fiscal Year 2016 required the Department of Defense to establish guidance for a streamlined middle tier of acquisitions for rapid prototyping and rapid fielding programs that are intended to be completed within 2 to 5 years. Programs using this authority are generally to be exempt from the Department of Defense's traditional acquisition and requirements development policies. Recent amendments to the statutory definition of an MDAP expressly exclude those acquisitions using the rapid fielding or rapid prototyping acquisition pathway described in section 804 of the National Defense Authorization Act for Fiscal Year 2016.

[6]Program identification data forms include program data such as program budget and schedule. The military departments generally are required to submit them to the Office of the Under Secretary of Defense for Acquisition and Sustainment for each MTA program on a biannual basis.

[7]The first acquisition program baseline is established after the program has assessed the viability of various technologies and refined user requirements to identify the most appropriate technology solution that demonstrates that it can meet users' needs.

- MDAPs: We obtained and analyzed cost, schedule, and quantity data for DOD's 85 MDAPs from DOD's December 2018 SARs—which detail initial cost, schedule, and performance baselines and changes from those baselines—and from the Defense Acquisition Management Information Retrieval (DAMIR) system, a DOD repository for program data.

  We also assessed additional information for 42 MDAPs that were between the start of development and the early stages of production as of the issuance of the program's December 2018 SAR. For these programs, we developed a web-based questionnaire to obtain information on the extent to which these programs were following knowledge-based acquisition practices for technology maturity, design stability, and production readiness. We also used the questionnaire to collect data about software development approaches and cybersecurity practices. We then compared this information 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.[8] We received questionnaire responses from all 42 programs from September 2019 through January 2020.

- Future MDAPs: We assessed eight future MDAPs to gain additional insights into knowledge they plan to attain before starting development and their plans for implementing recent key acquisition reforms. We provided a questionnaire to program offices to obtain information on schedule events, costs, and acquisition reforms, and we received responses from all eight programs from September 2019 through January 2020.
- MTA programs: We obtained and analyzed data from program identification data forms that the military departments submitted to OSD in July 2019. This data included program start and end dates, program funding estimates, and assessments of technology maturity. To collect additional data from MTA programs—such as key schedule milestones, information on business case documentation developed by the program, and software development approaches—we

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

distributed a web-based questionnaire. We received responses from all 13 programs from September 2019 through December 2019.

- Major IT programs: We compared each program's cost and schedule estimates that were established in their first acquisition baseline with their latest total life-cycle cost and schedule estimates as of December 2019. In addition, to determine whether system performance targets were tested and met, we identified ten of the 14 major IT programs that had conducted performance tests.[9] We then analyzed each program's self-identified system performance targets and compared them against actual system performance metrics. We also aggregated DOD program office responses to a web-based questionnaire seeking information about the software development approaches and cybersecurity practices used by each program. We compared the aggregated information with relevant guidance and leading practices. We received responses from all 15 major IT programs in October 2019.

In addition, this report presents individual knowledge-based assessments of 63 MDAPs and MTA programs.[10] Of the 63 assessments:

- Thirty-eight assess MDAPs—most in development or early production—in a two-page format discussing each program's knowledge about technology, design, and manufacturing as well as software and cybersecurity, and other program issues.[11]
- Twelve assess future or current MDAPs in a one-page format that describes the program's current status. Those one-page assessments include (1) seven future MDAPs not yet in development, and (2) five MDAPs that are well into production, but introducing new increments of capability or significant changes.
- Thirteen assess MTA programs in a two-page format discussing each program's knowledge when compared to key elements of a program

[9]Testing data for one program were classified.

[10]We generally 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. This report also does not include assessments of the major IT programs we reviewed. Those assessments are included in a separate report we plan to issue at a later date.

[11]One of the 38 two-page assessments is for a future MDAP—the Navy's FFG(X) Guided Missile Frigate—because the Navy scheduled it to begin development in advance of our planned issuance date. We reported cost and quantity amounts that align with the program's Future Years Defense Program estimates because the current cost estimate provided by the program does not include a full funding profile beyond fiscal year 2024.

business case as well as technology maturation, software development and cybersecurity, and other program issues.

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 the SAR data and the DAMIR data. For MTA programs, we assessed the reliability of the program identification data forms by comparing the data included in the forms with fiscal year 2020 budget documents and supplemental questionnaire responses to verify cost and quantity data. For major IT programs, we corroborated program office responses with relevant program documentation and interviews with agency officials. To ensure the reliability of the data collected through each of our questionnaires, we took a number of steps to reduce measurement error and nonresponse error, such as conducting pretests and following up with program offices on discrepancies or non-responses. We determined that the data were sufficiently reliable for our reporting purposes.

To summarize recent organizational and legislative changes that have potential implications for execution and oversight of the portfolio, we reviewed acquisition-related provisions contained in the NDAA for FY 2019. We selected provisions that, in our view, may affect the execution and oversight of DOD's most expensive weapon and IT acquisitions. We met with DOD officials from OSD and the military departments to discuss the specific provisions and the potential impact they may have on defense acquisitions. Additionally, we reviewed provisions in the NDAA for FY 2020 related to our June 2019 report on acquisition reform and obtained information from DOD on actions taken to address these provisions through March 1, 2020.[12] We also reviewed recently issued DOD policy and guidance that addressed organizational and legislative changes, including those that clarify acquisition roles and decision authority and establish alternative acquisition pathways for the DOD acquisition community.

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

We conducted this performance audit from May 2019 to June 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain

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

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.[13] The objective of the defense acquisition system, as outlined in DOD Instruction 5000.02, 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. To achieve this objective, DOD Instruction 5000.02, which was reissued in January 2020, establishes an adaptive acquisition framework comprised of six acquisition pathways, each tailored for the characteristics and risk profile of the capability being acquired. DOD has issued or plans to issue additional acquisition policy documents to address each of these six acquisition pathways.[14] Three of these pathways relate to the three types of programs we include in this report: 1) major capability acquisition, used to acquire MDAPs; 2) MTA, used for rapid prototyping and rapid fielding efforts; and 3) defense business systems, used to acquire certain major IT programs.

MDAPs

Under DOD Instruction 5000.02, DOD's major capability acquisition pathway is designed to support MDAPs, major systems, and other

[13]Department of Defense Directive No. 5000.01, *The Defense Acquisition System* (May 12, 2003, Incorporating change 2, Aug. 31, 2018); Department of Defense Instruction No. 5000.02, *Operation of the Adaptive Acquisition Framework* (Jan. 23, 2020).

[14]For example, see Department of Defense Instruction 5000.81, *Urgent Capability Acquisition* (December 31, 2019) and Department of Defense Instruction 5000.74, *Defense Acquisition of Services* (January 10, 2020). Until all of the planned issuances are released, the previous version of the DOD Instruction 5000.02 (now renumbered as DOD Instruction 5000.02T) remains in effect with content removed as it is cancelled or transitions to a new issuance.

complex acquisitions.[15] Within this process, 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.[16] 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.[17] We have found that in order to reduce risk, there are three key points where programs should demonstrate critical levels of knowledge before proceeding to the next acquisition phase: development start, system-level critical design review, and production start.[18] Figure 1 aligns the acquisition milestones associated with the major capability acquisition pathway with these three key decision points.

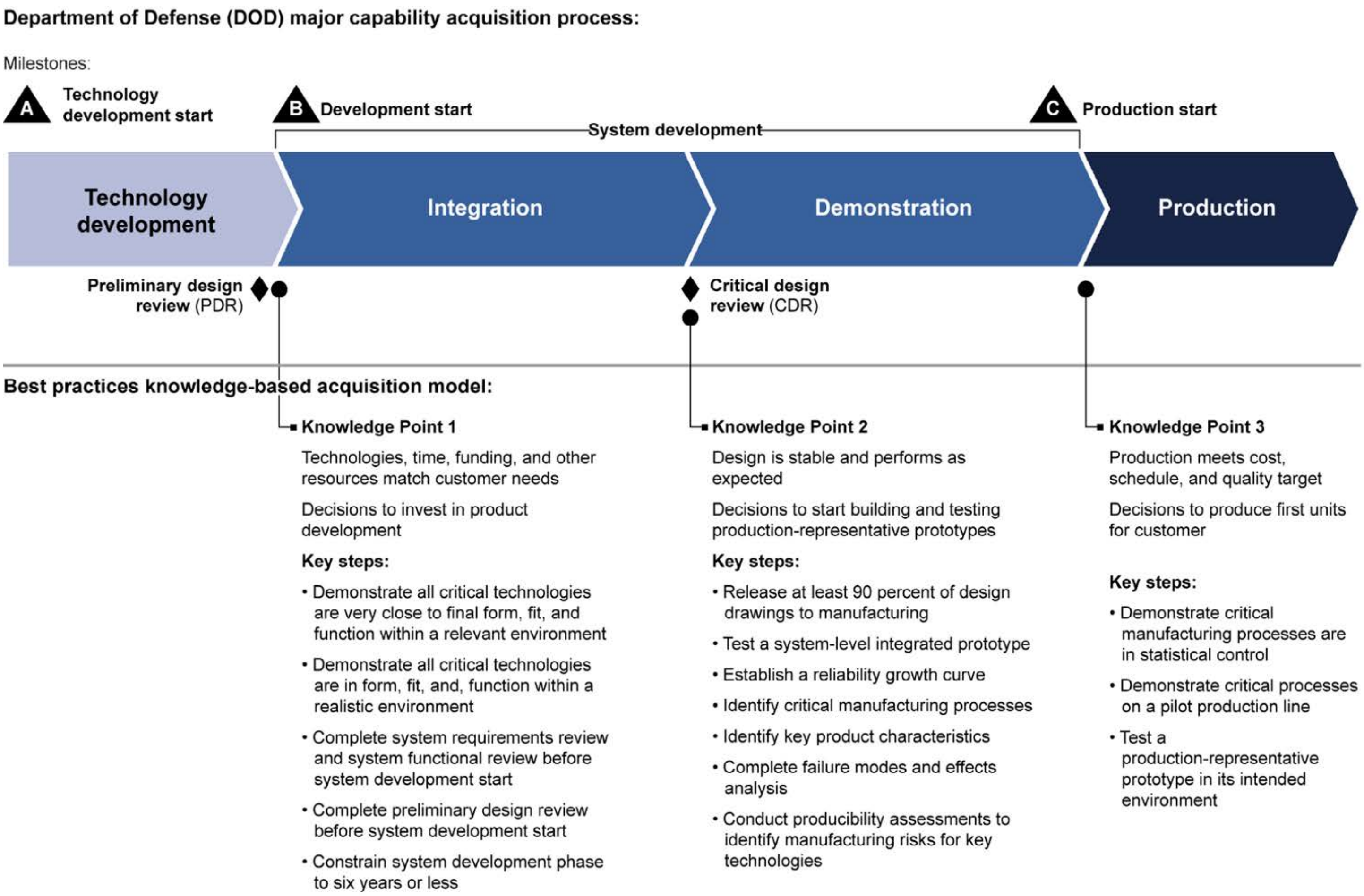
[15]To date, DOD has not issued an acquisition policy document for the major capability acquisition pathway. DOD has indicated the core acquisition policy in the previous version of DOD Instruction 5000.02 (DOD Instruction 5000.02T) will be covered in the forthcoming major capability acquisition policy document. Pending issuance of that document, the core acquisition policy in DOD Instruction 5000.02T remains in effect and applicable to programs in the major capability pathway.

[16]The procedures for these milestone reviews and key decision points are addressed within the core acquisition policy of DOD Instruction 5000.02T.

[17]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).

[18]To accommodate shipbuilding programs in this report, we correlated detail design contract awards, fabrication starts, and lead ship deliveries with development start, critical design review, and production start, respectively.

Figure 1: Department of Defense Major Capability Acquisition Pathway and GAO-Identified Knowledge Points



Source: GAO analysis of DOD-provided data, DOD Instruction 5000.02, DOD Instruction 5000.02T, and best practices. | GAO-20-439

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.

In the NDAAs for recent fiscal years, Congress included numerous reforms related to MDAPs that could help to streamline acquisition oversight and field capabilities faster. Collectively, the reforms Congress put forth fundamentally altered roles and responsibilities for MDAP oversight to give significantly more authority for managing acquisition programs to the military departments. OSD also restructured its acquisition oversight functions in an effort to increase innovation in the earlier stages of the acquisition process and reduce cost, schedule, and performance risks in later stages. Table 1 provides additional detail on selected reforms from recent years.

Table 1: Summary of Selected Reforms that Affect Acquisition Program Oversight from the National Defense Authorization Acts for Fiscal Years 2016 and 2017

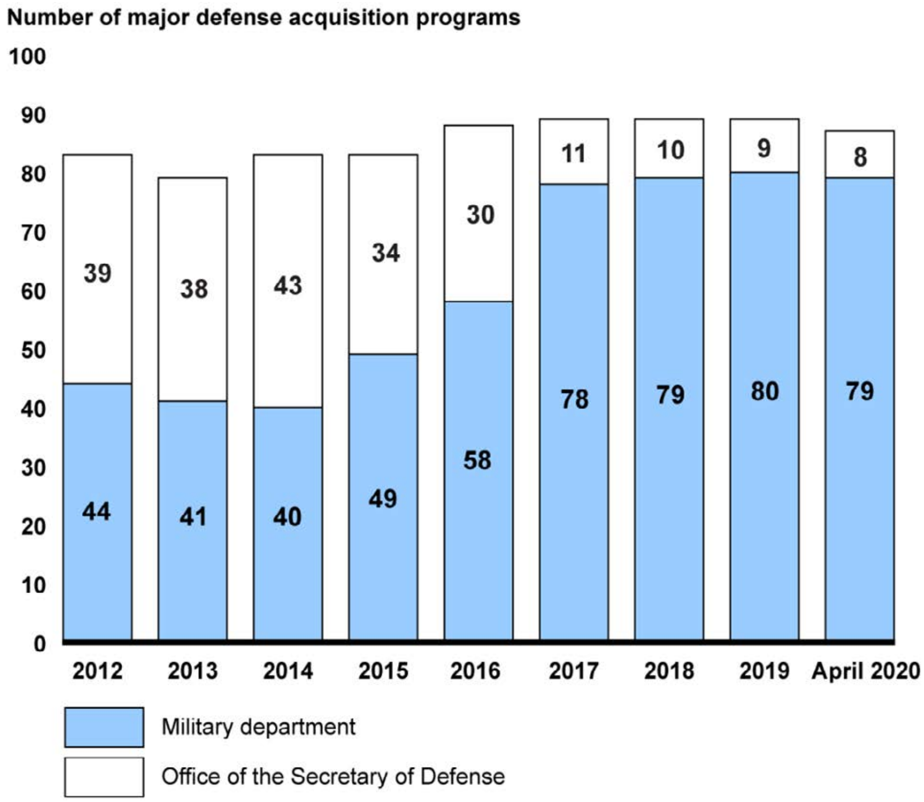
Action related to reform	National Defense Authorization Act year and section	Description
Changes to oversight processes for major defense acquisition programs (MDAP)		
Designating military departments to be milestone decision authority	Section 825 of the National Defense Authorization Act for Fiscal Year 2016	Required that the service acquisition executive of the military department concerned be designated as the milestone decision authority for MDAPs initiated 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 effort.
Performing independent technical risk assessments	Section 807(a) of the National Defense Authorization Act for Fiscal Year 2017	Required independent technical risk assessments identifying critical technologies and manufacturing processes that need to be matured be conducted for MDAPs that reach milestone A after October 1, 2017. The assessments are to be conducted before any decision to grant milestone A or milestone B approval; before any decision to enter into low rate initial production or full rate production; or at any other time considered appropriate by the Secretary of Defense.
Establishing cost, fielding, and performance goals	Section 807(a) and section 925(b) of the National Defense Authorization Act for Fiscal Year 2017	Required cost, fielding, and performance goals be set for MDAPs that reach milestone A after October 1, 2017. The goals must be established before funds are obligated for technology development, systems development, or production. The goals are to ensure that the milestone decision authority approves a program that will: be affordable; anticipate the evolution of capabilities to meet changing threats, technology insertion, and interoperability; and be fielded when needed.
Reorganizing acquisition oversight functions in the Office of the Secretary of Defense		
Reorganizing the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics	Sections 901(a) and (b) of the National Defense Authorization Act for Fiscal Year 2017	Restructured the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics and distributed the responsibilities previously carried out by that office to two newly created undersecretary positions—the Under Secretary of Defense for Research and Engineering and the Under Secretary of Defense for Acquisition and Sustainment.

Source: GAO analysis of National Defense Authorization Acts for Fiscal Years 2016 and 2017. | GAO-20-439

Note: The statutes associated with several of these reforms have been amended by subsequent National Defense Authorization Acts since being signed into law.

In relation to the acquisition reform changes outlined in table 1, in June 2019, we found that decision-making authority for many MDAPs had shifted from OSD to the military departments, a trend that has continued since our last report (see fig. 2).[19]

Figure 2: Level of Milestone Decision Authority for Major Defense Acquisition Programs from 2012 to 2020



Source: GAO analysis of Department of Defense data. | GAO-20-439

Note: Data for 2012 to 2017 were obtained from the Defense Acquisition Management Information Retrieval system. Data for 2018 to 2020 were obtained from the Defense Acquisition Visibility Environment system.

[19]GAO-19-439.

In addition, we also found in June 2019 that:

- new processes were in place to improve DOD's consideration of program cost, fielding, and performance goals and assessment of technical risk although questions remained about how they would be implemented, and
- OSD had begun to restructure, but additional steps remained to be completed, including developing charters and fully staffing new offices.

MTA Programs

Section 804 of the NDAA for FY 2016 required DOD to issue guidance establishing two new streamlined acquisition pathways for DOD—rapid prototyping and rapid fielding—under the broader term "middle tier of acquisitions." According to the Joint Explanatory Statement accompanying the NDAA, the guidance was to create an expedited and streamlined middle tier of acquisition programs intended to be completed within 5 years. The Joint Explanatory Statement noted that middle-tier programs would be distinct from rapid acquisitions that are generally completed within 6 months to 2 years and traditional acquisitions that last longer than 5 years. Statute lays out more specifically intended time frames and expectations for programs using these two pathways:

- The rapid prototyping pathway is to provide for the use of innovative technologies to rapidly develop fieldable prototypes to demonstrate new capabilities and meet emerging needs. The objective of a rapid prototyping program 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.
- The rapid fielding pathway is to provide for the use of proven technologies to field production quantities of new or upgraded systems with minimal development required. The objective of a rapid fielding program is to begin production within 6 months and complete fielding within 5 years of the development of an approved requirement.

MTA pathways are distinct from the major capability pathway intended for MDAPs. These MTA pathways allow for programs to be exempted from the acquisition and requirements processes defined by 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.[20] The statute does not identify a dollar threshold for programs using MTA pathways.

DOD issued final policy and procedures for the management of MTA pathways and programs in December 2019.[21] However, during most of our review period, MTA programs were operating under interim guidance from the Office of the Under Secretary of Defense for Acquisition and Sustainment (OUSD(A&S))—issued in April 2018, and updated with supplemental interim guidance in October 2018, March 2019, and April 2019—and the military departments.[22]

Major IT Programs

Prior to being reissued in January 2020, DOD's Instruction 5000.02 outlined the framework for, among other things, major IT programs (which historically have been referred to as major automated information system programs).[23] According to this instruction, major IT programs were those designated as such by the milestone decision authority or those meeting certain dollar thresholds, in constant FY 2014 dollars. Specifically, the guidance generally established the thresholds as estimated dollar values exceeding (1) $40 million for all program costs in a single year, (2) $165 million for all program acquisition costs for the entire program, or (3) $520

[20]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).

[21]Department of Defense Instruction 5000.80.

[22]Department of Defense, Under Secretary of Defense (Acquisition and Sustainment): *Middle Tier of Acquisition (Rapid Prototyping/Rapid Fielding) Interim Authority and Guidance* (Apr. 16, 2018). Department of Defense, Under Secretary of Defense (Acquisition and Sustainment): *Middle Tier of Acquisition (Rapid Prototyping/Rapid Fielding) Interim Governance* (Oct. 9, 2018). Department of Defense, Under Secretary of Defense (Acquisition and Sustainment): *Middle Tier of Acquisition (Rapid Prototyping/Rapid Fielding) Interim Governance 2* (Mar. 20, 2019). Department of Defense, Director, Cost Assessment and Program Evaluation: *Life-Cycle Cost Estimating Policy for Programs Carried Out Using the Rapid Fielding Pathway Under Section 804 of the National Defense Acquisition Act (NDAA) for Fiscal Year (FY) 2016 (Public Law 114-92)* (Apr. 05, 2019).

[23]The January 2015 version of DOD Instruction 5000.02 was updated periodically, most recently in January 2020. Also in January 2020, this instruction was re-designated as DOD Instruction 5000.02T. The National Defense Authorization Act for Fiscal Year 2017 repealed the statutory definitions and requirements for major automated information system programs. As of February 2020, DOD Instruction 5000.02T continued to refer to and provide guidance about major automated information system programs.

million for the total life-cycle costs of the program (including operation and maintenance costs).

In February 2017, DOD issued updated guidance in *Business Systems Requirements and Acquisition*, DOD Instruction 5000.75, which superseded DOD Instruction 5000.02 for all business system acquisition programs that were not designated as an MDAP.[24] This report refers to programs covered by DOD Instruction 5000.75 as major business IT programs. The report refers to the remaining major IT programs as major nonbusiness IT programs.

DOD Instruction 5000.75 specifically established policy for the use of a five-phase business capability acquisition cycle for business systems requirements and acquisition. Under the instruction, DOD business system acquisitions are to be aligned to commercial best practices and are to minimize the need for customization of commercial products to the maximum extent possible. The instruction also calls for thorough industry analysis and market research of both process and IT solutions using commercial off-the-shelf and government off-the-shelf software.[25] In addition, the instruction calls for authority to proceed decision points, which are milestone-like events, to be tailored as necessary to contribute to successful delivery of business capabilities. These decision points are to be informed by measures that assess the readiness to proceed to the next phase of the process. Decision-making is to focus on the executability and effectiveness of planned activities, including cost, schedule, acquisition strategy, incentive structure, and risk. In the decision point process, the functional sponsor (i.e., business sponsor) is the senior leader with business function responsibility seeking to improve mission performance.

Software Development

For years, commercial companies have recognized software's value for providing new capabilities to consumers. Consequently, the commercial industry has developed leading practices that foster quicker, more cost-

[24]DOD issued an updated version of DOD Instruction 5000.75 in January 2020. This report refers to the February 2017 version of the instruction because it established the guidelines under which major IT systems discussed in this report were operating as of December 2019. However, the Business Capability Acquisition Cycle described in the February 2017 version of the instruction remains unchanged.

[25]Government off-the-shelf software is developed for the government to meet a specific government purpose. It is not commercially available to the general public. Commercial off-the-shelf software is sold in substantial quantities in the commercial marketplace and is purchased without modification, or with minimal modification, to its original form.

effective software development, which allows for speedier delivery of new capability to users and consumers. DOD is also recognizing software as an increasingly critical element for meeting weapon systems' requirements. However, DOD's software development approaches have not kept pace with the warfighters' needs for enhanced software-dependent capabilities, nor do those practices reflect the leading practices utilized by commercial companies.

Having recognized the disparity between commercial and DOD software development approaches, a Defense Science Board Task Force concluded in February 2018 that DOD can, and should, leverage today's commercial development best practices to its advantage, including on its weapon systems.[26] The task force made seven recommendations for improving software acquisition in defense systems. Further, in the NDAA for FY 2018, Congress required the Secretary of Defense to direct DOD's Defense Innovation Board to conduct a study on streamlining software development and acquisition regulations.[27] In its May 2019 report, the board emphasized three themes, including using speed and delivery time as a performance metric, hiring and retaining qualified staff, and focusing on continuous improvement throughout the software life cycle. The board encouraged DOD to prioritize modern software development methods and made over 10 recommendations to address statutory, regulatory, and cultural hurdles DOD faces in modernizing its approach to software.

Our past work has found that DOD acquisition programs employ a wide range of software development models, including various incremental models of the type recommended by the Defense Innovation Board in its 2019 report. Table 2 provides descriptions of selected software development models employed by DOD acquisition programs.

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

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

Table 2: 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	This approach is a combination of two or more different methodologies or systems to create a new model.

Source: GAO analysis of Department of Defense and software industry documentation. | GAO-20-439

OUSD(A&S) recently issued interim policy for the software acquisition pathway.[28] The guidance establishes the pathway as the preferred path for acquisition and development of software-intensive systems and emphasizes that program managers should ensure the use of iterative and incremental software development methodologies and modern tools to achieve continuous delivery of user capabilities and frequent user feedback and engagement, among other goals.

Cybersecurity in DOD Acquisition Programs

Safeguarding federal IT programs has been a long-standing concern of GAO. Due to increasing cyber-based threats and the persistent nature of information security vulnerabilities, we have designated information security as a government-wide high-risk area since 1997. Cybersecurity

[28]Department of Defense, Under Secretary of Defense for Acquisition and Sustainment Memorandum: *Software Acquisition Pathway Interim Policy and Procedures* (Jan. 3, 2020).

for weapon systems has also increasingly been recognized as a critical area in which DOD must improve. Cybersecurity is the process of protecting information and information systems by preventing, detecting, and responding to attacks. It aims to reduce the likelihood that attackers can access DOD systems and limit the damage if they do.[29] We previously reported that DOD had gotten a late start in prioritizing cybersecurity for weapon systems.[30] Cyberattacks can target any weapon subsystem that is dependent on software, potentially leading to an inability to complete military missions or even loss of life. Examples of functions enabled by software—and potentially susceptible to compromise—include powering a system on and off, targeting a missile, maintaining a pilot's oxygen levels, and flying aircraft. An attacker could potentially manipulate data in these systems, prevent components or systems from operating, or cause them to function in undesirable ways.

DOD guidance generally requires that MDAPs develop a cybersecurity strategy by milestone A (technology development start) and update the strategy at subsequent milestones.[31] The strategy is to detail the cybersecurity practices the program will use to address cybersecurity risks and reduce the likelihood and severity of potential attacks. DOD's Cybersecurity Test and Evaluation Guidebook promotes assessment methods for cybersecurity testing and evaluation and applies to all DOD programs and systems, regardless of their acquisition category or phase of the acquisition life cycle, unless noted.[32] In addition, section 1647 of the NDAA for FY 2016 included a section that generally required DOD to complete a cybersecurity vulnerability evaluation for each major weapon system by the end of 2019. DOD's evaluations allow testers to identify systems' weaknesses that are susceptible to cybersecurity attacks and that could potentially jeopardize mission execution.

[29]Definition adapted from National Institute of Standards and Technology, *Framework for Improving Critical Infrastructure Cybersecurity,* Version 1.1 (Apr. 16, 2018).

[30]GAO-19-128.

[31]Department of Defense Instruction 5000.02T.

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

Overview of the Combined DOD Weapons and IT Portfolio

DOD's combined portfolio of its most costly weapons and IT programs consists of 121 programs—100 of which have baselined cost information, meaning that they have formal cost estimates included in a SAR or APB, and 21 that do not. The 100 baselined programs include 85 MDAPs and 15 major IT programs, which are estimated to cost a combined $1.81 trillion to acquire.[33] The 21 unbaselined programs, which do not have a formal cost estimate included in a SAR or APB, include eight future MDAPs and 13 MTA programs.[34] Formal cost estimates are unavailable for these programs, but the department's preliminary estimates indicate planned spending of at least $48.3 billion, although these preliminary estimates in some cases do not reflect the full level of the department's total investment. Table 3 summarizes DOD's total investments in the selected programs we reviewed.

Table 3: Department of Defense Total Investments in Selected Acquisition Programs GAO Reviewed (Fiscal Year 2020 Dollars in Billions)

Type of program	Number of programs reviewed	Total investment
Major defense acquisition programs (current and future)	93	$1823.8
Major information technology programs	15	$15.1
Middle-tier acquisition programs	13	$19.5
Total	**121**	**$1858.4**

Source: GAO analysis of Department of Defense data. | GAO-20-439

Note: Total investment includes both funding to date and estimated funding to complete the portfolio's development and procurement.

[33]For MDAPs, we included programs that published an unclassified December 2018 SAR. We identified major IT programs as defense programs on DOD's April 10, 2019 list of major IT programs that had an initial acquisition program baseline and that were not fully deployed as of December 31, 2019.

[34]DOD has also identified six additional unbaselined major IT systems, but we did not validate cost information for these programs.

DOD's Baselined Weapons and IT Portfolio Is Expected to Cost at Least $1.81 Trillion to Acquire, but Costs Have Not Been Fully Identified for Some Unbaselined Programs

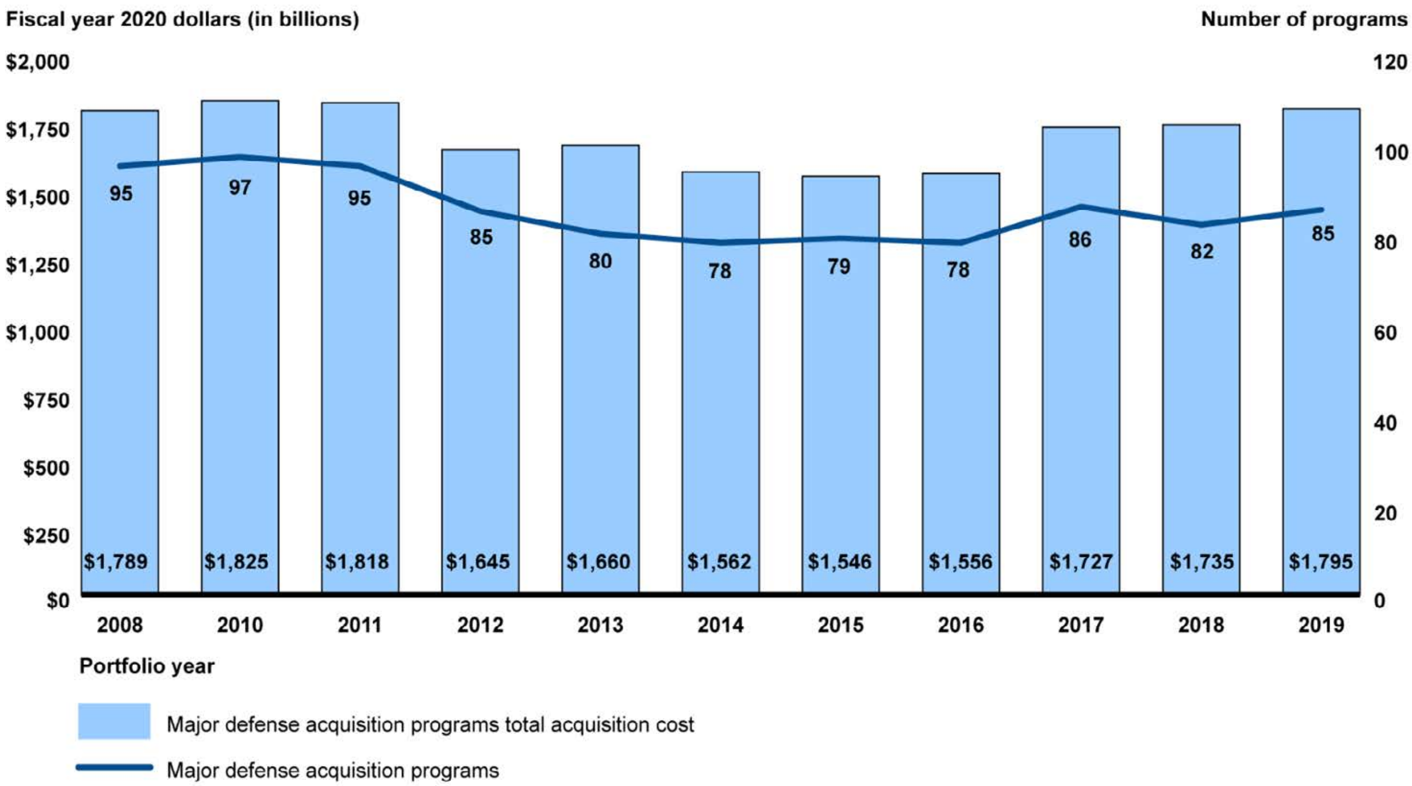
Baselined Programs

DOD plans to invest at least $1.81 trillion to acquire 100 of its most costly baselined weapon and IT programs. These costs primarily consist of development and procurement costs, and do not include sustainment costs.

DOD's MDAP portfolio, which accounts for the vast majority of the combined portfolio of baselined weapon and IT programs, has grown in the past year both in number of programs and planned total investment and now consists of 85 programs—a net increase of three MDAPs since last year. This net increase reflects eight MDAPs entering the portfolio—six of which DOD approved for system development starts after January 2018.[35] Of the five MDAPs exiting the portfolio, all completed over 90 percent of their planned deliveries. DOD estimates it will spend $1.80 trillion to acquire the 85 programs in the MDAP portfolio, its largest planned level of investment in an MDAP portfolio since 2011. Figure 3 shows the number of programs and the total cost of the 2019 MDAP portfolio as compared to the previous 10 years.

[35]The two remaining MDAPs entered the portfolio for other reasons. The Navy's Expeditionary Sea Base program's procurement value exceeded thresholds for Acquisition Category II programs, which triggered the program to produce a SAR. Due to an increase in funding, the Air Force's Wideband Global Satellite Communications re-entered the portfolio after last producing a SAR in 2016.

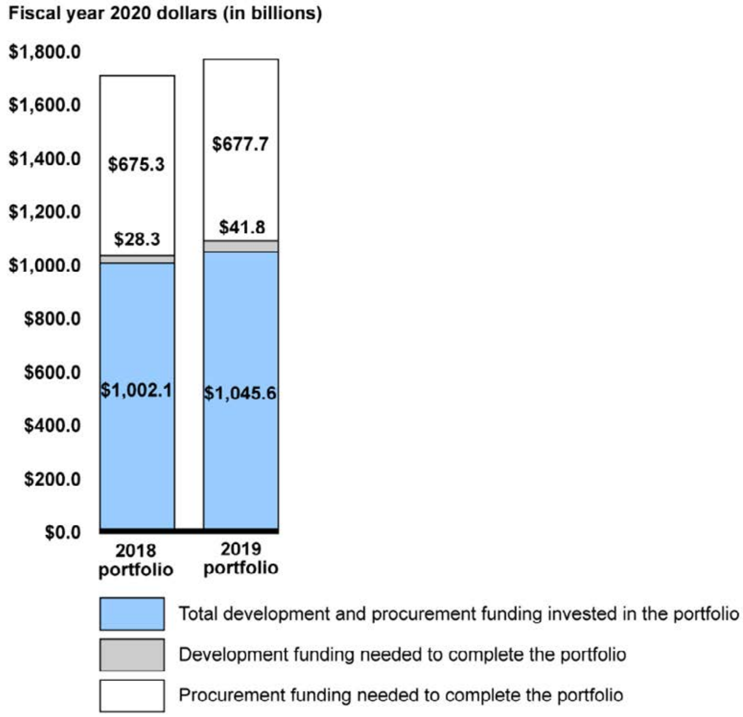
Figure 3: Historical Number and Cost of Major Defense Acquisition Programs from 2008 to 2019 (billions of 2020 dollars)



Source: GAO analysis of Department of Defense data. | GAO-20-439

DOD has invested $44 billion more funding to date in its 2019 MDAP portfolio than it had in its 2018 MDAP portfolio. This amount of increased investment is more than the $19 billion investment increase from the 2017 to 2018 MDAP portfolios, but comparable to the investment increases for the 2017 and 2016 MDAP portfolios, respectively. DOD also expects to invest $16 billion more in future funding to complete the 2019 portfolio than it planned for the 2018 portfolio. Figure 4 displays last year's and the current MDAP portfolio's development and procurement funding (invested versus remaining).

Figure 4: Major Defense Acquisition Programs' Invested and Remaining Funding, 2018 and 2019 Portfolios



Source: GAO analysis of Department of Defense data. | GAO-20-439

Note: The figure does not account for classified programs, which we excluded from our analyses. The figure also excludes $8.3 billion in spent development and procurement funding and $4.3 billion in development funding needed to complete the Chemical Demilitarization—Assembled Chemical Weapons Alternatives program managed by DOD.

Unbaselined Programs

Another 21 programs we reviewed do not have cost baselines, and projected costs for these investments are not fully known.

- Of the 21, eight are future MDAPs that DOD estimates will require a total of at least $28.8 billion to acquire. In some cases, cost estimates reported by future MDAPs do not fully reflect total expected acquisition costs. For example, the Army's Future Long Range Assault Aircraft program reported cost includes funding only for fiscal years 2018 to 2024. The Army did not identify full funding needs beyond fiscal year 2024, and, as a result, has yet to report procurement funding for the program.
- Thirteen are MTA programs that the military departments identified as having estimated costs equivalent to the MDAP cost threshold. The current combined available estimate for these 13 programs is $19.5

billion. However, the MTA estimates do not reflect any investment that DOD will need after the current MTA effort, if it decides to further develop and field the capabilities being prototyped. For example, most estimates do not include future procurement costs because these costs would be incurred to procure production units to field under follow-on programs. These costs can be significant. We have found that, on average, MDAPs typically spend four times more in procurement than they spend on RDT&E.

This is our first year incorporating MTA programs and major IT programs into our reporting. As a result, we are unable to report on trend data for these programs or the combined 2019 portfolio, although we plan to do so in future reports to the extent that consistent data are available.

MDAPs Have Generally Stabilized Non-quantity-related Cost and Schedule Growth, but Continue to Proceed with Limited Knowledge and Inconsistent Software Approaches and Cybersecurity Practices

Between 2018 and 2019, total acquisition cost estimates for the 85 MDAPs in DOD's 2019 portfolio increased by a combined $64 billion (a 4 percent increase), while capability delivery schedules increased, on average, by just over 1 month (a 1 percent increase). The 1-year cost growth was predominately driven by DOD decisions to increase planned quantities in some MDAPs. However, since their initial, or first full, estimates, these 85 MDAPs have accumulated over $628 billion (or 54 percent) in total cost growth, and schedule growth has increased by 29 percent, resulting in an average capability delivery delay of more than 2 years.[36] Among MDAPs we surveyed, we found that programs continue to move forward without the benefit of knowledge at key acquisition points, while future MDAPs reported plans to modestly increase the implementation of knowledge practices. These practices are key because we have found a statistically significant correlation between implementation of certain knowledge-based practices and improved cost and schedule performance. We also found, among the MDAPs we surveyed, inconsistent implementation of leading software development approaches and cybersecurity practices. This included longer than expected delivery times for software and delays completing statute-based cybersecurity vulnerability evaluations.

[36]We included 80 of 85 current MDAPs in our schedule growth analysis because data was not available for five programs.

Decisions to Increase Quantities Have Led to Increased MDAP Portfolio Costs since Last Year, Although Unit Costs Were Lower

MDAP portfolio total acquisition cost estimates have increased by about 4 percent ($64 billion) over the past year, largely due to quantity increases.[37] Procurement costs, which account for 81 percent of the 2019 portfolio's estimated costs, also increased by 4 percent ($49 billion). Research and development costs, which account for most of the remaining 19 percent of the portfolio's estimated costs, increased by 5 percent. Table 4 details the 1-year change in cost estimates for the 2019 portfolio of 85 programs.

Table 4: Cost Changes to the Department of Defense's 2019 Portfolio of 85 Major Defense Acquisition Programs over the Past Year (Fiscal Year 2020 Dollars in Billions)

	Estimated portfolio cost in 2018	Estimated portfolio cost in 2019	Estimated portfolio change since 2018	Percentage change since 2018
Total estimated research and development cost	317.38	332.08	14.69	4.6
Total estimated procurement cost	1396.24	1445.56	49.33	3.5
Total estimated other acquisition cost[a]	17.55	17.37	(0.18)	(1.0)
Total estimated acquisition cost	1731.17	1795.01	63.84	3.7

Source: GAO analysis of Department of Defense (DOD) data. | GAO-20-439

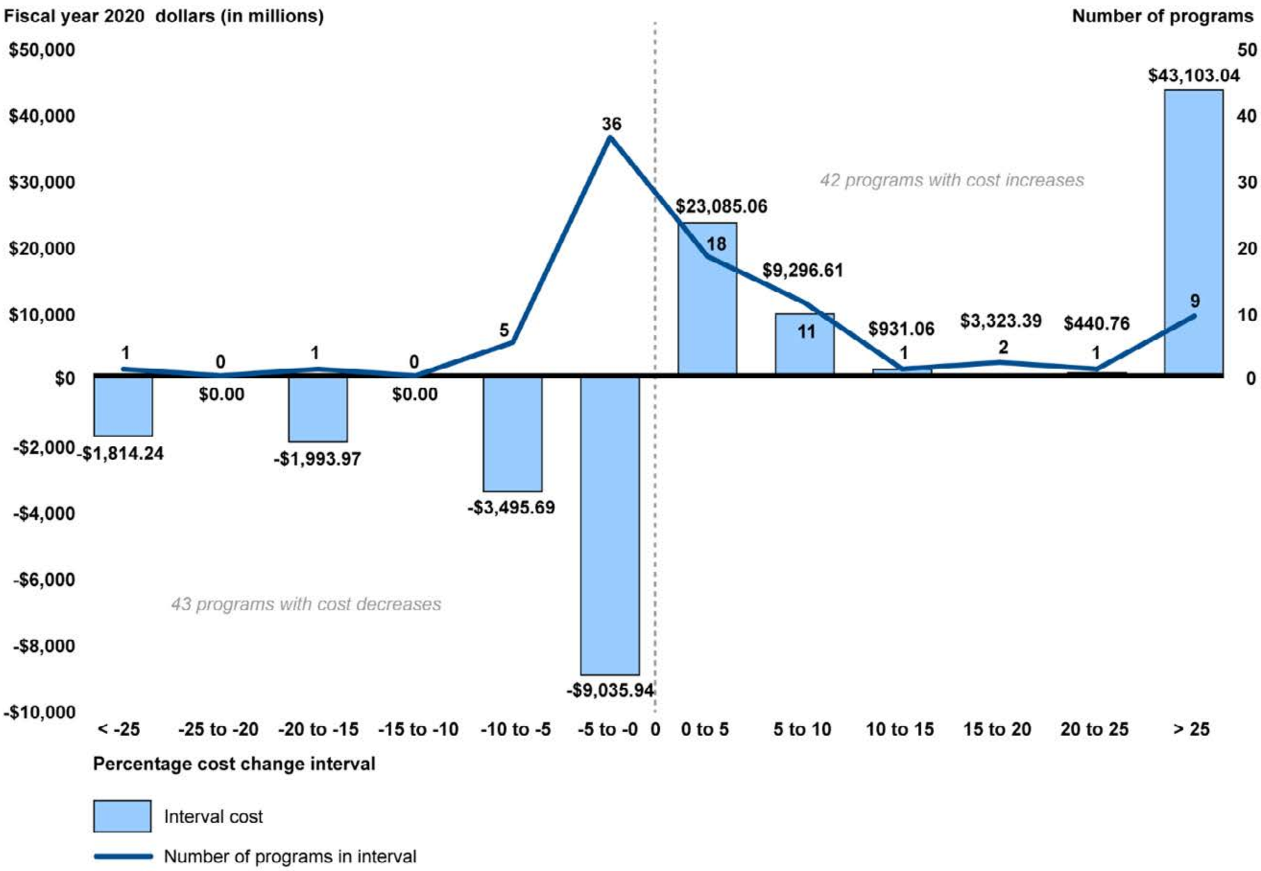
[a]Other acquisition cost includes costs for military construction and acquisitions-related operations and maintenance.

Over the past year, roughly an equal number of MDAPs reported cost increases and cost decreases. Of the 85 MDAPs, 42 reported combined total acquisition cost increases of over $80 billion. While most individual program increases were less than 10 percent, nine programs increased their total acquisition cost estimates by more than 25 percent and combined for more than $43 billion in planned investment growth. This is more than half of the total cost increase in the 2019 portfolio. At the same time, the remaining 43 MDAPs experienced cost decreases, totaling over $16 billion in savings that partially offset the aforementioned cost increases. Thirty-six of those programs realized a decrease of less than 5 percent.

[37]In order to make the 2018 and 2019 MDAP portfolios comparable, we added the first full estimates of the eight entering programs in 2019 to 2018's portfolio and removed funding and schedule information of the five programs that exited the portfolio since 2018.

Figure 5 displays changes in the portfolio's total acquisition cost estimates from 2018 to 2019 by percentage change intervals, irrespective of changes in quantity.

Figure 5: Total Acquisition Cost Changes in Major Defense Acquisition Programs, 2018-2019



Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

Quantity increases since last year drove DOD's $49.3 billion increase in estimated procurement costs within the 2019 MDAP portfolio. Our analysis, however, shows that these increased quantities, if funded at programs' 2018 average procurement unit costs, would have totaled nearly $66 billion. That means that DOD also achieved aggregate procurement-related efficiencies in its 2019 portfolio. These efficiencies provided more than $16 billion to offset the estimated procurement cost increases that were driven by the quantity changes. Table 5 summarizes this analysis.

Table 5: Effects of Quantity Changes on 2019 Major Defense Acquisition Program (MDAP) Estimated Procurement Costs since 2018 (Fiscal Year 2020 Dollars in Billions)

	Estimated change from 2018 to 2019
Estimated procurement cost change attributable to quantity changes in MDAPs	65.59
Estimated procurement cost change not attributable to quantity changes in MDAPs	(16.26)
Estimated total procurement cost change	49.33

Source: GAO analysis of Department of Defense (DOD) data. | GAO-20-439

In some cases, quantity changes result from military department decisions to buy more units of a weapon system and thus do not reflect changes in program approach. In other cases, quantity changes are indicative of DOD decisions to introduce new capabilities through additions to existing programs rather than by starting new programs. We have recommended in our prior work that specific programs create separate baselines for new increments of capability in order to improve insight into true program performance.[38]

Nonetheless, our analysis found that a total of 19 programs in the 2019 portfolio achieved efficiencies in the past year when adding quantities, which offset some of the costs of acquiring those increased quantities. Generally, these efficiencies materialized as lower average procurement unit costs from 2018 to 2019. For example, the Air Force increased its planned quantities in the Joint Air-to-Surface Standoff Missile program from 2,866 to 7,200 units. If the Air Force had needed to fund these additional 4,334 units at the program's 2018 average procurement unit cost, then the program's procurement costs would have increased by $6 billion. However, new efficiencies in the program, including an 11 percent decrease in average procurement unit costs, meant the Air Force only needed $5 billion for the new quantities—a savings of $1 billion in estimated procurement costs.

[38]GAO, *Arleigh Burke Destroyers: Delaying Procurement of DDG 51 Flight III Ships Would Allow Time to Increase Design Knowledge*, GAO-16-613 (Washington, D.C.: Aug. 4, 2016); *F-35 Joint Strike Fighter: Continued Oversight Needed as Program Plans to Begin Development of New Capabilities*, GAO-16-390 (Washington, D.C.: Apr. 14, 2016).

Overall, we found that 55 MDAPs—more than half of the MDAP portfolio—had lower average procurement unit costs since last year. Examples of programs with lower unit costs include the Navy's Joint Precision Approach and Landing System (16 percent decrease) and the Air Force's F-22 Increment 3.2B Modernization (15 percent decrease). Table 6 details the five programs with the highest percentage unit cost decreases since last year. It also describes the factors—one or more per program—that led to the cost decreases, based on our analysis of program documentation.

Table 6: Five Programs with the Highest Percentage Estimated Average Procurement Unit Cost Decreases, 2018 to 2019

Program name	Lead Component	Estimated average procurement unit cost in 2018 (fiscal year 2020 dollars in millions)	Estimated average procurement unit cost in 2019 (fiscal year 2020 dollars in millions)	Estimated average procurement unit cost percent change since last year	Contributing factors for estimated average procurement unit cost decreases
Joint Precision Approach and Landing System	Navy	18.57	15.57	-16.2	(1) Accelerated procurement schedule (2) Lower support needs
F-22 Increment 3.2B Modernization	Air Force	2.33	1.98	-14.8	(1) Revised estimates
LPD 17 San Antonio Class Amphibious Transport Dock	Navy	1866.40	1658.69	-11.1	(1) Quantity increase
Joint Air-to-Surface Standoff Missile	Air Force	1.43	1.28	-10.7	(1) Quantity increase (2) Accelerated procurement schedule
B61 Mod 12 Life Extension Program Tailkit Assembly	Air Force	0.48	0.43	-10.1	(1) Revised estimates

Source: GAO analysis of Department of Defense (DOD) data and selected acquisition reports. | GAO-20-439

DOD's MDAP Portfolio Has Incurred Cost Increases since First Full Estimate Due to Quantity Changes and Other Factors

When measuring MDAP costs since programs' first full estimates, cost growth is more pronounced as compared with 1-year cost changes since 2018. Specifically, since first full estimates, estimated total acquisition costs of DOD's 2019 MDAP portfolio have increased by $628 billion, a 54 percent increase. Table 7 details the change in the cost estimates for the 2019 portfolio since MDAPs' first full estimates.

Table 7: Cost Changes to DOD's 2019 Portfolio of 85 Major Defense Acquisition Programs since First Full Estimates (Fiscal Year 2020 Dollars in Billions)

	Estimated portfolio cost at first full estimates	Estimated portfolio cost in 2019	Estimated portfolio change since first full estimates	Percentage change since first full estimates
Total estimated research and development cost	209.90	332.08	122.18	58.2
Total estimated procurement cost	943.83	1445.56	501.73	53.2
Total estimated other acquisition cost[a]	12.94	17.37	4.43	34.2
Total estimated acquisition cost	1166.67	1795.01	628.34	53.9

Source: GAO analysis of Department of Defense (DOD) data. | GAO-20-439

[a]Other acquisition cost includes costs for military construction and acquisitions-related operations and maintenance.

Unlike the 1-year cost changes, we found that other factors beyond quantity changes contributed more substantially to increase total acquisition costs since first full estimates. Specifically, while total procurement cost estimates for the 2019 portfolio increased by $502 billion since first full estimate, our analysis shows that quantity changes account for only $245 billion of this increase. Other factors, including program inefficiencies and underperformance, account for the remaining $257 billion increase in procurement estimates. Table 8 summarizes this analysis.

Table 8: Effects of Quantity Changes on 2019 Major Defense Acquisition Program Estimated Procurement Costs since 2018 and since First Full Estimates (Fiscal Year 2020 Dollars in Billions)

	Estimated change since first full estimates	Estimated change from 2018 to 2019
Estimated procurement cost change attributable to quantity change	244.88	65.59
Estimated procurement cost change not attributable to quantity change	256.85	(16.26)
Estimated total procurement cost change	501.73	49.33

Source: GAO analysis of Department of Defense (DOD) data. | GAO-20-439

Increases in average procurement unit costs among programs are often indicative of program inefficiencies and underperformance. We found that 38 MDAPs—nearly half of the 77 MDAPs in the 2019 portfolio that track and report unit costs—had higher average procurement unit costs since their first full estimates.[39] Table 9 identifies the five programs with the highest average procurement unit cost increases—measured by percentage increase—since first full estimate. It also identifies the factors contributing to these increases, according to our analysis of program documentation.

Table 9: Five Programs with the Highest Estimated Average Procurement Unit Cost Increases (by Percentage) since First Full Estimate

Program name	Lead Component	Estimated average procurement unit cost at first full estimate (fiscal year 2020 dollars in millions)	Estimated average procurement unit cost in 2019 (fiscal year 2020 dollars in millions)	Estimated average procurement unit cost percent change since first full estimate	Contributing factors for estimated average procurement unit cost increases
DDG 1000 Zumwalt Class Destroyer	Navy	1171.15	4668.59	298.6	(1) Quantity decrease
Guided Multiple Launch Rocket System	Army	0.04	0.14	221.0	(1) Production inefficiencies

[39]Our analysis included the 77 of 85 current MDAPs in the 2019 portfolio that reported procurement cost and quantity information in both December 2018 SARs and the program's initial SAR. Some programs, including the Chemical Demilitarization Program – Assembled Chemical Weapons Alternatives, are not traditional acquisition programs and do not have procurement quantities and were therefore not included in our analysis.

Program name	Lead Component	Estimated average procurement unit cost at first full estimate (fiscal year 2020 dollars in millions)	Estimated average procurement unit cost in 2019 (fiscal year 2020 dollars in millions)	Estimated average procurement unit cost percent change since first full estimate	Contributing factors for estimated average procurement unit cost increases
National Security Space Launch	Air Force	99.29	313.36	215.6	(1) Scope of work increase
H-1 Upgrades	Navy	12.05	34.43	185.7	(1) Overhead increase
MQ-8 Fire Scout Unmanned Aircraft System	Navy	11.54	30.61	165.2	(1) Quantity decrease (2) Additional engineering (3) Higher support needs

Source: GAO analysis of Department of Defense (DOD) data. | GAO-20-439

In some instances, program inefficiencies and underperformance can precede decisions to reduce quantities. For example, development cost growth led the Navy to reduce planned quantities of the DDG 1000 Zumwalt Class Destroyer program quantities from 32 ships to three ships. Consequently, the Navy lost cost efficiencies from the economies of scale associated with higher quantities, which in turn drove up average procurement unit costs in the program.

At the same time, programs with the most quantity increases reversed the trend of average procurement unit cost decreases. We attribute this reversal to a few programs that incurred significant average procurement unit cost increases during early production, which DOD later followed with decisions to buy more quantities once this cost growth had stabilized. Table 10 compares quantity changes and average procurement unit cost changes since first full estimate among the 77 MDAPs in the 2019 portfolio that reported data to facilitate this analysis.

Table 10: Comparison of Quantity Changes to Average Procurement Unit Cost Changes since First Full Estimate for DOD’s 2019 Portfolio of Major Defense Acquisition Programs

Change in quantity range	Number of programs	Average procurement unit cost percentage change
<-50%	2	232
-50 to -25%	3	87
-0 to -25%	10	46
0 to 25%	34	10

Change in quantity range	Number of programs	Average procurement unit cost percentage change
25 to 50%	6	0
50 to 100%	7	-11
>100%	15	19
Total	**77**	**23**

Source: GAO analysis of Department of Defense data. | GAO-20-439

Note: Eight programs in the 2019 Major Defense Acquisition Program portfolio did not report procurement cost and quantity in December 2018 Selected Acquisition Reports and were not included in this analysis.

Most Selected MDAP Delivery Schedules Are Largely Unchanged since Last Year but Have Generally Increased since First Full Estimates

We analyzed 40 MDAPs in DOD's 2019 portfolio that had yet to declare initial operational capability as of the December 2018 SAR. Among these 40 selected programs, we found that most program schedules were largely unchanged since last year. On average, these programs are scheduled to deliver capability in 126 months, 4 percent higher than last year's average.[40] Since last year, acquisition cycle times remained unchanged for 24 programs and grew longer for 16 programs within our selection. Table 11 details the estimated acquisition cycle time change between 2018 and 2019 for the 40 MDAPs in our selection.

Table 11: Estimated Schedule Changes of 40 Selected Department of Defense 2019 Portfolio Major Defense Acquisition Programs over the Past Year in Months

	Cycle time in 2018	Cycle time in 2019	Cycle time change since 2018	Cycle time percentage change since 2018
Estimated average cycle time to deliver initial capabilities	120.3	125.6	5.3	4.4

Source: GAO analysis of Department of Defense (DOD) data. | GAO-20-439

While most program cycle times have been steady from 2018 to 2019, cycle times have generally grown since first full estimate in the 2019 MDAP portfolio. We found that program cycle time grew by an average of 29 percent from first full estimates to current estimates, resulting in an

[40]We calculated cycle time as the difference between a program's start date and its declaration of initial operational capability, which is when a system can meet the minimum operational capabilities for a user's stated need. Cycle times will not change for programs that have already declared an initial operational capability. Accordingly, we excluded them from our analysis of cycle time changes.

average capability delivery delay of more than 2 years. Some MDAPs have experienced capability delays of over 10 years, including the Navy's V-22 Osprey Joint Services Advanced Vertical Lift Aircraft, which declared initial operational capability in June 2007 after a 15-year delay. Table 12 summarizes estimated acquisition cycle time changes since first full estimate and over the past year for 80 selected programs in DOD's 2019 MDAP portfolio.[41]

Table 12: Schedule Changes since First Full Estimate for 80 Selected Major Defense Acquisition Programs in the Department of Defense's 2019 Portfolio in Months

	Identified in programs' first full estimates	Reported by programs in 2019	Cycle time change since first full estimate	Cycle time percentage change since first full estimate
Estimated average cycle time to deliver initial capabilities	93.0	120.2	27.2	29.2

Source: GAO analysis of Department of Defense (DOD) data. | GAO-20-439

Note: Five programs did not factor into the analysis because their December 2018 SARs (1) did not report a current date for initial operational capability (four programs) or (2) identified a program start date that is not representative of the beginning of acquisition activities in the program (one program).

Since first full estimate, cycle time increased for 62 MDAPs and decreased or remained unchanged for 18 MDAPs. This means more MDAPs than not have experienced or anticipate experiencing schedule growth that results in delays delivering initial capabilities.

Selected MDAPs Identified Software Development as a Program Risk Based on Various Factors

Over the years, weapon acquisition program officials, through their responses to our questionnaires, have consistently acknowledged software development as a risk item in their efforts to develop and field capabilities to the warfighter, and this year is no different. According to the Defense Innovation Board's 2019 report, software development is often the limiting factor for integrating sensors, platforms, and weapons.[42] Further, in the acquisition of new systems, the Defense Science Board

[41]Five programs did not factor into the analysis because their December 2018 SARs either: (1) did not report a current date for initial operational capability (four programs) or (2) identified a program start date that is not representative of the beginning of acquisition activities in the program (one program).

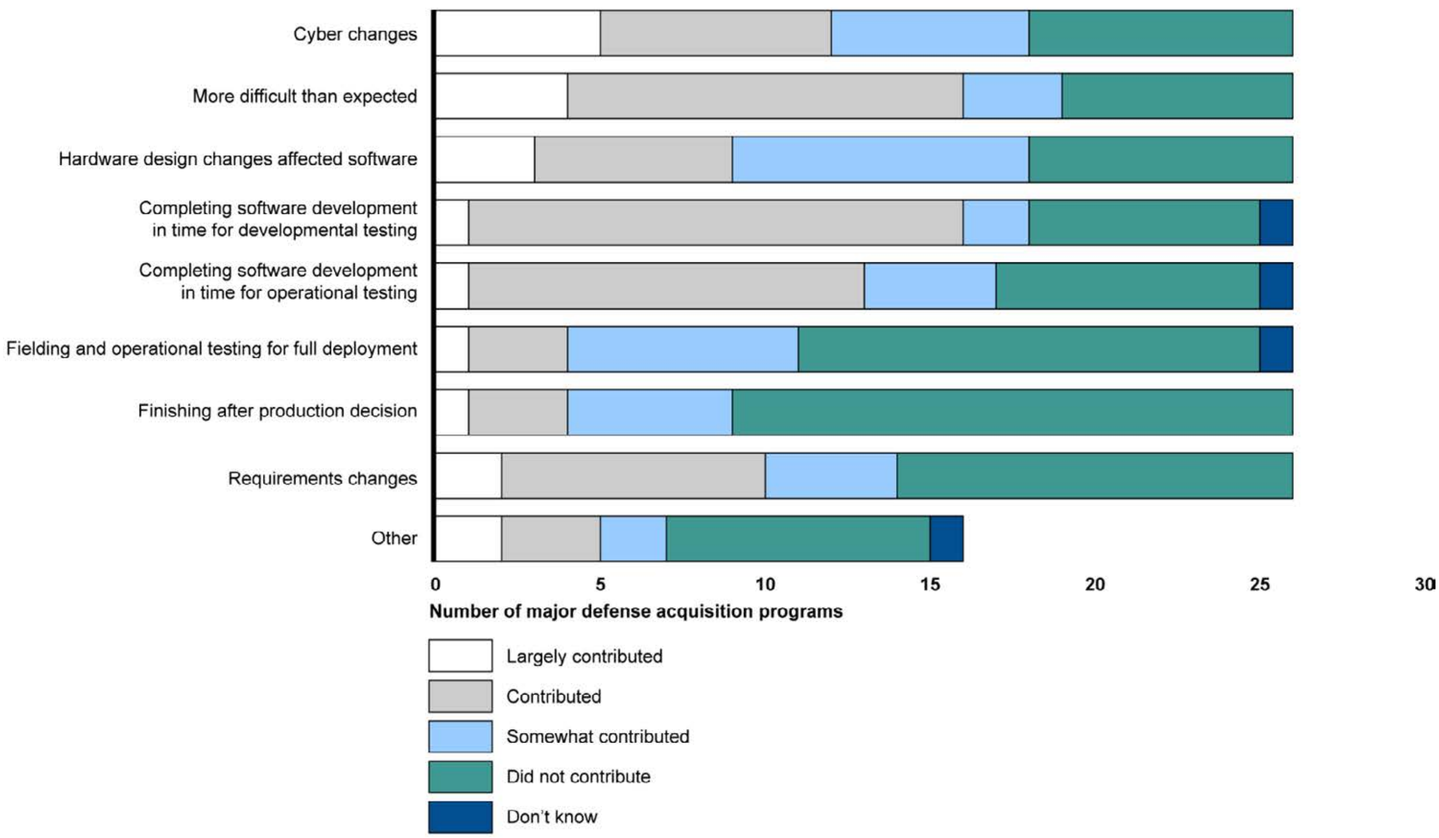
[42]Defense Innovation Board, *Software Is Never Done: Refactoring the Acquisition Code for Competitive Advantage,* May 2019.

reported that software development drives program risk for approximately 60 percent of programs.[43]

This year, we selected 42 MDAPs between the start of development and the early stages of production to survey on software development approaches. We also included MDAPs that were well into full-rate production, but planning to introduce new increments of capability, should the costs of the new increment exceed the threshold needed to qualify as a MDAP. In their questionnaire responses, officials from 26 of these 42 MDAPs reported software development as having been a risk item at some point during their program's history. We asked these 26 MDAPs to note the factors that contributed, to any degree, to their identification of software development as a program risk. Program officials frequently identified more than one factor that led to them designating software development as a program risk item. Figure 6 illustrates the various contributing factors the 26 programs cited to us.

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

Figure 6: Factors That Contributed to the 26 Selected Major Defense Acquisition Programs That Identified Software Development as a Program Risk



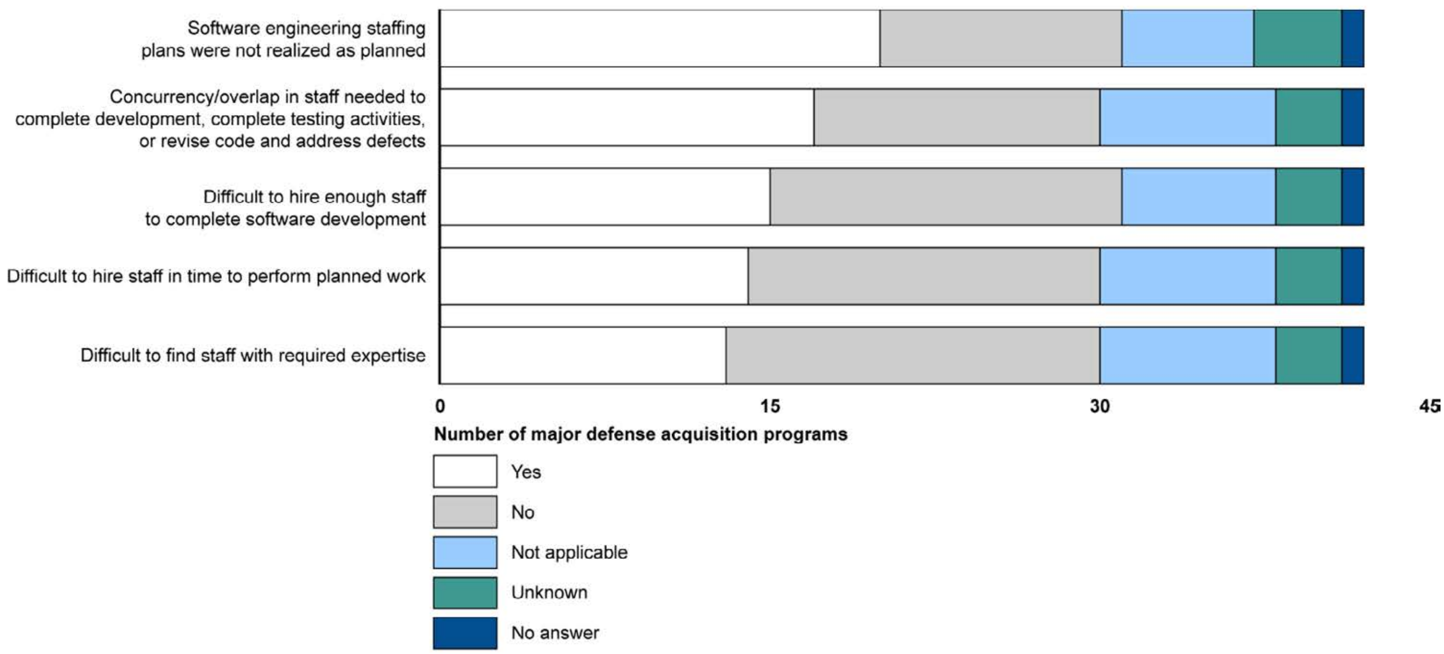
Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

Note: Examples of "Other" factors that programs identified in their questionnaire responses included late delivery of hardware that compressed integration schedules, system integration difficulties that required additional development, or changes to meet anti-tamper requirements.

Software Development Staff

In our questionnaire, we asked officials from the 42 MDAPs what sort of software development challenges directly related to government and contractor software staff they experienced, if any. The two most common responses pertained to the difficulty of hiring staff with the required expertise and hiring staff in time to perform the required work. Figure 7 identifies the distribution of various challenges associated with software development staffing among the 42 MDAPs we surveyed.

Figure 7: Challenges Associated with Government and Contractor Software Development Staff among 42 Selected Major Defense Acquisition Programs

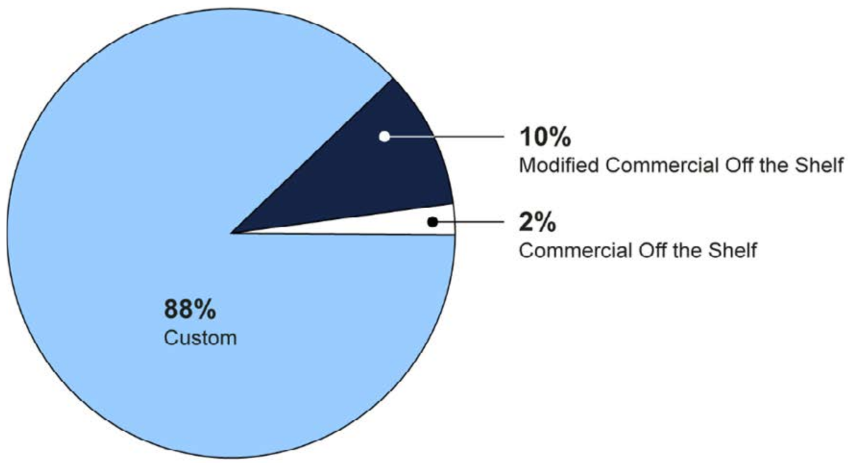


Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

Reliance on Custom Software

DOD weapon acquisition programs seek to develop new and specialized capabilities to meet the needs of warfighters. In most cases, these capabilities are not available commercially and therefore must be developed as new weapon systems. Similar to commercial innovations, though, these new weapon systems increasingly depend on software to function and deliver capability. Given the generally unique nature of DOD weapon systems, much of the software for a weapon system is custom-created. This requires more coding hours from software development staff than would be necessary if programs were able to use commercial, off the shelf (COTS) software. Based on questionnaire responses from the 42 MDAPs we surveyed and other information we obtained from program offices, we found that MDAPs are heavily dependent upon custom software to provide their systems' required capabilities. Figure 8 illustrates the use of COTS, modified COTS, or custom code among MDAPs.

Figure 8: Percentage of Types of Software Used by 42 Selected Major Defense Acquisition Programs

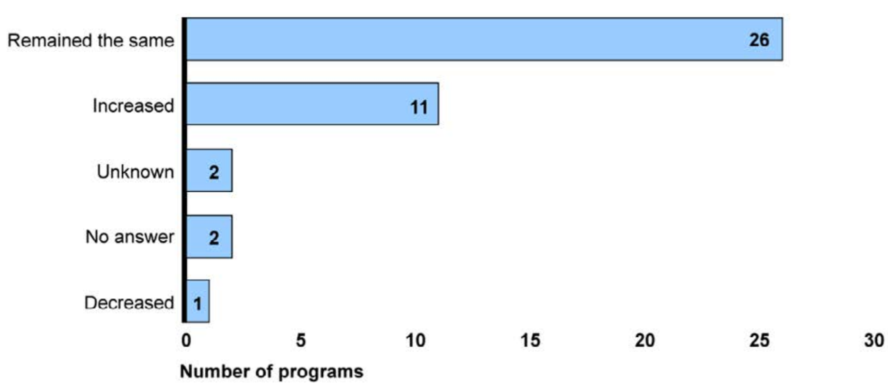


Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

More Than a Quarter of MDAPs Reported Total Acquisition Cost Growth Resulting from Software Challenges, but Details Are Limited

We surveyed the 42 MDAPs on whether they realized any total cost changes after the start of system development that resulted from challenges associated with the software development effort. Though most indicated that costs had remained the same, more than a quarter (11 of 42) of the responding programs indicated their total costs increased as a result of either changes or challenges associated with software development (see fig. 9).

Figure 9: Ways that 42 Selected Major Defense Acquisition Programs Indicated Software Development Challenges Had Changed Total Cost



Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

DOD relies on contractor-generated software resources data reports (SRDR) to provide information on the size, schedule, effort, and quality of programs' software products and help improve the accuracy of cost estimation.[44] DOD policy requires these reports be submitted to OSD for all major contracts with a projected software effort greater than $20 million, as well as for subsequent software releases.[45] Out of the 24 MDAPs that reported over $20 million in software development, only 20 program responses to our questionnaire indicated that initial SRDRs were submitted.[46] Further, out of the 11 programs that involved additional software deliveries, only four indicated that subsequent reports were submitted.

Officials with DOD's Office of Cost Analysis and Program Evaluation (CAPE) told us that not all programs whose software development effort exceeds the $20 million threshold are completing the SRDRs. Without programs' timely submission of SRDRs, CAPE lacks information needed to prepare acquisition and life-cycle cost estimates.[47] CAPE officials told us they have implemented a verification and validation process (with guidance) to identify problems early and, ultimately, improve the SRDR data quality. The officials said they also travel to visit with programs and major contractors to educate them on the SRDR requirement and process.

MDAPs Are Transitioning More to Leading Commercial Approaches for Software Development, but Deliveries Often Lag behind Industry Standards

MDAPs reported a number of different approaches for developing software. These include some leading commercial software approaches, such as Agile development approaches. Eighteen of the 42 MDAPs reported using multiple software development models to generate their systems' required software. In some of these cases, programs develop software for a number of different subsystems; notionally, a program may choose to use an incremental approach for a firing system but may also utilize a waterfall approach for a flight control subsystem. Figure 10

[44]DOD, *Department of Defense Software Resource Data Report (SRDR) Verification and Validation (V&V) Guide Version 4.0*, (Washington, D.C.: Feb. 2, 2018).

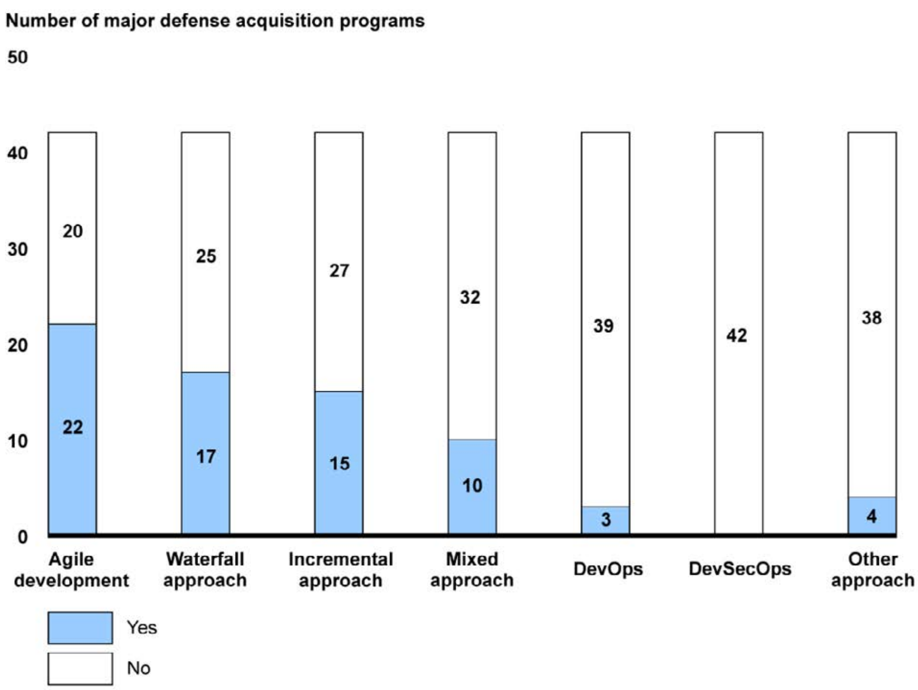
[45]DOD Manual 5000.04, *Cost and Software Data Reporting (CSDR) Manual* (Nov. 4, 2011) (Incorporating Change 1, Apr. 18, 2018).

[46]DOD Manual 5000.04 requires that, for software efforts that exceed $20 million, software developers submit an initial SRDR, and subsequent SRDRs for each deliverable software release or element, and a final SRDR upon contract completion.

[47]CAPE provides DOD with analysis on resource allocation and cost estimation problems. Part of CAPE's role includes collecting and analyzing software-specific cost information to allow DOD to make more informed management decisions.

shows several software development models employed by the 42 MDAPs that completed our questionnaire.

Figure 10: Software Development Approaches Employed by 42 Selected Major Defense Acquisition Programs



Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

In August 2016, the Under Secretary of Defense for Acquisition, Technology, and Logistics asked the Defense Science Board to examine the state of DOD software acquisitions and recommend practical actions to improve performance by the DOD and its suppliers. The task force found that DOD and its suppliers are using software development mechanisms that are not aligned with the realities of current, continuous software development and deployment as practiced commercially.[48] Per a May 2019 report, the Defense Innovation Board stated that speed and

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

cycle time are the most important metrics for managing software.[49] The Board further reported that statutes, regulations, and cultural norms that get in the way of deploying software to the field quickly weaken national security and expose the nation to risk. Industry documentation we reviewed showed that commercial programs utilizing Agile methods deliver useful increments of software capabilities in a few weeks. Such programs focus on delivering smaller increments of capabilities in more frequent iterations.

Based on our questionnaire responses, we found that while some MDAPs reported using current software development approaches, they are delivering software capabilities at rates often much slower than those current approaches demand. Of the 30 MDAPs that provided software delivery times via our questionnaire, the majority (21) reported that the length of time between software deliveries to the user is 10 months or more. Of the 22 MDAPs that reported using Agile development methods, 16 identified longer delivery times than are typical in commercial industry. Thirteen of the MDAPs using Agile reported delivery times equal to or greater than 7 months.

Further, industry standards state that Agile development should begin with the creation of a software factory, which is a set of software tools that programmers use to write their code; confirm it meets style and other requirements; collaborate with other members of the programming team; and automatically build, test, and document their progress. This allows teams of programmers to do iterative development with frequent feedback from users. The Defense Science Board recommended in its February 2018 report that, for iterative development approaches, the software factory be a key evaluation criterion in the source selection process. Of the 22 MDAPs that reported using Agile in our questionnaire, only four reported the use of a software factory.

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

DOD Has Begun Emphasizing Cybersecurity Measures, but Program Implementation Has Been Inconsistent

We have reported that DOD weapon systems are more networked than ever before.[50] This has transformed weapon capabilities and is a fundamental enabler of the United States' modern military capabilities. Yet this change has come at a cost. More weapon components can now be attacked using cybersecurity capabilities. Further, networks can be used as a pathway to attack other systems. In our 2018 report on weapon systems cybersecurity, we found that the federal government was just beginning to, among other things, improve its abilities to detect, respond to, and recover from cybersecurity incidents for its weapons systems. Our analysis this year looked at DOD's progress with developing (1) strategies that help ensure that programs are planning for and documenting cybersecurity risk management efforts (cybersecurity strategies), (2) evaluations that allow testers to identify systems' weaknesses that are susceptible to cybersecurity attacks and that could potentially jeopardize mission execution (cybersecurity vulnerability evaluations), and (3) assessments that evaluate the ability of a unit equipped with a system to support assigned missions (cybersecurity assessments).

Cybersecurity Strategies

Thirty-eight of the 42 MDAPs we surveyed reported having an approved cybersecurity strategy, while the remaining four planned to have one in the future. DOD guidance generally requires that MDAPs develop a cybersecurity strategy by technology development start (Milestone A) and update the strategy at subsequent milestones.[51] Other DOD guidance establishes that a program's cybersecurity strategy should (1) serve as a tool for decision makers to plan for, identify, assess, mitigate, and manage risks as systems mature; (2) be developed as early as possible and continually updated and maintained; and (3) reflect both the program's long-term approach for and implementation of cybersecurity throughout the program life cycle.

[50]GAO, *Weapon Systems Cybersecurity: DOD Just Beginning to Grapple with Scale of Vulnerabilities*, GAO-19-128 (Washington, D.C.: Oct. 9, 2018). We made no recommendations in this report.

[51]Department of Defense Instruction 5000.02T, *Operation of the Defense Acquisition System* (Jan. 2015) [incorporating change 6 (Jan. 23, 2020)].

Cybersecurity Vulnerability Evaluations

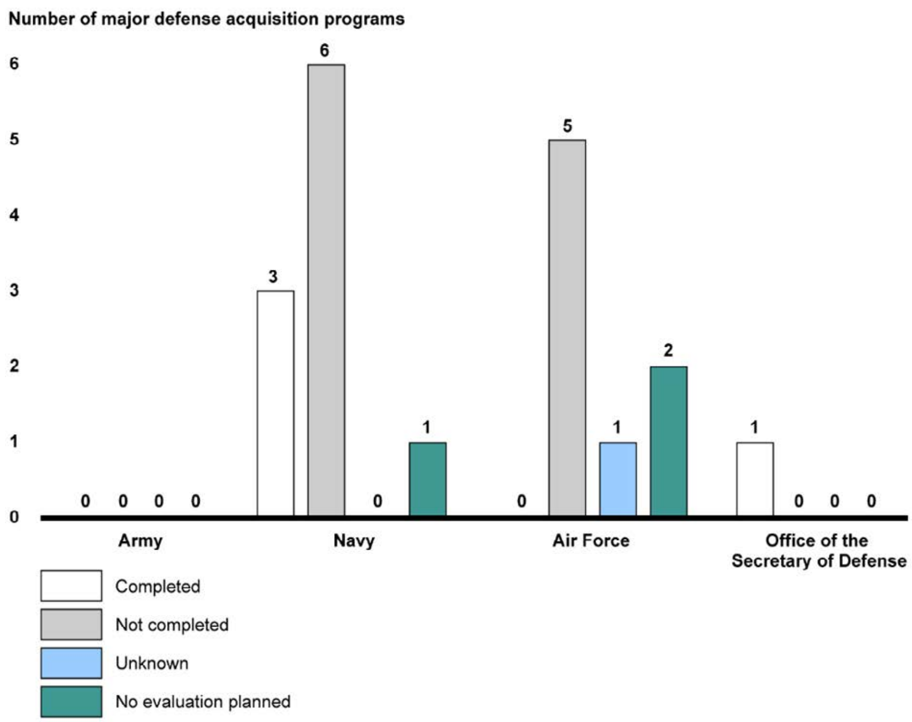
Section 1647 of the NDAA for FY 2016 included a section that generally required DOD to complete cyber vulnerability evaluations for each major weapon system by December 31, 2019.[52]

Of the 42 MDAPs we surveyed, DOD identified 19 that are subject to cyber vulnerability evaluations.[53] Of these 19, 11 responded that they either had yet to complete a cyber vulnerability evaluation, or they had completed an evaluation, but not by the statutory date of December 31, 2019. Another three MDAPs did not have a scheduled date for completing such an evaluation. Four programs reported completing a cybersecurity vulnerability evaluation, while one program did not know whether such an evaluation had been conducted. None of the programs reported receiving a waiver or deferral for the evaluation. Figure 11 identifies, by military department, these 19 MDAPs' progress to date completing cyber vulnerability evaluations.

[52]Section 1647 permitted the Secretary of Defense to waive or defer the cyber vulnerability evaluation for a weapon system if the Secretary certified to the congressional defense committees before December 31, 2019, that all known cyber vulnerabilities in the weapon system have minimal consequences for the capability of the weapon system to meet operational requirements or otherwise satisfy mission requirements. Section 1633 of the National Defense Authorization Act for Fiscal Year 2020 amended section 1647 to include a requirement that the Secretary of Defense provide written notification to the congressional defense committees in cases where the cyber vulnerability evaluation for a major weapon system would not be completed by December 31, 2019. Section 1633 also amended section 1647 to require the Secretary of Defense to provide a report to the congressional defense committees upon completion of the cyber vulnerability evaluations of each major weapon system.

[53]Section 1647 does not define the major weapon systems subject to the cyber vulnerability evaluation. OUSD (A&S) officials reported that they selected weapon systems for evaluation through an analysis of weapon systems identified in the most recent quadrennial defense review.

Figure 11: Completion Status of Cyber Vulnerability Evaluations among 19 Selected Major Defense Acquisition Programs

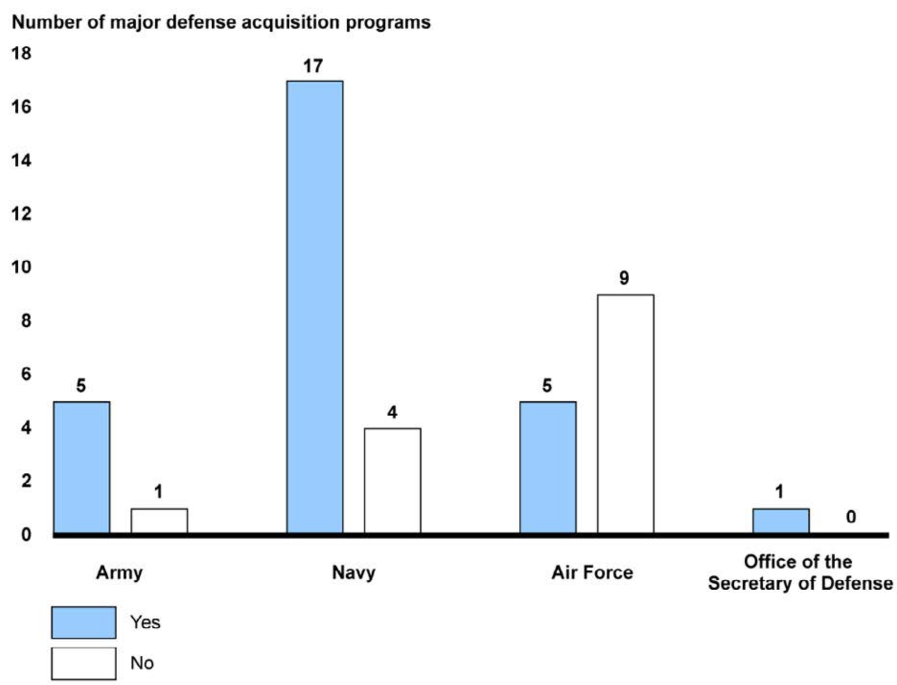


Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

Cybersecurity Assessments

Fourteen MDAPs we surveyed reported that they had not completed cybersecurity assessments, which differ from the aforementioned cybersecurity vulnerability evaluations. Of these 14 programs, half are less than 2 years old and have not begun developmental testing, including cybersecurity testing. We also found variation among the military departments in the rates they had completed these assessments. Specifically, among the three military departments, the Army reported the best rate for programs conducting cybersecurity assessments, while the Air Force had the lowest rate. Figure 12 shows that, of the 42 MDAPs, 28 programs have completed one or more cybersecurity assessments.

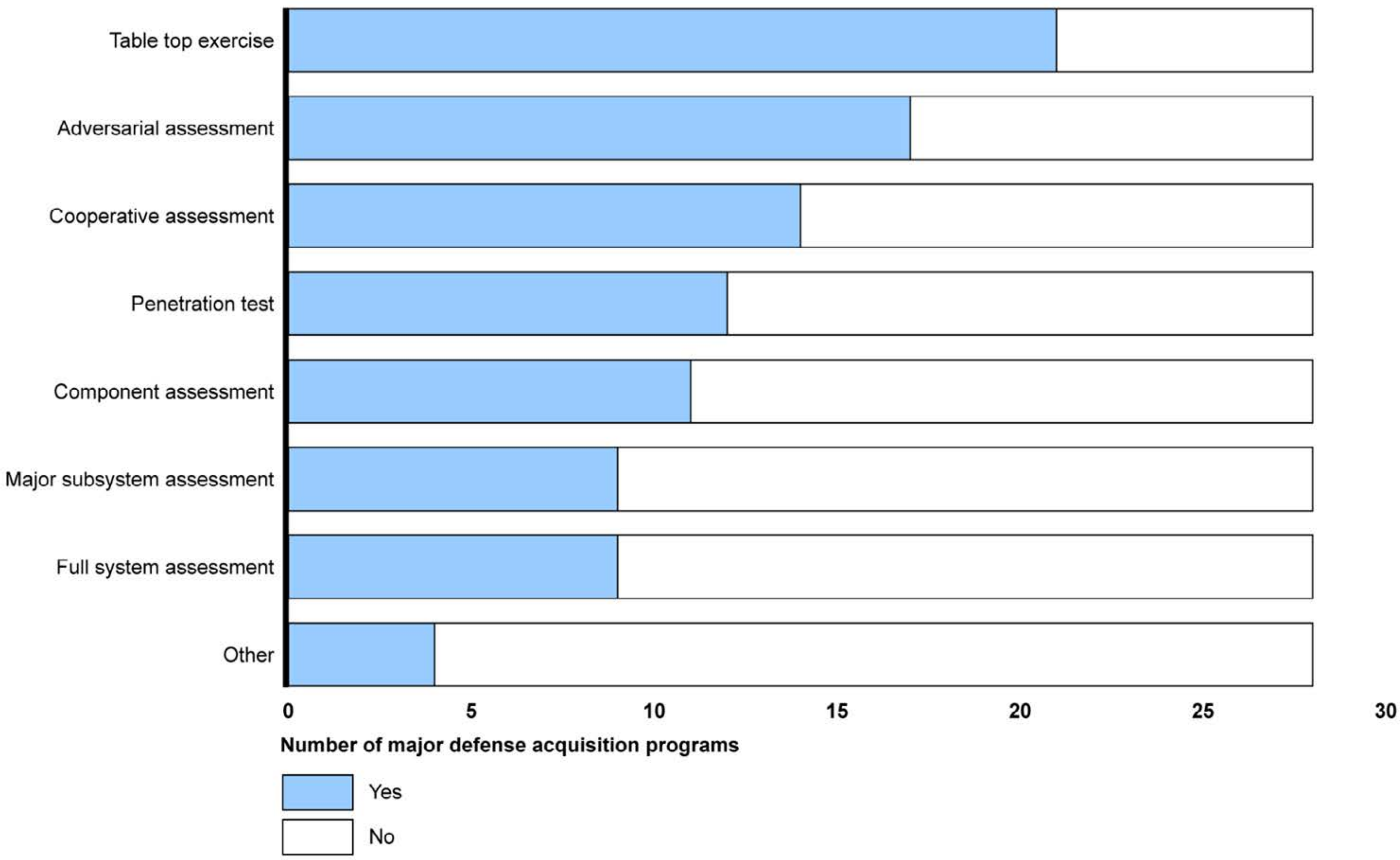
Figure 12: Breakdown of 42 Selected Major Defense Acquisition Programs That Have Completed at Least One Cybersecurity Assessment



Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

In response to our questionnaire, 28 MDAPs indicated they had completed a cybersecurity assessment. We asked the programs to identify the characteristics that best describe the assessments they have conducted to date. Figure 13 presents these programs' responses.

Figure 13: Selected Major Defense Acquisition Programs' Cybersecurity Assessment Characteristics



Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

Note: Program officials were able to select multiple characteristics to describe their cybersecurity assessments. Other than the table top exercise, all assessment characteristics include the use of actual hardware or software.

Programs we surveyed reported a variety of characteristics to describe their cybersecurity assessments. Programs most frequently reported the table top exercise as characterizing their cybersecurity assessments. Table top exercises bring people together to talk through how they would respond to simulated scenarios and often involve small collaborative teams that prepare briefings on notional threat scenarios. Based on those results, officials can create a path forward for addressing those scenarios, which could include administering additional testing, conducting follow-on analysis, or accepting the risk posed by the threat.

DOD guidance also promotes assessment methods for cybersecurity test and evaluation that apply to all DOD programs and systems, regardless of their acquisition category or phase of the acquisition life cycle, unless noted.[54] The guidance outlines, among other things, two assessments—the Cooperative Vulnerability and Penetration Assessment (CVPA) and the Adversarial Assessment (AA)—that pertain to cybersecurity-specific operational test and evaluation activities. We asked the 42 MDAPs whether they included either of these assessments in either developmental testing or operational testing activities for their systems. Of the 14 programs that have undergone operational testing, 13 reported they have had a CVPA and 12 reported they have had an AA. Of the 24 that have undergone developmental testing, 14 reported their testing included a CVPA and 12 included an AA.

DOD Does Not Often Factor Cybersecurity into MDAP Requirements

Key performance parameters (KPP) are considered the most critical requirements by the sponsor military organization, while key system attributes (KSA) and other performance attributes are considered essential for an effective military capability. We previously found that, historically, DOD did not require that programs factor cybersecurity into their KPPs.[55] We also 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.[56] In 2015, DOD modified its main requirements policy—the Joint Capabilities Integration and Development System Manual. Specifically, DOD revised the mandatory system survivability KPP, which is intended to ensure the system maintains its critical capabilities under applicable threat environments, so that it requires systems to be able to operate in a degraded cyber environment.

We surveyed the 42 MDAPs on how many of their KPPs and KSAs address cybersecurity. Twenty-five programs reported that none of their KPPs address cybersecurity. Even more programs reported that their KSAs did not address cybersecurity. Figures 14 and 15 show by military department the extent to which the 42 MDAPs we surveyed have

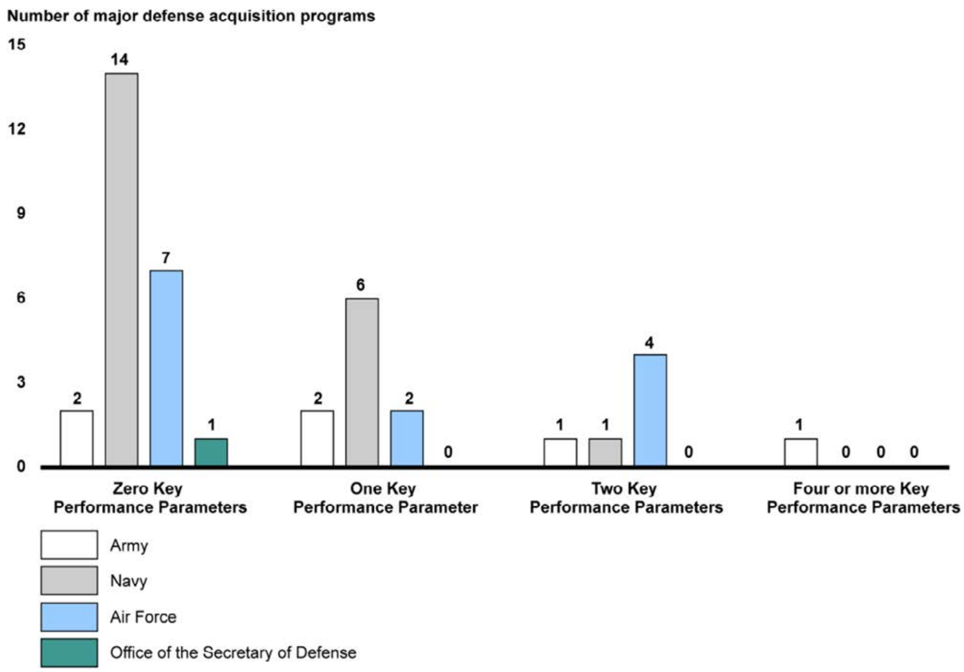
[54] Department of Defense, *Cybersecurity Test and Evaluation Guidebook,* Version 2.0, Change 1 (Washington, D.C.: February 2020).

[55] GAO-19-128.

[56] The Joint Staff has enterprise-level responsibilities related to the requirements process, including identifying, assessing, validating, and prioritizing capability needs.

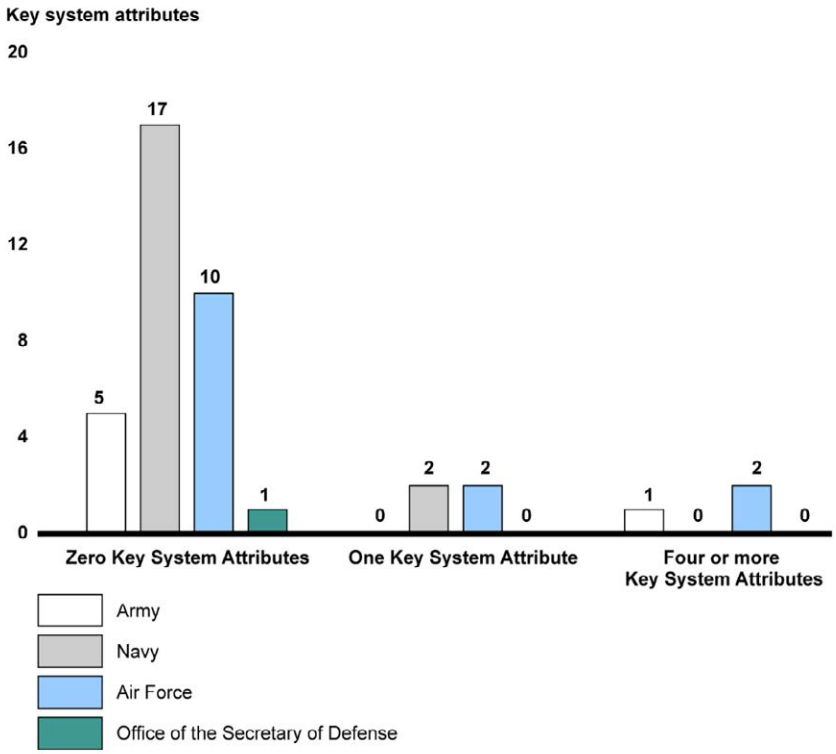
incorporated cybersecurity requirements into their program KPPs and KSAs.

Figure 14: Number of Cybersecurity-Related Key Performance Parameters Reported by 42 Selected Major Defense Acquisition Programs



Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

Figure 15: Number of Cybersecurity-Related Key System Attributes Reported by 42 Selected Major Defense Acquisition Programs



Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

MDAPs Have Missed Opportunities to Improve Cost and Schedule Outcomes by Not Adopting Knowledge-Based Approaches

MDAPs reported only limited implementation of knowledge-based practices at key points during the acquisition process, thereby foregoing opportunities to improve cost and schedule outcomes. For instance, one practice is that programs should 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. DOD and commercial technology development cases show the more mature a technology is at the start of the program, the more likely the program will succeed in meeting its objectives.[57] Technologies that were

[57]GAO, *Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects*, GAO-20-48G (Washington, D.C.: Jan. 7, 2020).

included in a product development effort before they were mature later contributed to cost increases and schedule delays in those products.[58]

Based on our analysis of 42 selected MDAPs that are between the start of development and the early stages of production, we found that most programs have not consistently implemented key practices at knowledge point 1. We found only one practice—demonstrating all critical technologies are very close to final form, fit, and function within a relevant environment—where more than half the programs demonstrated sufficient knowledge. Table 13 identifies the percentage of MDAPs we surveyed that reported implementing key knowledge point 1 practices.

Table 13: Extent to Which 42 Major Defense Acquisition Programs Had Implemented Key Knowledge Point 1 Practices

Practices associated with knowledge point 1	Percentage of programs that satisfied the practice
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	○
Completed preliminary design review before system development start	○

Legend:

● 75 - 100 percent

◐ 50 - 74 percent

○ 0 - 49 percent

Source: GAO analysis of Department of Defense acquisition programs' responses to GAO questionnaire. | GAO-20-439

Note: Knowledge point 1 coincides with when technology, time, funding, and other resources match customer needs and a decision is made to invest in product development. 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 assessment of the preliminary design review, and certifies, based on that assessment, that the program has 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). Eleven MDAPs in our sample predated this requirement.

Based on our analysis of the 42 MDAPs, we also found that programs have not consistently implemented key practices at knowledge point 2. Knowledge of a product's design stability early in the program facilitates informed decisions about whether to significantly increase investments and reduces the risk of costly design changes that can result from

[58]Ibid.

unknowns after initial manufacturing begins. This knowledge comes in the form of completed engineering drawings before transitioning from the system integration phase to the system demonstration phase of product development. In the DOD process, knowledge point 2 should happen by the critical design review, before system demonstration and the initial manufacturing of production representative products begins. Knowledge-based acquisition practices suggest that a program complete at least 90 percent of the drawings for a product's design before it makes a decision to commit additional resources. Table 14 identifies the percentage of MDAPs that have implemented key knowledge point 2 practices.

Table 14: Extent to Which 42 Major Defense Acquisition Programs Had Implemented Key Knowledge Point 2 Practices

Practices associated with knowledge point 2	Percentage of programs that satisfied the practice
Release at least 90 percent of design drawings to manufacturing (or for ships, 100 percent of 3D product modeling)	○
Test a system-level integrated prototype	○

Legend:

● 75 - 100 percent

◐ 50 - 74 percent

○ 0 - 49 percent

Source: GAO analysis of Department of Defense acquisition programs' responses to GAO questionnaire. | GAO-20-439

Note: Knowledge point 2 coincides with when a program's system design is stable and performs as expected and a decision is made to start building and testing production-representative prototypes. For ships, we apply only one practice—completing basic and functional design to include 100 percent of 3D product modeling—for demonstrating design knowledge. Testing a system-level integrated prototype does not apply to ships.

Based on our analysis of the 42 MDAPs, we found that programs have not consistently implemented key practices at knowledge point 3. Later knowledge that the design can be manufactured affordably and with consistent high quality prior to making a production decision ensures that cost and schedule targets will be met. This knowledge comes in the form of evidence from data that shows manufacturing processes are in control and system reliability is achievable. Leading commercial companies rely on knowledge obtained about critical manufacturing processes and product reliability to make their production decisions. In DOD acquisitions, this is consistent with a decision to begin low-rate initial production, which we equate to knowledge point 3. Table 15 identifies the percentage of MDAPs that have implemented key knowledge point 3 practices.

Table 15: Extent to Which Major Defense Acquisition Programs Are Implementing Key Knowledge Point 3 Practices

Practices associated with knowledge point 3	Percentage of programs that satisfied the practice
Demonstrate critical manufacturing processes are in statistical control	○
Demonstrate critical processes on a pilot production line	○
Test a production-representative prototype in its intended environment	○

Legend:

● 75 - 100 percent

◐ 50 - 74 percent

○ 0 - 49 percent

Source: GAO analysis of Department of Defense acquisition programs' responses to GAO questionnaire. | GAO-20-439

Note: Knowledge point 3 coincides with production meeting cost, schedule, and quality targets and a decision is made to produce first units for customers. 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. Acquisition best 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 also surveyed eight future MDAPs to assess their plans for demonstrating knowledge at key points in the program. Based on these programs' responses to our questionnaire, they plan to demonstrate higher levels of knowledge for certain practices than what MDAPs demonstrated for those same practices. Table 16 presents the number of future MDAPs that plan to meet three key knowledge practices associated with beginning system development.

Table 16: Planned Implementation of Selected Knowledge-Based Acquisition Practices at Development Start among Eight Future Major Defense Acquisition Programs

	Plan to demonstrate all critical technologies in a realistic environment	Plan to complete all system engineering reviews	Plan for a development phase of less than 6 years
Yes	0	5	5
No	1	0	0
Information not available or practice not applicable	7	3	3

Source: GAO analysis of Department of Defense acquisition programs' responses to GAO questionnaire. | GAO-20-439

In particular, six of the eight future MDAPs plan to conduct one key system engineering review—preliminary design review—before proceeding into development. Another program is procuring an already-fielded system and will not be required to conduct a preliminary design review.

Of the three future MDAPs that identified critical technologies, one was unable to identify the current maturity levels or projected maturity for starting development. A second program identified only one critical technology that reasonably demonstrates functionality but had yet to achieve the required form and fit. The third future MDAP that reported technology information in its questionnaire responses identified 14 critical technologies. The program anticipates that only one of these 14 critical technologies will be fully mature at the time of the system development start decision, currently scheduled for June 2021.

Certain Knowledge-Based Practices Are Linked to Better Program Outcomes

For the third consecutive year, we conducted an exploratory statistical correlation analysis to determine whether a statistically significant link exists between nonshipbuilding MDAPs' unit cost and schedule performance and their implementation of knowledge-based acquisition practices. We found that, in general, MDAPs that completed certain knowledge practices had better cost and schedule outcomes than programs that did not implement those same practices.

This year, we analyzed 21 programs—an increase of four programs as compared to our 2019 analysis—that have completed system development, held a critical design review, and started production (i.e., completed knowledge points 1 through 3). 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.[59] This year we observed three knowledge practices with a statistically significant correlation to improved program acquisition unit costs, which are a measure of the unit cost for the total acquisition; improved schedule performance; or both.

[59]Our prior work demonstrates that completion of all the knowledge-based practices by the time programs reach their knowledge points underpins a sound business case, positioning programs to meet their cost and schedule goals. In general, a business case is a justification for a proposed project or undertaking. We have reported that a sound business case for successful defense acquisition programs contains key elements, including firm requirements, mature technologies, a knowledge-based acquisition strategy, a realistic cost estimate, and sufficient funding.

Table 17 identifies the three key practices that contribute to statistically significant unit cost and schedule performance differences between programs that did or did not implement them.

Table 17: Statistically Significant Knowledge-Based Acquisition Practices and Their Corresponding Performance Outcomes among 21 Selected Major Defense Acquisition Programs

Knowledge practice	Programs that implemented the practice	Programs that did not implement the practice	Net performance difference
Complete a system-level preliminary design review prior to starting system development	• -13.1% unit cost growth • 11.6% schedule growth	• 33.6% unit cost growth • 46.3% schedule growth	• 46.7% less unit cost growth • 34.7% less schedule growth
Release at least 90 percent of design drawings by critical design review	• -5.5% unit cost growth • 10.3% schedule growth	• 45.1% unit cost growth • 50.3% schedule growth	• 50.6% less unit cost growth • 40.0% less schedule growth
Test a system-level integrated prototype by critical design review [a]	• 13.3% schedule growth	• 43.2% schedule growth	• 29.9% less schedule growth

Source: GAO analysis of Department of Defense data. | GAO-20-439.

[a]For this year's assessment, our statistical correlation analysis did not identify this practice as having a statistically significant correlation to unit cost changes. Unit cost performance reported in the table is for program acquisition unit costs, which are unit costs that measure a program's total acquisition effort. Differences significant at the 90 percent confidence level.

Oversight Challenges Exist for DOD's Costliest MTA Programs

DOD has taken steps to improve oversight of its costliest MTA programs, but challenges remain to tracking cost and schedule performance. The 13 programs we reviewed—nearly all of which were rapid prototyping efforts—were expected to last about 4 years on average, although most planned follow-on efforts. DOD issued guidance in December 2019 that increased oversight for its largest MTA programs, including requiring documentation to help assess whether programs are well positioned to field capabilities within 5 years, as we recommend in June 2019. While most of the MTA programs we reviewed began before the December 2019 guidance and were lacking some or all of this documentation at program initiation, we found that programs had made significant progress in receiving approval of these documents by the time of this review. Finally, we observed inconsistent cost reporting and wide variation in schedule metrics across MTA programs, which pose oversight challenges for OSD and military department leaders trying to assess performance of these programs. According to DOD officials, the department is in the process of improving MTA program data.

DOD Had Initiated 13 MTA Programs with Estimated Costs Equivalent to the MDAP Cost Threshold as of June 2019, but Cost and Cycle Time Estimates for These Programs May Not Reflect DOD's Full Planned Investment

As of June 2019, the military departments had initiated 13 MTA programs that they identified as having costs equivalent to the cost threshold for MDAPs, either because the current MTA effort had estimated costs equivalent to the MDAP cost threshold, or because the military department planned multiple MTA efforts that had total estimated costs equivalent to the MDAP cost threshold. Twelve of these programs were using the rapid prototyping pathway, which statute describes as intended for programs that will provide for the use of innovative technologies to rapidly develop fieldable prototypes to demonstrate new capabilities and meet emerging military needs. The last program, the Air Force's F-22 Capability Pipeline, was approved to conduct activities under both the rapid prototyping pathway and the rapid fielding pathway, which statute describes as intended for programs that will provide for the use of proven technologies to field production quantities of new or upgraded systems with minimal development required.

The 13 MTA programs we reviewed had a total estimated cost of $19.5 billion for current MTA efforts. These programs represent a range of products, dollar amounts, and complexity. For example:

- the most costly MTA program we reviewed was the Air Force's Next Generation Overhead Persistent Infrared-Block 0 rapid prototyping effort—which aims to develop mission payloads to satisfy DOD's urgent requirement to develop a satellite system to provide initial missile warning capabilities and survivability against emerging threats—with a cost estimate of approximately $8.4 billion.
- the least costly MTA program we reviewed was the Air Force's Protected Tactical Enterprise Service Release 1 rapid prototyping effort—which aims to enable adaptive anti-jam wideband satellite communications capabilities—with a cost estimate of approximately $292 million.

MTA programs, both rapid prototyping and rapid fielding, are statutorily required to have an objective of being completed within 2 to 5 years of the development of an approved requirement. While DOD guidance on when MTA program start occurs has continued to evolve, our analysis showed that the average expected length for MTA programs we reviewed was 3.8 years from the time that DOD obligated funding for the MTA program; the minimum was 2.1 years, and the maximum was 5 years.

Table 18 shows the planned time frames for each of the MTAs.[60]

Table 18: Summary of Middle-Tier Acquisition Programs Identified by the Military Departments as Having Estimated Costs Equivalent to the Major Defense Acquisition Programs Cost Threshold Initiated as of June 2019

Program name	Military department	Cost estimate for current middle-tier acquisition effort ($2020, millions)	Type of technology	Expected length of current middle-tier acquisition effort (years)
Air Launched Rapid Response Weapon	Air Force	$1,162.59	Hypersonic missile	4.1
B-52 Commercial Engine Replacement Program-Spiral 1	Air Force	$539.68	Aircraft engine	2.3
Extended Range Cannon Artillery-Increment 1C	Army	$485.79	Cannon artillery	5.0
F-22 Capability Pipeline	Air Force	$976.29	Aircraft hardware and software upgrades	2.9
Hypersonic Conventional Strike Weapon	Air Force	$1,332.50	Hypersonic missile	3.8
Integrated Visual Augmentation System	Army	$991.34	Visual augmentation headset	2.1
Lower Tier Air and Missile Defense Sensor	Army	$1,298.81	Multi-function radar	3.8
Mobile Protected Firepower	Army	$924.22	Direct fire capability	3.7
Next Generation Overhead Persistent Infrared-Block 0	Air Force	$8,410.41	Missile warning satellite system	5.0
Optionally Manned Fighting Vehicle-Increment 1	Army	$1,570.23	Armored vehicle	3.2
Protected Tactical Enterprise Service-Release 1	Air Force	$292.02	Communications support	3.0
Protected Tactical SATCOM	Air Force	$920.07	Communications support	4.9
Unified Platform	Air Force	$588.98	Software platform	5.0

Source: GAO analysis of Department of Defense data. | GAO-20-439

As a result of the time-limited nature of MTA programs, MTA program cost and schedule estimates often do not reflect DOD's full planned level

[60]In October 2018, DOD issued interim MTA guidance that stated that an MTA program's limit for completing the program will be calculated from the date of the first obligation of funds for a program purpose. In December 2019, DOD released final guidance defining MTA program start as the date an acquisition decision memorandum is signed. The final guidance stated that MTA programs may not be planned to exceed 5 years to completion and, in execution, will not exceed 5 years after MTA program start, without a Defense Acquisition Executive waiver. However, the final guidance also stated that MTA programs that were designated prior to the effective date of the new issuance will maintain their MTA program start date of funds first obligated.

of investment in acquiring the capability being prototyped or fielded. In accordance with DOD guidance, the MTA program estimates reflect only the current MTA effort. While DOD may ultimately decide not to continue with the development or fielding of a capability after the current MTA effort, in some cases, programs we reviewed anticipated additional development or production efforts at the end of the current effort. DOD guidance establishes that middle-tier rapid prototyping programs will be considered complete when the program has:

- transitioned to an existing acquisition program;
- transitioned to a new acquisition program;
- transitioned to a different acquisition pathway;
- residual operational capability sustained in the field;
- transitioned to a rapid fielding MTA effort; or
- been terminated.[61]

Additionally, some of these MTA efforts are developing capabilities that are critical to meeting the department's mission, which may increase the importance and likelihood of the department continuing to pursue the capability after the current MTA effort. For example:

- The Air Force's B-52 Commercial Engine Replacement Program is planning two sequential rapid prototyping efforts. The first rapid prototyping spiral is expected to cost approximately $539 million, but in total the program plans to spend over $1 billion over 6 years to accomplish both rapid prototyping spirals. After the completion of those efforts, if the prototyping is successful, the Air Force then intends to procure new engine pods to modify the remaining B-52H aircraft. The overall re-engining effort is intended to allow the Air Force to sustain the B-52H fleet until at least 2050.
- Similarly, the Army's Extended Range Cannon Artillery program is also planning two separate rapid prototyping efforts, to be followed by either a fielding effort or a traditional acquisition program. The first rapid prototyping program is expected to cost approximately $485 million over 5 years, while the second rapid prototyping program is expected to cost an additional $1 billion. After completion of the two rapid prototyping efforts, the Army plans a separate fielding effort but

[61]For rapid fielding programs, DOD guidance establishes that the program will be considered complete when the minimum fielding plan criteria approved by the decision authority have been met.

has yet to develop a formal cost estimate for fielding. The overall Extended Range Cannon Artillery effort is intended to address existing cannon artillery capability gaps, including increasing firing range.

About Half of the MTA Programs Plan to Mature Critical Technologies during the Current MTA Effort and Subsequently Transition to another MTA Effort or a Different Acquisition Pathway

Technology Maturity

Seven MTA programs we reviewed are starting with immature technologies that they expect to mature by the end of the rapid prototyping effort. 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.[62] Our prior work has found that correctly identifying critical technologies is an important step in ensuring that programs accurately understand the technical risk facing the program.[63]

For the 13 MTA programs we reviewed, we found that most had identified critical technologies.

- Eight of the 13 programs reported that they had identified critical technologies, with the number of critical technologies reported ranging from two to 18.
- Two of the 13 programs reported that they did not have critical technologies. One of these programs is largely focused on software development efforts, and the other is a direct fire capability.

[62]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).

[63]GAO-18-158.

- The remaining three programs reported that they had yet to identify critical technologies but that they planned to identify them during the course of the MTA program.

For the eight MTA programs we reviewed that had identified critical technologies, we found that:

- all but one had at least one critical technology that was considered immature because it had not been fully tested in an operational environment, and
- four of the eight programs had at least one technology that was still being studied in a laboratory environment, and had yet to reach the point of doing any testing in a relevant environment.

All of the eight programs reported that they expected to mature their critical technologies during the current MTA effort. Knowledge-based best practices that apply to acquisition programs generally state that programs should fully demonstrate critical technologies in a realistic environment before starting system development. DOD and commercial technology development cases show that the more mature technology is at the start of the program, the more likely the program will succeed in meeting its objectives.[64]

We have yet to conduct in-depth work on technology maturity specifically for MTA programs. However, knowledge-based best practices suggest that MTA programs that expect to transition to the major capability pathway at system development or production milestones, or transition to a rapid fielding pathway, should plan to have matured critical technologies by the completion of the MTA effort. We have ongoing work on MTA programs in which we expect to address technology readiness requirements and practices specific to this type of rapid prototyping and rapid fielding programs.

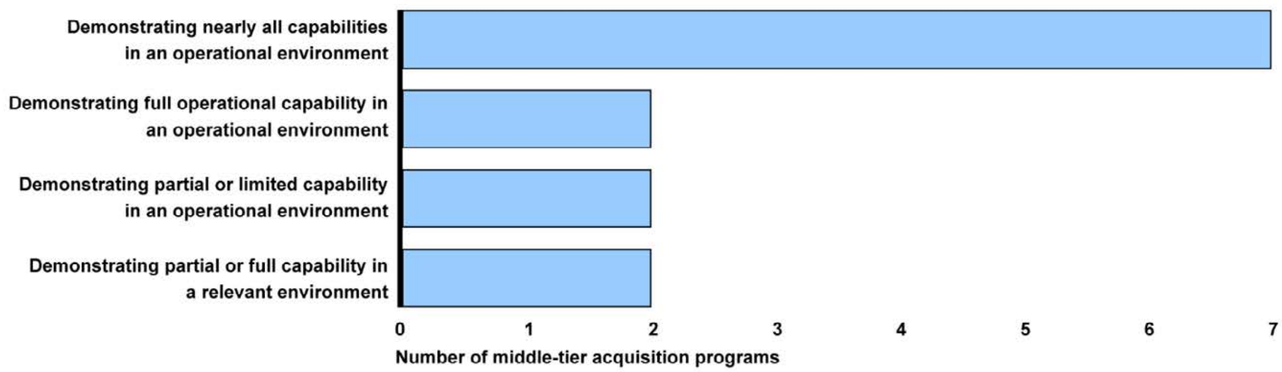
Planned Deliverables and Transition Plans

All MTA programs we reviewed reported that they would field a prototype that provides for residual operational capability within 5 years. Statute establishes that the objective of a rapid prototyping program 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. All 13 MTA programs reported that they expected to achieve this objective by program completion. However, as shown in figure 16, the programs varied with regard to the

[64] GAO-20-48G.

extent that they expected to demonstrate capability in an operational environment.

Figure 16: Planned Deliverables at Completion of the 13 Middle-Tier Acquisition Efforts in GAO's Review



Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

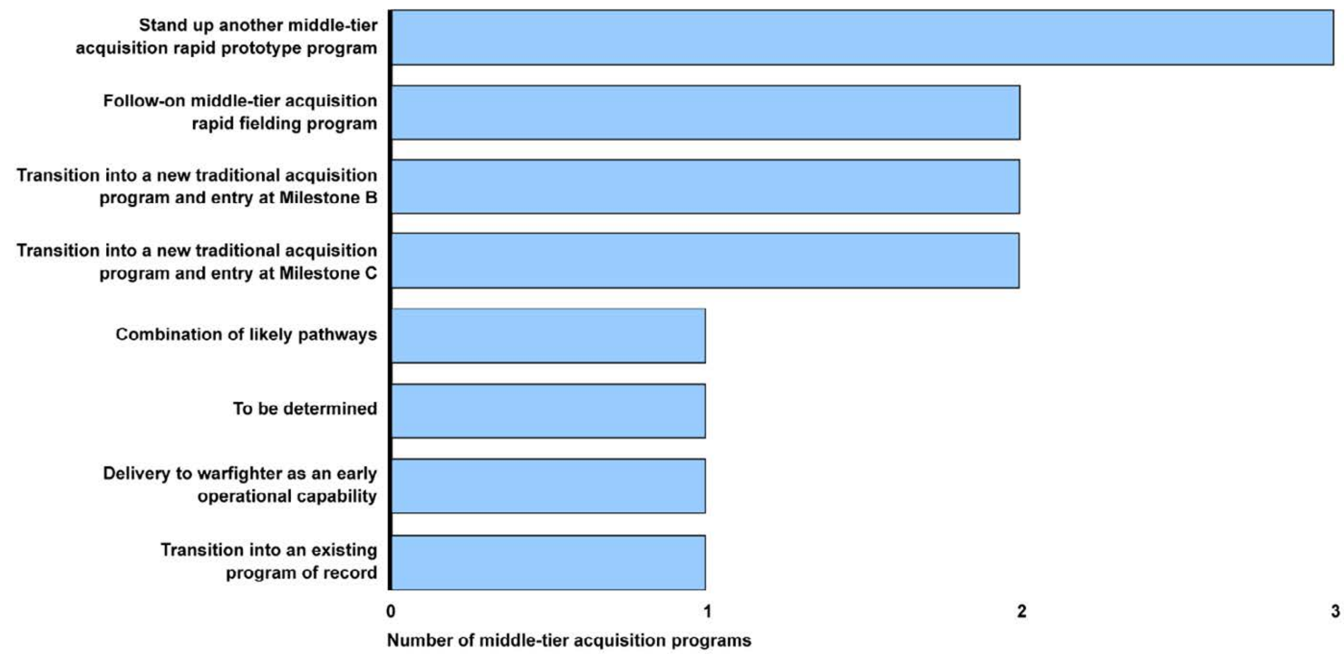
The programs also reported a range of plans regarding the development of a residual operational capability, which, by statute, must be part of the objective for a rapid prototyping program.[65] Some programs plan to provide capability for a limited group of users, while other programs plan to largely produce prototypes for testing. For example:

- The Air Force's Protected Tactical Enterprise Service – Release 1 plans to demonstrate early operational readiness for anti-jam tactical communications on two Navy carrier strike groups in the Pacific by the end of the current MTA effort.
- The Army's Mobile Protected Firepower program expects to develop 24 pre-production prototype vehicles for test and evaluation by the end of the current MTA effort.
- The Air Force's Next Generation Overhead Persistent Infrared-Block 0 program plans to produce five satellites. The MTA effort is intended to carry the main mission payload for three of the satellites through successful thermal vacuum testing and delivery to the spacecraft for integration, but the payload will not actually be integrated during the effort.

[65]DOD's MTA policy defines residual operational capability for rapid prototyping programs as any military utility for an operational user that can be fielded.

Nine out of 13 MTA programs we reviewed indicated they plan to subsequently transition to another MTA program or the major capability acquisition pathway for further development or fielding efforts. As shown in figure 17, programs in our review reported various transition plans, though most programs indicated they planned to subsequently transition to another MTA program or to the major capability acquisition pathway (which can be used for the acquisition of an MDAP) for further development or fielding efforts.

Figure 17: Planned Transition Plans for the 13 Middle-Tier Acquisition Efforts in GAO's Review



Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

Note: For a program under the Department of Defense's major capability acquisition pathway, referred to in this chart as a traditional acquisition program, Milestone B is the event at which a program is approved to begin development, and Milestone C is the event at which a program is approved to begin production.

Practices for Cost and Schedule Reporting by MTA Programs May Pose Challenges for Monitoring and Assessing Performance across the Portfolio

Because this is our first year of reporting on MTA programs, we did not have sufficient data to report on trends in cost or schedule performance for these programs. However, we observed variances in program reporting on cost and schedule performance that are indicative of DOD's challenges with monitoring and assessing performance across the portfolio of MTA programs during program execution. These observations were consistent with our finding in June 2019 that DOD had few reporting mechanisms to measure the performance of MTA programs during execution.[66] In that report, we found that Army and Air Force MTA programs were generally required by interim guidance from those departments to develop metrics to measure performance, but these metrics are not required to be consistent across each military departments' programs. Decisions about specific metrics to be reported were left to the discretion of the decision authority for each program, who is typically the service acquisition executive or a program executive officer. At that time, we recommended that DOD identify in final guidance for MTA programs the metrics that will be used to assess the performance of MTA programs across the military departments, including whether programs are meeting statutory objectives. DOD agreed with this recommendation, stating that the specific approach to metrics was expected to be coordinated with the release of the middle tier policy. DOD subsequently clarified that that the data elements captured in the guidance would be used to help determine the metrics.

While DOD's December 2019 MTA guidance did not identify the metrics that will be used to consistently assess the performance of middle-tier acquisition programs across the military departments, as we recommended in June 2019, DOD reported to Congress in January 2020 on certain oversight metrics it uses.[67] For example, DOD reported on the programs' total estimated funding and the planned number of months between operational demonstration and program completion for rapid prototyping programs.

However, characteristics of MTA program reporting on cost and schedule that we observed in our review of the 13 MTAs may create challenges for the department in using these metrics going forward to assess the performance of the portfolio. With regard to tracking cost performance, DOD's new MTA program guidance required programs to report total

[66] GAO-19-439.

[67] This report was submitted to the congressional defense committees in response to section 837 of the National Defense Authorization Act for Fiscal Year 2020.

MTA program funding on a biannual basis to OUSD(A&S). However, we observed in reviewing program reporting from July/August 2019 and October 2019 that programs did not always report funding consistently with the guidance from OUSD(A&S). For example:

- The Air Force's Hypersonic Conventional Strike Weapon program only reported funding through the fiscal year 2020 in its identification form and budget request, which does not reflect the full estimated cost of the MTA program through completion. Specifically, in October 2019, this program reported a total MTA program cost through fiscal year 2020 of less than half of its independent cost estimate.
- The estimate that the Air Force's Next Generation Overhead Persistent Infrared - Block 0 program reported in August 2019 included more than just the current MTA portion of the broader program. The program's December 2019 submission reduced the total cost reported by about half.
- In contrast, the Army's Extended Range Cannon Artillery program reported costs in both its July 2019 and October 2019 submission that included more than just the current MTA portion of the program, and this program did not adjust the cost estimate. In total, nearly two-thirds of the program's reported costs were not associated with the current MTA effort.

With regard to tracking schedule performance, DOD's new MTA guidance required programs to report biannually to OUSD(A&S) on a small number of schedule events; however, this reporting may not provide sufficient insight into program performance during program execution. Schedule events that programs are required to report include program start date, date of funds first obligated, date of operational demonstration, and program completion date. MTA programs are generally exempt from traditional acquisition and requirements processes, and we found that as a result, schedule events varied widely. While this flexibility may facilitate the streamlined processes that statute prescribes for MTA programs, it may also limit decision makers' insight into the schedule performance of the MTA portfolio.

Planned schedule events for the 13 MTA programs we reviewed varied in terms of the number, type, and when events are planned during the program life cycle. For example, all 13 programs cited operational demonstration, one of the key schedule events tracked by DOD, as a key schedule milestone in our questionnaire. However, this milestone happened or is planned to occur at widely varying times across programs. For example, the Air Force's Unified Platform program held an operational demonstration 5 months after it obligated funds, but plans to continue as an MTA program for an additional 4 and a half years after that event without a subsequent operational demonstration. In contrast, the Army's Integrated Visual Augmentation System program plans four operational demonstrations over the approximately 2-year life of the program, and expects for MTA completion to occur simultaneously with the fourth operational demonstration. Therefore, operational demonstration may not provide OSD sufficient insight to assess performance of these programs towards delivering capabilities to the warfighter, and OSD would need to look at each program individually to understand what measures and milestones that program is using to track progress. As a result, DOD may face challenges aggregating program data to understand the schedule performance of MTA programs across the department.

Congress and DOD have taken steps to revise the criteria for reporting cost and schedule estimates that would affect certain MTA programs. For example, through the NDAA for FY 2020, Congress expanded the requirement for SARs to include a dollar threshold that would require programs with estimated costs above the threshold, including MTA programs, to submit the reports.[68] According to DOD officials, they are working to meet this reporting requirement. They also noted that as part of the effort to address this reporting requirement, they are taking steps to improve the quality of MTA program data in response to congressional direction for increased reporting.

Additionally, DOD clarified in its December 2019 guidance that programs must ensure that MTA program names and budget reporting clearly and discretely indicate the scope of the effort being conducted under the MTA pathway, especially when the MTA program is a subprogram of a larger program or is a program spiral, increment, or block upgrade. However, for programs started before the December 2019 guidance was issued, some of which are approximately 2 years into execution, reporting approaches over the life of the program pose challenges to monitoring performance and identifying potential problems. We have ongoing work to more comprehensively assess DOD's implementation of MTA pathways and we expect to report in more detail about how DOD is measuring performance for its portfolio of MTA programs in that work.

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[68]See section 830 of the National Defense Authorization Act for Fiscal Year 2020. Prior to enactment of the FY2020 NDAA, the statute that establishes selected acquisition report requirements—10 U.S.C. § 2432—addressed only MDAPs.

DOD Has Taken Steps to Help Ensure MTA Programs Establish Sound Business Cases

In December 2019, DOD issued guidance requiring MTA programs to have certain elements of a business case, consistent with a recommendation we made in June 2019.[69] In our June 2019 report, we found that DOD had yet to determine what types of business case information should be submitted to decision makers to help ensure well-informed decisions about program initiation and that program performance is measured consistently. We recommended that DOD identify in final guidance the types of business case elements potential MTA programs should develop and decision makers should consider at program initiation to assess the soundness of programs' business cases, including whether programs are well positioned to meet the statute-based objectives. DOD agreed with the recommendation.

While most MTA programs we reviewed were lacking key business case documentation at the time of program initiation, we found that generally, programs had made significant progress in receiving approval of these business case elements by the time of our review. Of the 13 MTA programs we reviewed, all of which started before the issuance of DOD's new guidance, two had all five business case elements we assessed approved at program initiation, while three had none of the business case elements approved. Of the five business case elements we assessed, programs were least likely to have completed a cost estimate based on an independent assessment or a formal schedule risk assessment. However, by the time of our review in January 2020, programs were much more likely to have developed this critical documentation for the current MTA effort. For example, all the MTA programs had an approved acquisition strategy and an approved requirements document. However, several programs still lacked technology or schedule risk assessments, or cost estimates informed by independent assessments. See table 19 for additional detail of business case elements developed by MTA programs we reviewed.

[69] DOD Instruction 5000.80 and GAO-19-439.

Table 19: Summary of Business Case Elements Developed by Selected Middle-Tier Acquisition Programs at Program Initiation and as of January 2020

Program name	Approved requirements document		Approved acquisition strategy		Formal technology risk assessment		Cost estimate based on independent assessment		Formal schedule risk assessment	
	Initiation	Jan. 2020	Initiation	Jan. 2020	Initiation	Jan. 2020	Initiation	Jan. 2020	Initiation	Jan. 2020
Air Launched Rapid Response Weapon	✓	✓	✓	✓	⊗	✓	✓	✓	⊗	✓
B-52 Commercial Engine Replacement Program-Spiral 1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Extended Range Cannon Artillery - Increment 1C	✓	✓	⊗	✓	⊗	✓	⊗	⊗	⊗	✓
F-22 Capability Pipeline	✓	✓	✓	✓	⊗	✓	⊗	✓	⊗	✓
Hypersonic Conventional Strike Weapon	⊗	✓	⊗	✓	⊗	✓	⊗	✓	⊗	✓
Integrated Visual Augmentation System	✓	✓	⊗	✓	✓	✓	⊗	⊗	⊗	⊗
Lower Tier Air and Missile Defense Sensor	⊗	✓	⊗	✓	⊗	⊗	⊗	⊗	⊗	⊗
Mobile Protected Firepower	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Next Generation Overhead Persistent Infrared-Block 0	✓	✓	✓	✓	✓	✓	⊗	✓	⊗	✓
Optionally Manned Fighting Vehicle-Increment 1	⊗	✓	⊗	✓	⊗	⊗	⊗	✓	⊗	✓
Protected Tactical Enterprise Service-Release 1	✓	✓	✓	✓	⊗	⊗	⊗	✓	⊗	✓
Protected Tactical SATCOM	⊗	✓	⊗	✓	✓	✓	⊗	✓	⊗	⊗
Unified Platform	⊗	✓	✓	✓	⊗	⊗	⊗	✓	⊗	⊗

Legend:

✓= program had business case element

⊗ = program did not have business case element

Source: GAO analysis of Department of Defense data. | GAO-20-439

Most Selected Major IT Programs Experienced Cost Decreases and Schedule Delays and Reported a Variety of Software and Cybersecurity Experiences

As of December 2019, 11 of the 15 selected major IT programs had decreases in their planned life-cycle cost estimates, and ten had delays in their planned schedule estimates when comparing the first acquisition program baseline to the most recent cost and schedule estimates.[70] The changes in the cost estimates ranged from a decrease of $229 million (-33.8 percent) to an increase of $315.1 million (150.6 percent). Schedule delays ranged from a delay of 1 month to a delay of 5 years. Ten of 14 selected programs had conducted testing on at least some technical performance targets, and officials from eight of those programs reported meeting the performance targets they had tested.[71] Major IT programs reported using a range of software development and cybersecurity testing approaches, and many of these programs reported that they faced challenges related to software and cybersecurity.

Although Most Selected Major IT Programs Had Cost Estimate Decreases, Many Experienced Schedule Delays, and Most Programs That Had Tested Performance Targets Reported Meeting Them

Eleven of the 15 selected major IT programs had decreases in their cost estimates. These decreases ranged from $200,000 for the Air Force's Maintenance Repair and Overhaul Initiative program (.03 percent decrease) to $229 million (33.8 percent decrease) for the Army Contract Writing System. Two of the 11 programs with cost decreases experienced cost decreases greater than or almost equal to 20 percent.[72] Program officials cited a number of reasons, including lower-than-expected costs, program management efficiencies, and contract cost revisions, contributing to the cost reductions. The remaining four of the 15 programs experienced cost increases, two of them over 20 percent. Officials for these programs also cited a number of reasons for their cost increases, including development challenges.

While five of the 15 major IT programs experienced no delays to their planned schedule estimates, ten exceeded their planned schedule estimates, with delays ranging from 1 month for the Marine Corps' CAC2S Inc 1 to 5 years for the Air Force's Defense Enterprise Accounting and Management System-Increment 1. Reasons program officials cited

[70]The information presented in this section is a summary of work presented more comprehensively in a forthcoming GAO report, which deals specifically with DOD's major IT programs. This analysis includes sustainment costs to be consistent with other analyses in that forthcoming GAO report. We do not include sustainment costs in other analyses in this report because they are not considered to be acquisition-specific costs.

[71]Testing data for one program were classified.

[72]Teleport Generation 3 experienced a cost decrease of -$116.6 million (-19.6%) and Army Contract Writing System had a cost decrease of -$229 million (-33.8%).

for the delays included longer-than-expected maintenance periods and cybersecurity and performance issues.

As of December 2019, ten of 14 selected major IT programs reported conducting testing on at least some of their current technical performance targets. Testing data for one program were classified. Officials from eight of the ten programs reported having met all of their targets. Program officials cited a variety of reasons for meeting their performance targets, including the use of proven products, iterative processes and early planning, and efficient use of test and system integration staff. The remaining four programs had yet to conduct testing activities.

Major IT Programs Reported Using a Variety of Software Development Approaches and Cybersecurity Practices

Officials from the 15 major IT programs we reviewed reported a range of approaches to software development and cybersecurity. For example:

- Major business IT programs reported using commercial off-the-shelf software, which is consistent with DOD guidance. According to that guidance, DOD business system acquisitions should minimize the need for customization of commercial products to the maximum extent possible.[73] Specifically, programs should use COTS and government off-the-shelf solutions, to the extent practicable.[74] The use of COTS by business system programs is intended to reduce software development time, allow for faster delivery, and lower life-cycle costs due to increased product availability and use of modern technologies. Each of the eight major business IT programs reported using commercial software with DOD-specific customizations. By leveraging commercial software, these programs have positioned themselves to limit some of the risks inherent in other approaches and leverage the benefits of using commercial software.
- Nearly all programs reported using iterative software development approaches. Fourteen of the 15 programs included in our assessment reported using at least one of these types of continuous, iterative software development approaches. Of these 14 programs: seven reported using Agile development; seven reported using incremental

[73]DOD Instruction 5000.75. DOD Instruction 5000.02, *Operation of the Defense Acquisition System*, does not specify a specific software type for major non-business IT programs.

[74]Government off-the-shelf software is developed for the government to meet a specific government purpose. It is not commercially available to the general public. COTS software is sold in substantial quantities in the commercial marketplace and is purchased without modification, or with minimal modification, to its original form.

development; three reported using DevOps; and two reported using DevSecOps.[75] Three programs reported using a waterfall approach. One program reported using only a waterfall approach.

- All programs reported having approved cybersecurity strategies. DOD Instruction 8500.01 requires that DOD major nonbusiness and business IT programs have approved cybersecurity strategies.[76] If programs do not undertake cybersecurity risk management early in the system development, they are at risk of increased cost and schedule delays as well as negative impacts to the performance of the system.
- Most programs reported conducting operational cybersecurity testing, but less than half reported conducting developmental cybersecurity testing.[77] According to DOD's Cybersecurity Testing and Evaluation Guidebook, not conducting developmental cybersecurity testing puts programs at an increased risk of cost and schedule growth and poor program performance. The 15 major IT programs included in our assessment reported conducting operational cooperative vulnerability and penetration assessments and adversarial assessments more than developmental cooperative vulnerability identification and adversarial assessments. Specifically, six of the 15 programs reported conducting a cooperative vulnerability and penetration assessment or an adversarial assessment during developmental testing. In contrast, 11 of the 15 programs reported conducting a cooperative vulnerability and penetration test or adversarial assessment during operational testing.

Programs we reviewed reported a variety of challenges associated with their software development efforts, including risks associated with government and contractor software development staff. For example, 12

[75]The software development approaches are not mutually exclusive, and some programs reported using multiple software development approaches. DevOps entails running multiple Agile projects simultaneously to develop the next increment of an application. 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.

[76]DOD, Department of Defense Instruction 8500.01, *Cybersecurity*, (Washington, D.C.: Mar. 14, 2014).

[77]According to the Cybersecurity Testing and Evaluation Guidebook, operational cybersecurity testing provides information that helps to resolve operational cybersecurity issues, identify vulnerabilities in a mission context, and describe operational effects of discovered vulnerabilities. The guidebook further states that developmental testing identifies cybersecurity issues and vulnerabilities prior to early in system life cycle in order to facilitate the remediation and reduction of impact on cost schedule and performance.

of the 15 programs included in our assessment reported that they faced challenges with government and contractor software development staff. Specifically, nine of the 15 programs reported that they found it difficult to find staff with the requisite expertise. Seven programs reported that their program found it difficult to hire enough staff to complete development; seven also found it difficult to hire staff in time to perform planned work. Six programs reported that software engineering staff plans not being realized as expected was a challenge.

DOD Continues to Execute Recent Reforms That Fundamentally Alter Oversight and Execution of Many of Its Most Costly Programs

DOD is in the process of implementing significant organizational and legislative changes expected to affect the execution and oversight of acquisition programs. We asked officials from OUSD(R&E), OUSD(A&S), and the military departments their perspective on which changes in the last year would have a significant effect on program oversight and execution. The DOD officials generally agreed the section of the NDAA for FY 2019 that was most likely to have an effect on acquisition program execution and oversight was section 831. This section revised authority relating to MDAP program cost and fielding targets that were originally introduced through section 807 of the NDAA for FY 2017. Section 831 transfers the authority for establishing MDAP cost and fielding targets from the Secretary of Defense to the designated milestone decision authority, which, generally, resides within the military departments. DOD officials also noted that a few additional changes in the NDAA for FY 2019 may have an effect on acquisition execution and oversight. For example, officials from OUSD(A&S) stated that FY19 NDAA section 816 may help streamline the contracting process. Section 816 altered one of the standards for the award of single source task or delivery order contracts. According to officials, this change may allow DOD to use single source task or delivery order contracts in a more flexible manner and help streamline the contracting process.

However, these officials told us that reforms from the NDAAs for FYs 2016 and 2017 generally continue to have the most significant effect on acquisition program execution of any recent legislative and organizational changes. In June 2019, we reported that DOD had made progress in implementing several of these recent reforms related to the oversight of MDAPs.[78] Since our assessment, Congress and DOD have continued to take actions related to these reforms. For example, in December 2019,

[78]GAO-19-439 addresses the extent to which MDAPs were implementing acquisition-related reforms required by the NDAAs for FYs 2016 and 2017.

the Deputy Secretary of Defense issued a memorandum that clarified the roles and responsibilities of OSD and the military departments for acquisition oversight, which is consistent with a recommendation we made in our June 2019 report. Table 20 details selected acquisition reforms introduced in the NDAAs for FY 2016 and 2017, and selected congressional and DOD actions related to the reforms since our June 2019 report.

Table 20: Summary of Selected Congressional and Department of Defense (DOD) Actions since June 2019 on Selected Reforms that Affect Acquisition Program Oversight

Action related to reform and National Defense Authorization Act (NDAA) fiscal year (FY) and section	Congressional actions since June 2019	Department of Defense actions since June 2019
Changes to oversight processes for major defense acquisition programs		
Designating military departments to be milestone decision authority (section 825 of the NDAA for FY 2016)	None	DOD has continued to shift decision-making authority for major programs to the military departments. The service acquisition executive has been designated as the milestone decision authority for both major defense acquisition programs started since June 2019.
Performing independent technical risk assessments (section 807(a) of the NDAA for FY 2017)	In section 902 of the NDAA for FY 2020, Congress established that the Secretary of Defense is responsible for conducting or approving independent technical risk assessments for Major Defense Acquisition Programs and directed the Secretary of Defense to issue guidance and a framework for these assessments.	As of March 2020, officials from the Office of the Under Secretary of Defense for Research and Engineering told us they are in the process of developing the documents required by section 902. Additionally, in December 2019, the Deputy Secretary of Defense issued a memorandum that established roles and responsibilities for the Office of the Under Secretary of Defense for Research and Engineering and the military departments for conducting independent technical risk assessments.
Establishing cost, fielding, and performance goals (section 807(a) and section 925(b) of the NDAA for FY 2017)	None	Since GAO's June 2019 report, the department has begun to set program goals using DOD's policy for the process, which was issued in November 2018.[a] Officials from the Office of the Under Secretary of Defense for Acquisition and Sustainment told us that the military departments are responsible for tracking which programs have had goals established to date.

Action related to reform and National Defense Authorization Act (NDAA) fiscal year (FY) and section	Congressional actions since June 2019	Department of Defense actions since June 2019
Reorganizing acquisition oversight functions in the Office of the Secretary of Defense		
Reorganizing the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (sections 901(a) and (b) of the NDAA for FY 2017)	In section 902 of the NDAA for FY 2020, Congress made numerous statutory changes to allocate the responsibilities of the former Office of the Under Secretary of Defense for Acquisition, Technology and Logistics and clarify roles and responsibilities of the Under Secretaries of Defense for Research and Engineering and Acquisition and Sustainment.	In December 2019, the Deputy Secretary of Defense issued a memorandum that further clarified some roles and responsibilities of the Under Secretaries of Defense for Research and Engineering and Acquisition and Sustainment. However, as of March 1, 2020, DOD had not completed the charters that would fully clarify the roles and responsibilities after the reorganization.

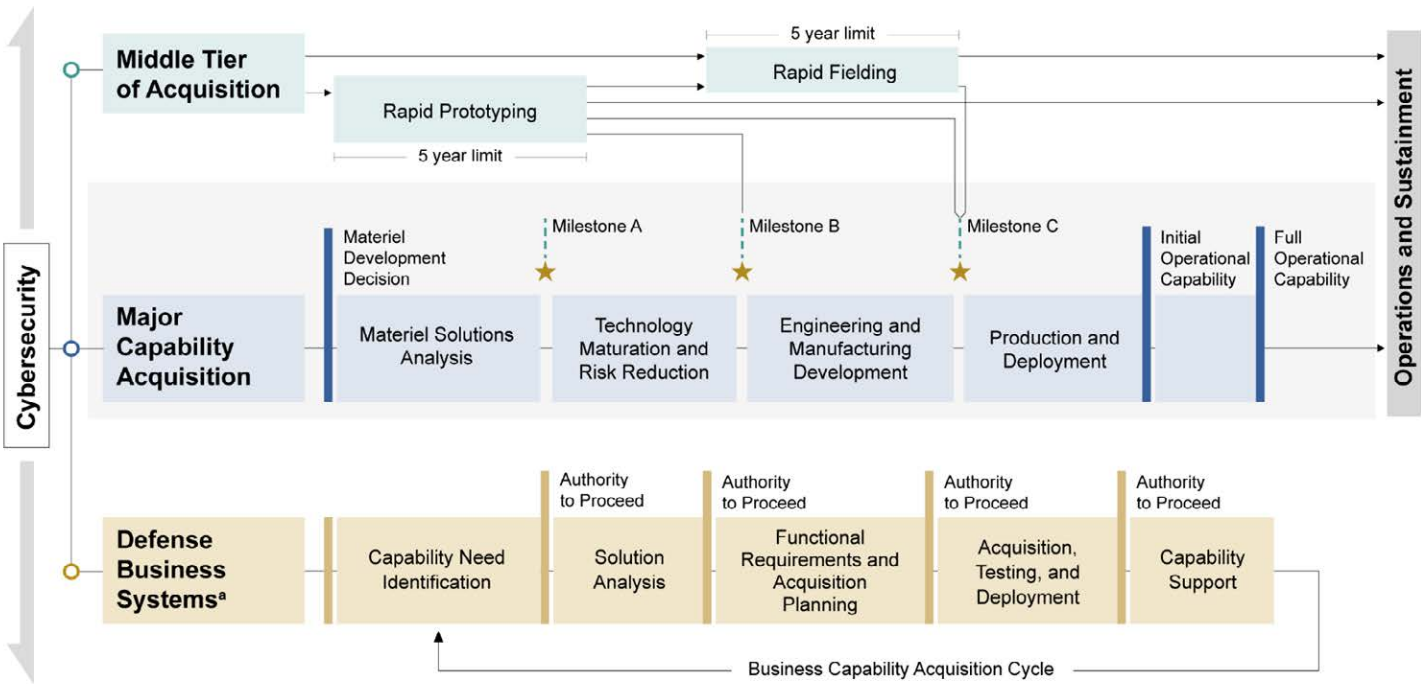
Source: GAO analysis of the NDAA for FY 2016, Pub. L. No. 114-92 (2015) (as amended), NDAA for FY 2017, Pub. L. No. 114-328 (2016) (as amended), and NDAA for FY 2020, Pub. L. No. 116-92 (2019), and DOD documentation. | GAO-20-439

Note: The congressional actions summarized in this table were drawn from the NDAA for FY 2020.

[a]In June 2019, GAO issued a report summarizing DOD's progress in implementing selected reforms to acquisition oversight, including establishing cost, fielding, and performance goals. See GAO, *DOD Acquisition Reform: Leadership Attention Needed to Effectively Implement Changes to Acquisition Oversight*, GAO-19-439 (Washington, D.C.: June 5, 2019).

In addition to implementing legislative changes from the NDAAs for the last several fiscal years, DOD has also been working to revise its foundational acquisition policy documents over the past year. These revisions are expected to broadly affect oversight and execution for acquisitions within the department, including MDAPs, MTA programs, and major IT programs. In January 2020, OUSD(A&S) issued the latest version of DOD Instruction 5000.02, *Operation of the Adaptive Acquisition Framework*. That document describes, at a high level, responsibilities for program managers and principal acquisition officials and key characteristics of acquisition pathways, including the newer middle tier of acquisition pathways. It also states that programs managers will recognize that cybersecurity is a critical aspect of program planning and must be addressed early and continuously during the program life cycle. Figure 18 provides additional detail on three of the six pathways in DOD's new guidance, including those most relevant to the weapon and IT programs we reviewed, and how those pathways ultimately transition into operations and sustainment.

Figure 18: Selected Acquisition Pathways from the Department of Defense (DOD) Adaptive Acquisition Framework



Source: GAO Analysis of DOD Instruction 5000.02. I GAO-20-439

Note: This figure reflects three selected pathways that are relevant to the programs GAO reviewed. DOD's Adaptive Acquisition Framework includes a total of six pathways.

[a]The major information technology (IT) systems GAO reviewed included both major business IT systems and major nonbusiness IT systems.

The instruction is a capstone document that lays the groundwork for operation of the adaptive acquisition framework. The instruction notes that DOD is still generating associated policy documents that provide greater fidelity for aspects of the adaptive acquisition framework and more detailed instructions for the specific pathways available to acquisition programs. For the three types of programs we included in this review, revised guidance has either yet to be issued or has been updated within the last few months.

- MDAPs: DOD issued the updated DOD Instruction 5000.02 in January 2020. However, MDAPs are currently operating under an updated version of the prior, January 7, 2015 version of this instruction, which was changed most recently in January 2020, and which has been renumbered DOD Instruction 5000.02T. DOD is redeveloping multiple sections of the MDAP guidance and will replace outdated sections with updated sections in subsequent versions of DOD Instruction 5000.02.

- MTA programs: DOD issued DOD Instruction 5000.08 in December 2019. The instruction clarifies the decision authority for middle-tier acquisitions, which is retained by the military departments. The guidance also clarifies roles for OUSD(R&E) and OUSD(A&S), MTA policy, approval processes, and other activities.
- Major IT programs: DOD has also been working to revise its foundational acquisition policy documents and guidance for major IT programs, such as for defense business systems. DOD issued an update to DOD Instruction 5000.75 in January 2020. The instruction designates OUSD(A&S) as the Defense Acquisition Executive with responsibility for establishing policy for business systems and delegating milestone decision authority. The guidance also clarifies roles for OUSD(A&S) and the military departments for requirements validation based on business system category level.

OUSD(A&S) also issued interim policy for the software acquisition pathway in January 2020, which establishes this pathway as preferred for the acquisition and development of software-intensive systems.[79]

Several officials we spoke with noted that generally DOD faces challenges keeping up with the pace of legislative changes to the acquisition system and that it has taken significant time to implement them all, including revising associated policies. DOD officials estimated there have been 400 to 500 acquisition-related legislative changes since 2015. These officials said unsettled policy and organizational changes have led to uncertainty in acquisition execution and oversight. For instance, DOD officials told us that, as of March 2020, they have yet to finish the charters for OUSD(A&S) and OUSD(R&E). We previously reported that finalizing the charters was important to determining how acquisition oversight roles within OSD—which had been executed by a single office for decades—will be divided and how new offices will be structured to effectively carry out their work.[80]

[79]Department of Defense, Under Secretary of Defense for Acquisition and Sustainment Memorandum: *Software Acquisition Pathway Interim Policy and Procedures* (Jan. 3, 2020).

[80]GAO-19-439.

Assessments of Individual Programs

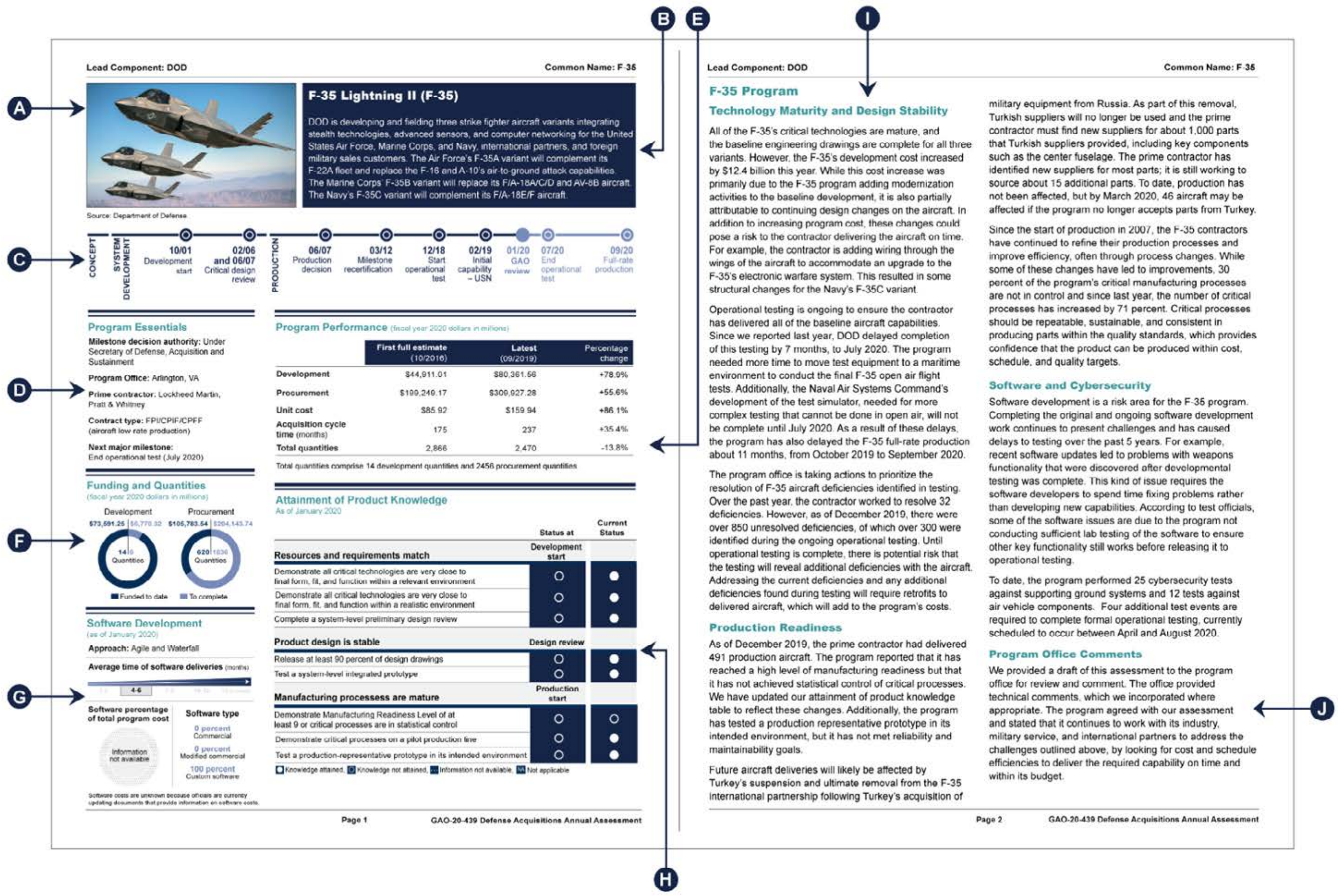
This section contains (1) 63 assessments of individual weapon programs and (2) four summary analyses—each segmented by military department. Each assessment presents data on the extent to which programs are following a knowledge-based acquisition approach to product development.[81] Each military department's summary analysis page presents aggregated information about the selected programs' acquisition phases, current estimated funding needs, knowledge attained, cost and schedule performance, milestone decision authorities when applicable, and software characteristics.

For 37 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 37 MDAPs for which we developed two-page assessments are in development or early production.[82] See figure 19 for an illustration of the layout of each two-page assessment.

[81]The assessments also contain basic information about the program, including the prime contractor(s) and contract type(s). We abbreviated the following contract types in the individual assessments: cost-plus-award-fee (CPAF), cost-plus-fixed-fee (CPFF), cost-plus-incentive-fee (CPIF), cost-sharing (CS), firm-fixed-price (FFP), fixed-price incentive (FPI), and indefinite-delivery, indefinite quantity (IDIQ).

[82]We prepared a two-page assessment for one future MDAP—the Navy's FFG(X) Guided Missile Frigate—because the Navy scheduled it to begin development in advance of our planned issuance date. We reported cost and quantity amounts that align with the program's Future Years Defense Program estimates because the current cost estimate provided by the program does not include a full funding profile beyond fiscal year 2024.

Figure 19: Illustration of Program Two-Page MDAP Assessment

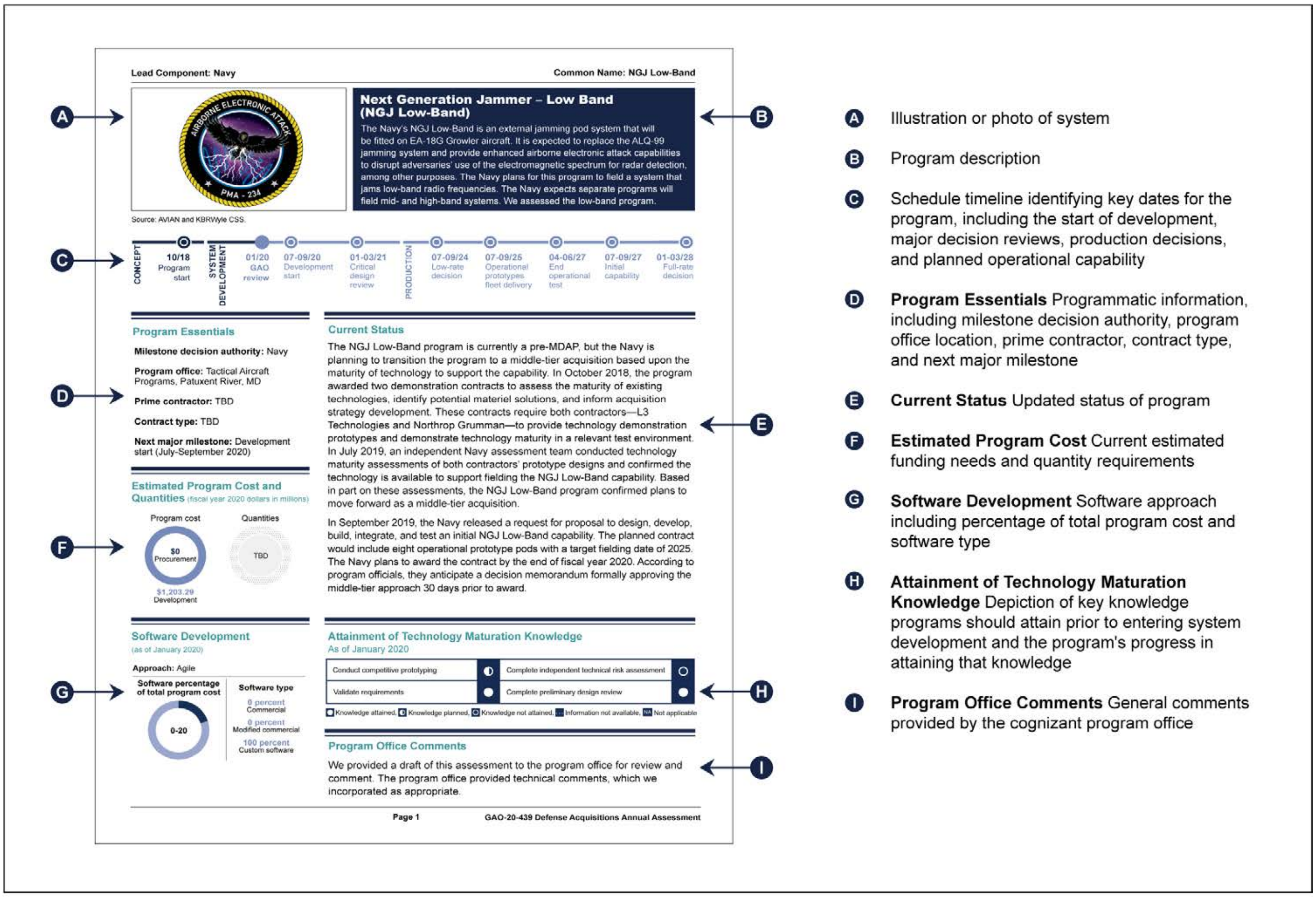


- **A** Illustration or photo of system
- **B** Program description
- **C** Schedule timeline identifying key dates for the program, including the start of development, major decision reviews, production decisions, and planned operational capability
- **D** **Program Essentials** Programmatic information, including milestone decision authority, program office location, prime contractor, contract type, and next major milestone
- **E** **Program Performance** Cost, quantity and schedule baseline estimates and the latest estimate provided
- **F** **Funding and Quantities** Development and production funding and quantity requirements to date and from fiscal year 2020 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--20-439

In addition, we produced one-page assessments on the current status of 12 programs, which include seven future MDAPs; and five MDAPs that were well into production, but planned to introduce new increments of capability. See figure 20 for an illustration of the layout of each one-page assessment.

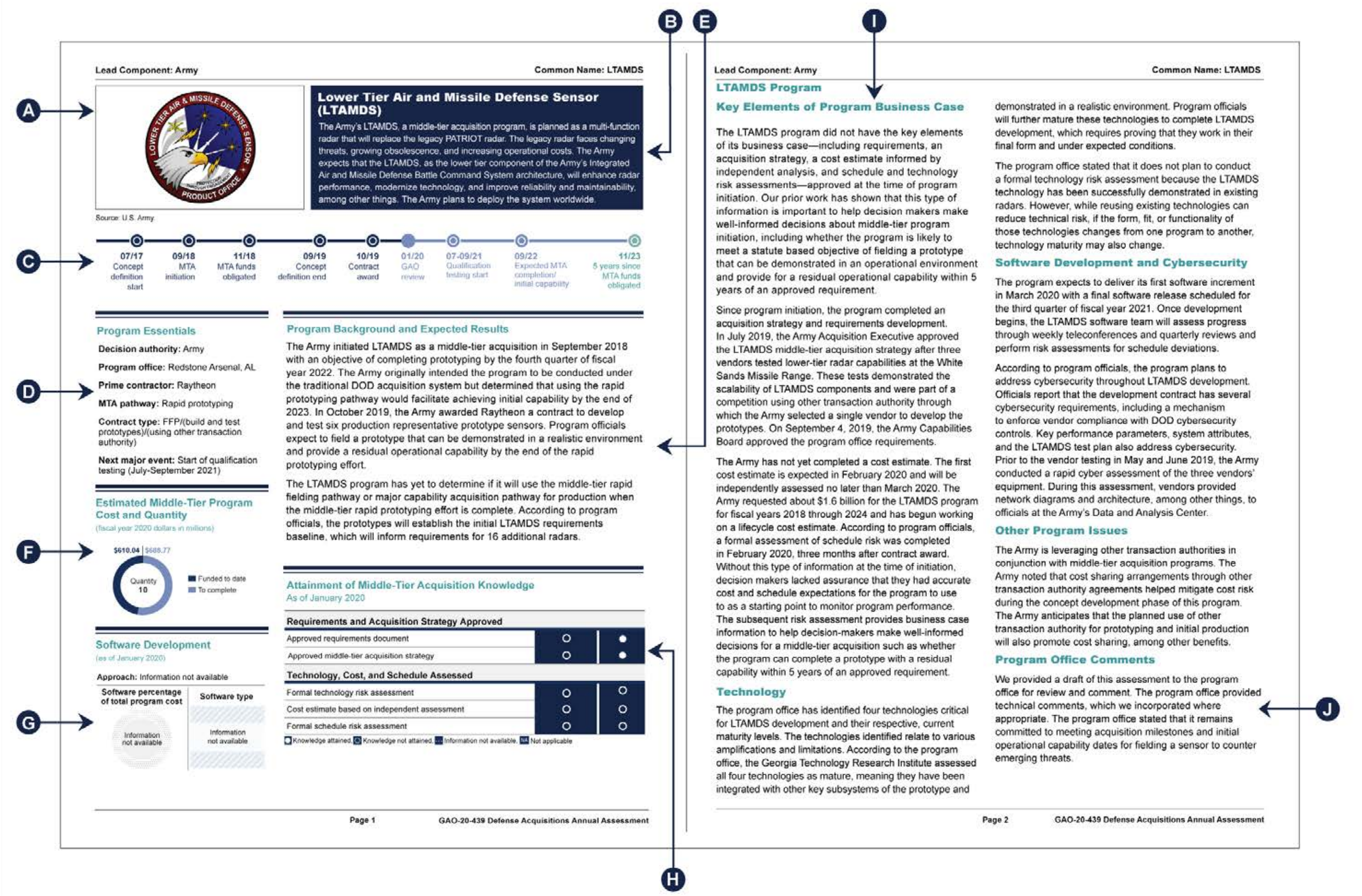
Figure 20: Illustration of Program One-Page Future or Current MDAP Assessment



Source: GAO. | GAO-20-439

For 13 programs using MTA pathways, we produced two-page assessments discussing program background and expected results as well as attainment of key elements of a business case, technology maturity, 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 21 for an illustration of the layout of each two-page middle-tier acquisition assessment.

Figure 21: Illustration of Program Two-Page MTA Assessment



- **A** Illustration or photo of system
- **B** Program description
- **C** Schedule timeline identifying key dates for the program including program initiation, funds obligation, contract award, expected MTA completion, and significant relevant programmatic decision points
- **D** **Program Essentials** Programmatic information including decision authority, program office location, prime contractor, MTA pathway, contract type, and next major event
- **E** **Program Background and Expected Results**
- **F** **Estimated Middle-Tier Program Cost and Quantity** Estimated cost and quantity requirements as of January 2020
- **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 Middle-Tier Acquisition Knowledge** Depiction of key knowledge programs should attain and the program's progress in attaining that knowledge
- **I** Assessment of program's elements of a business case that should be completed by program initiation, technology, software and cybersecurity, and other program issues
- **J** **Program Office Comments** General comments provided by the cognizant program office

Source: GAO. | GAO--20-439

For 58 of our 63 assessments, we used scorecards to depict the extent of knowledge that a program has gained.[83] These scorecards display key knowledge-based acquisition 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. In a current MDAP, knowledge deficits signal that the program is proceeding without sufficient knowledge about its technologies, design, or manufacturing processes, and faces unresolved risks that could lead to cost growth and schedule delays. With regard to MTA programs, our prior work has also found that establishing a sound business case for individual programs depends on disciplined requirements and funding processes, and calls for a realistic assessment of risks and costs.[84] For a middle-tier acquisition program, business case information would help decision makers make well-informed decisions, to include assessing whether the program is likely to meet the statute-based objective of fielding a prototype that can be demonstrated in an operational environment with a residual operational capability within 5 years of an approved requirement (in the case of a rapid prototyping program) or begin production within 6 months and complete fielding within 5 years of an approved requirement (in the case of a rapid fielding program).

For each scorecard, we used a closed circle to denote a knowledge-based practice the program implemented. We used an open circle to denote a knowledge-based practice the program did not, or has not yet implemented. For future MDAPs only, we used a partially closed circle to denote a knowledge-based practice that the program reported it plans to implement. If the program did not provide us with enough information to make a determination, we showed this with a dashed line. We also marked as “NA” any scorecard field that corresponded with a knowledge-based practice that was not applicable to the program. A knowledge-based practice may be marked as “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.

[83] We did not use scorecards in our five 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.

[84] GAO-19-439.

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 key points knowledge-based practices for shipbuilding programs than we did for other MDAPs. These shipbuilding key points and practices were informed by our prior work.[85] Appendix II provides additional detail on our scorecard methodology. Figures 22, 23, and 24 provide examples of the knowledge scorecards we used in our assessments.

Figure 22: Examples of Knowledge Scorecards on Two-Page MDAP Assessments

Program in production

Attainment of Product Knowledge
As of January 2020

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

Shipbuilding program

Attainment of Product Knowledge
As of January 2020

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

Source: GAO analysis of Department of Defense data. | GAO-20-439

[85] GAO-09-322.

Figure 23: Example of Knowledge Scorecard on One-Page Future MDAP Assessments

Attainment of Technology Maturation Knowledge
As of January 2020

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 Department of Defense data. | GAO-20-439

Figure 24: Example of Knowledge Scorecard on Two-Page MTA Program Assessments

Attainment of Middle-Tier Acquisition Knowledge
As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	●	●
Approved middle-tier acquisition strategy	○	●
Technology, Cost, and Schedule Assessed		
Formal technology risk assessment	…	○
Cost estimate based on independent assessment	●	NA
Formal schedule risk assessment	○	○

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

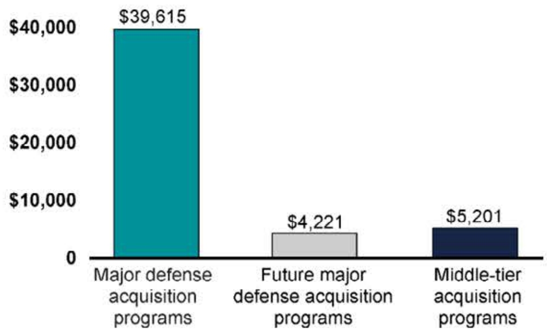
Source: GAO analysis of Department of Defense data. | GAO-20-439

ARMY
PROGRAM ASSESSMENTS

GAO Assessed 14 Army Weapon Acquisition Programs

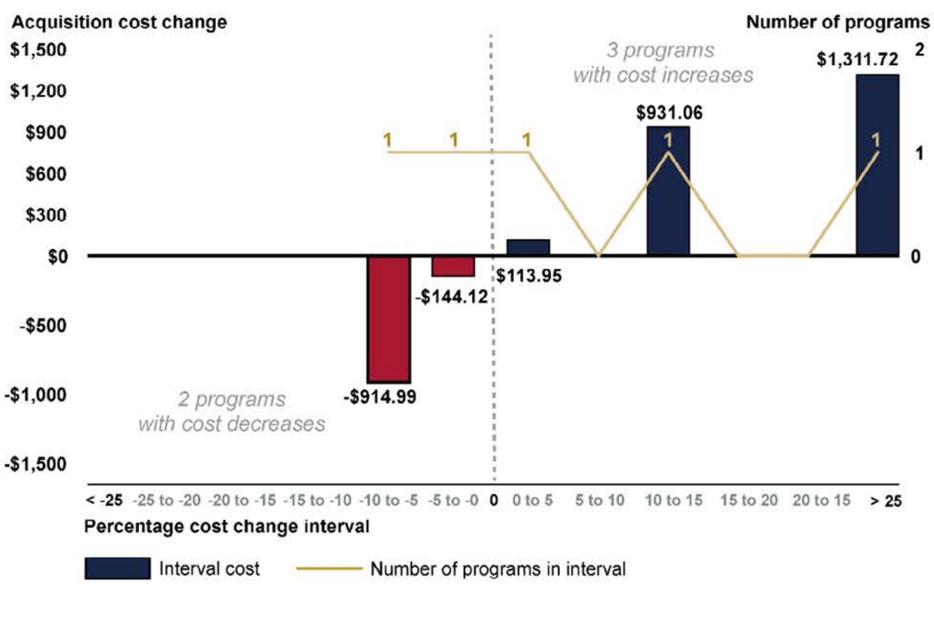
The Army Programs GAO Reviewed Have a Combined Estimated Total Acquisition Cost of $49 Billion

(Fiscal Year 2020 dollars in millions)

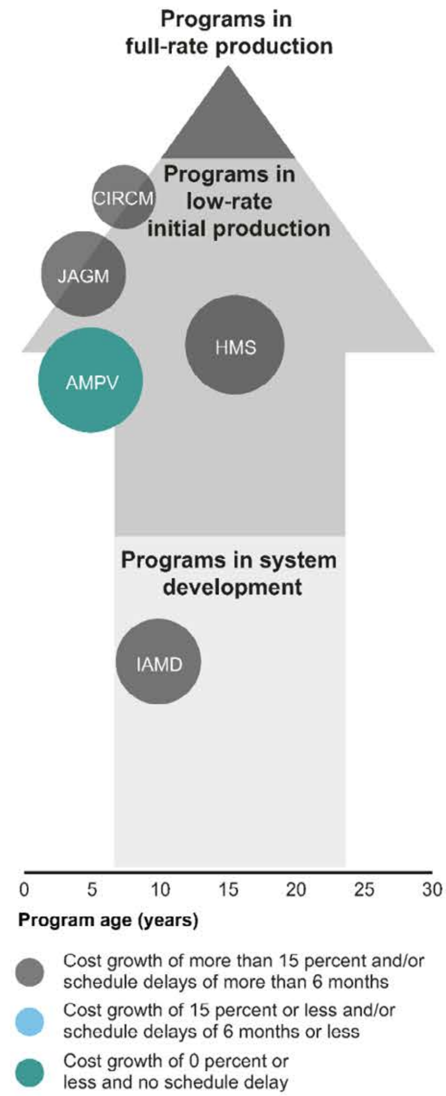


Most Army Major Defense Acquisition Programs GAO Assessed Had Cost Increases Since Last Year

(Fiscal Year 2020 dollars in millions)



Most Army Major Defense Acquisition Programs GAO Assessed Have Had Cost Growth, Schedule Delays, or Both since First Full Estimate

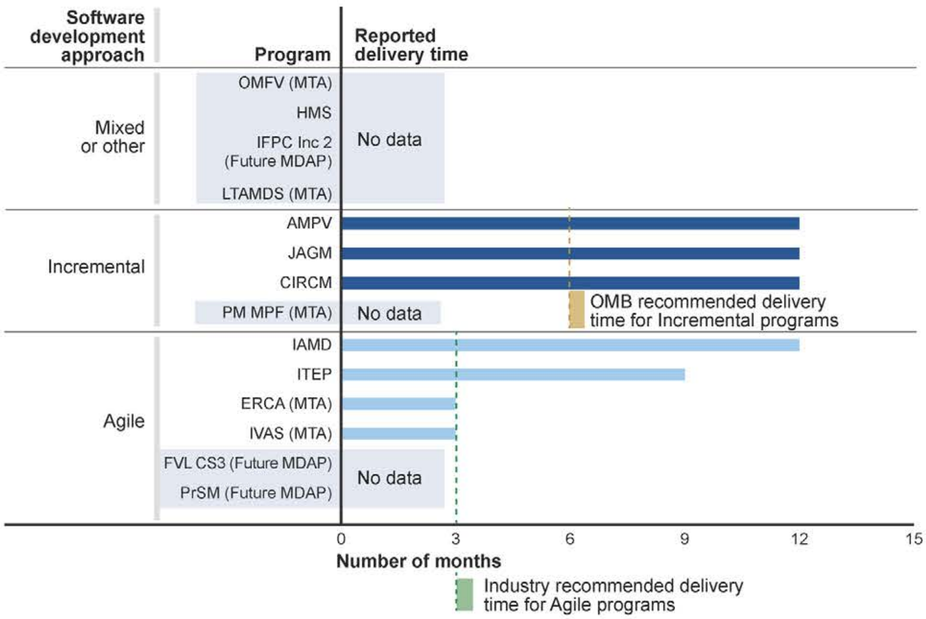


Note: Bubble size is based on each program's currently estimated total acquisition cost.

- Figures with titles that do not reference major defense acquisition programs or middle-tier acquisition programs provide information for the entire group of Army major defense acquisition programs, future major defense acquisition programs, and middle-tier acquisition programs that GAO assessed. Figures with titles that do reference major defense acquisition programs or middle-tier acquisition programs provide information for only the Army major defense acquisition programs or middle-tier acquisition programs that GAO assessed.
- GAO excluded the Improved Turbine Engine Program from the estimated total acquisition cost, acquisition cost change, and cost growth and schedule delay analyses because the program had not yet reported cost and schedule data as of the issuance of the December 2018 SARs.
- Cost and schedule analyses are primarily based on estimates from December 2018 selected acquisition reports. This information may differ from information reported in the Program Performance table and Funding and Quantities figures in individual assessments, which are based on more recent program estimates in some cases. Please see appendix II for details.

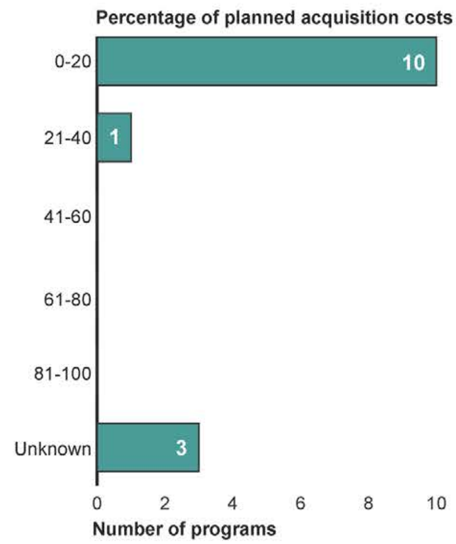
ARMY PROGRAM ASSESSMENTS

Army Programs that GAO Assessed 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. The Office of Management and Budget (OMB) guidance recommends deliveries every 6 months for Incremental programs. Programs reported deliveries to GAO in 0-3 month increments.
- The ERCA and IVAS programs reported alternative timeframes to deliver working software to users, including deliveries within a cycle or across cycles, and for evaluation events, respectively.

Most Army Programs GAO Assessed Reported that Less than 20 Percent of Planned Acquisition Costs are Specifically for Software



Army Major Defense Acquisition Programs GAO Assessed Generally Did Not Attain Knowledge at Key Points, but Some Attained Knowledge Later

- Note: For each knowledge point, GAO assessed the major defense acquisition programs that had reached that point as of January 2020. GAO excluded programs for which it determined that the practice was not applicable.

At Occurrence of Knowledge Point

Knowledge Point 1
0 of 6
programs attained knowledge

Knowledge Point 2
1 of 5
programs attained knowledge

Knowledge Point 3
0 of 4
programs attained knowledge

As of January 2020

Knowledge Point 1
3 of 5
programs attained knowledge

Knowledge Point 2
4 of 4
programs attained knowledge

Knowledge Point 3
1 of 4
programs attained knowledge

Army Middle-Tier Acquisition Programs GAO Assessed Generally Completed Business Case Activities and Assessments, but Some Did Not by Program Initiation

At initiation

1 of 5
middle-tier acquisition programs completed five key business case activities

As of January 2020

2 of 5
middle-tier acquisition programs completed five key business case activities

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.

Program Essentials

Milestone decision authority: Army

Program office: Warren, MI

Prime contractor: BAE Systems Land and Armaments, LP

Contract type: CPIF/FPI (design, integration and low-rate initial production)

Next major milestone: Start of operational testing (February 2021)

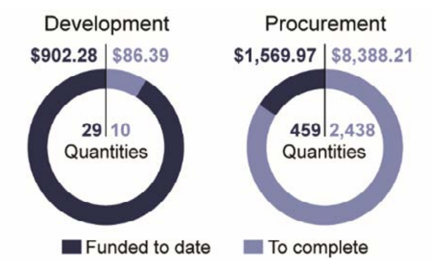
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (05/2015)	Latest (12/2018)	Percentage change
Development	$1,081.42	$988.68	-8.6%
Procurement	$10,655.07	$9,958.18	-6.5%
Unit cost	$4.00	$3.76	-6.0%
Acquisition cycle time (months)	87	87	+0.0%
Total quantities	2,936	2,936	+0.0%

Total quantities comprise 39 development quantities and 2,897 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Attainment of Product Knowledge

As of January 2020

	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	●	●

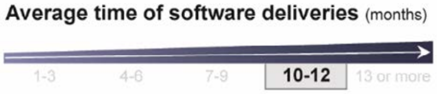
● Knowledge attained, ○ Knowledge not attained, … Information not available, NA Not applicable

Software Development

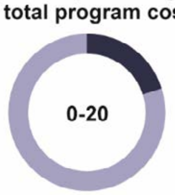
(as of January 2020)

Approach: Incremental

Average time of software deliveries (months)



Software percentage of total program cost



Software type

10 percent Commercial

20 percent Modified commercial

70 percent Custom software

AMPV Program

Technology Maturity, Design Stability, and Production Readiness

The AMPV program entered system development in December 2014 with mature critical technologies. The program has also released over 90 percent of expected design drawings to manufacturing, which indicates a stable design. However, the overall number of drawings has fluctuated due to vehicle configuration changes and testing results.

Although the AMPV entered low-rate initial production in January 2019, the program's manufacturing readiness level does not indicate 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 DOD standard falls short of industry best practices. Further, the program office did not demonstrate its critical manufacturing processes on a pilot production line, which program officials attributed to the contractor's need to address manufacturing process deficiencies discovered during production of prototype AMPV units. However, program officials stated pre-production hulls were used to validate new weld processes and serve as pilots for fabrication.

The contractor started fabrication of low-rate initial production vehicles in March 2019 after spending nearly a year addressing manufacturing challenges experienced during prototype production. These challenges—such as parts shortages and changes to engineering drawings—resulted in late prototype deliveries. To improve manufacturing timeliness and quality, the contractor implemented new manufacturing processes, such as robotic welding. However, the Defense Contract Management Agency reported that the contractor has yet to fully validate these processes due to welding challenges and quality problems with supplier parts. As a result, the vehicle production schedule has been delayed by 4 to 6 months.

Continued vehicle delivery delays beyond those anticipated could affect the start of initial operational test and evaluation, currently planned for February 2021. While program officials expect the contractor to deliver low-rate initial production vehicles late due to lingering manufacturing challenges, they believe sufficient schedule margin exists prior to the start of operational testing to accommodate the late production vehicles. However, until the program demonstrates that its critical manufacturing processes are in statistical control, there is increased risk that the design may not be producible at the program's cost, schedule, and quality targets.

Software and Cybersecurity

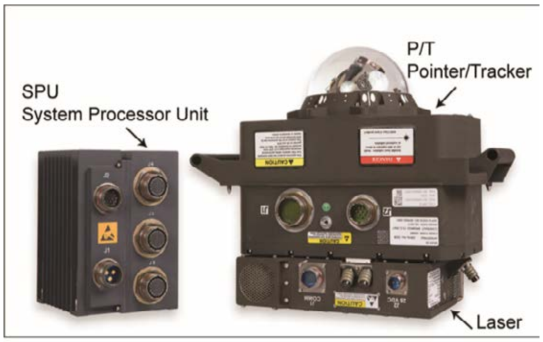
The AMPV program reported it is using an incremental approach to develop software for vehicle control, communications, and other software areas. However, the program delivers software to testers—not users—in 10- to 12-month increments. Office of Management and Budget and DOD guidance both call for regular incremental deliveries to users. We previously reported that involving users in early stages and obtaining frequent feedback helps reduce risk and is critical to software development success. Program officials reported that the program has no significant software-related issues. Initial cybersecurity testing revealed system vulnerabilities, and the program is planning future testing to include the mitigation of identified vulnerabilities. The program is scheduled to complete an evaluation for potential cybersecurity vulnerabilities in 2021.

Other Program Issues

The Army's updated cost position for the program reflected procurement cost growth of nearly 10 percent since the program's first full estimate. This cost position, prepared for entry into low-rate production, was based on the independent cost estimate prepared by the Office of Cost Assessment and Program Evaluation, which noted concerns with the contractor's manufacturing capacity to meet expected production vehicle delivery dates. The contractor expects system development to continue through 2021—more than 1 year later than planned—largely due to delays in developing logistics documentation such as operator technical manuals. This delay increases risk that the program may not fully demonstrate vehicle supportability and training in an operational environment prior to entering full-rate production, which is also planned for October 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 the AMPV remains within cost, schedule, and performance baselines, taking into account user-requested design upgrades and added European Deterrence Initiative vehicles, among other things. It also stated that the development contract extension accommodates these design upgrades as well as potential design changes from further testing. The program office said that it adjusted test schedules without compromising requirements for the full rate production decision, including its plans to meet DOD manufacturing readiness level guidance at that decision point. The office also stated that it used pre-production hulls to validate weld processes and met the DOD manufacturing readiness level guidance for its initial production start. The program office noted major contractor process improvements and lessons learned that have led to improved production metrics such as fewer defects.



Source: Northrop Grumman Systems Corporation.

Common Infrared Countermeasure (CIRCM)

The Army's CIRCM is the next-generation lightweight, laser-based infrared countermeasure system for rotary-wing, tilt-rotor, and small fixed-wing aircraft across DOD. CIRCM consists of three major items—a system processor unit, a pointer tracker, and an infrared laser. CIRCM receives input from the Army's Common Missile Warning System and employs the pointer tracker to track incoming missiles. It jams the missile by using laser energy. CIRCM is to replace the Advanced Threat Infrared Countermeasures system.

CONCEPT
- 12/11 Program start (MS A)

SYSTEM DEVELOPMENT
- 08/15 Development start
- 10/16 Critical design review

PRODUCTION
- 09/18 Low-rate decision
- 06/19 Start operational test
- 11/19 End operational test
- 01/20 GAO review
- 06/20 Full-rate decision
- Initial operational capability Future event; the Army deemed the actual date as not suitable for public release

Program Essentials

Milestone decision authority: Army

Program office: Huntsville, AL

Prime contractor: Northrop Grumman

Contract type: CPFF/FFP (development and low-rate initial production)

Next major milestone: Full-rate production (June 2020)

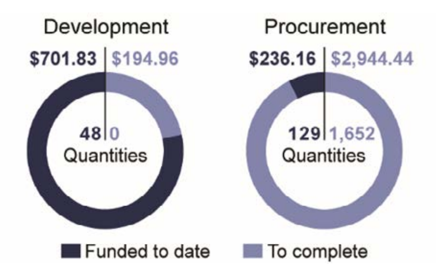
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (07/2016)	Latest (07/2019)	Percentage change
Development	$825.78	$896.80	+8.6%
Procurement	$1,950.65	$3,180.61	+63.0%
Unit cost	$2.47	$2.24	-9.5%
Acquisition cycle time (months)	115	117	+1.7%
Total quantities	1,124	1,829	+62.7%

Total quantities comprise 48 development quantities and 1,781 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

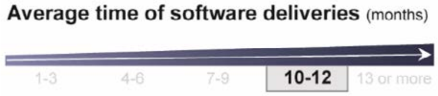


Software Development

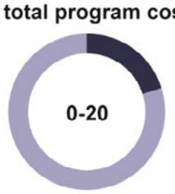
(as of January 2020)

Approach: Incremental

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent Commercial

67 percent Modified commercial

33 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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

CIRCM Program

Technology Maturity, Design Stability, and Production Readiness

CIRCM has fully matured its six critical technologies—the laser and five pointer-tracker hardware and software components. It also has released 100 percent of its design drawings. However, CIRCM entered production in September 2018 with a design that the Army was aware did not meet the requirement for system reliability and that the program planned to mature over time.

The Army intended to reach its “mean time between operational mission failure” reliability requirement by first achieving 150 consecutive hours during initial operational test and evaluation in June to December 2019, and then achieving the full requirement of 214 consecutive hours before full-rate production. Before the test began, however, the Army shortened the longest expected mission for two of three helicopters the CIRCM program plans to use to achieve initial operational capability. The program office anticipated that the Army would relax CIRCM’s test goal to 125 hours and the full-rate production requirement to 179 hours; however, according to the program office, this revision did not occur prior to the end of the testing and CIRCM consequently flew over 214 hours. A program official stated that operational test results would not be available until March 2020 at the earliest. According to program risk documentation, if the testing reveals critical hardware or software problems, these problems could jeopardize system performance and impact CIRCM’s schedule.

Additionally, the program has been slower to demonstrate manufacturing knowledge than acquisition best practices recommend. In 2019, the Aircraft Survivability Equipment project management office, which oversees the CIRCM program office, concluded that CIRCM suppliers had demonstrated statistical control of manufacturing processes. However, at that point, CIRCM had been in low-rate production for a year. 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. Acquisition best 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.

The CIRCM program has addressed some risks that we reported last year related to producing quantities necessary for testing, but continues to face production problems that could impact manufacturing processes. Specifically, the program has identified a risk that the pointer-tracker supplier may not be able to successfully build at full-rate production rates. Moreover, the supplier is experiencing problems with component obsolescence. If it cannot find enough of the components, it will need to identify alternate ones. The program office and supplier have mitigation efforts for these risks underway. However, the program also stated that, if realized, the risks could impact CIRCM’s schedule, including delaying the start of full-rate production currently planned for June 2020.

Software and Cybersecurity

The program identified software as a risk area, in part based on the need to complete software required to evaluate fielding plans and support operational testing. It also cited other factors, including requirements and hardware design changes that drove additional software development. The program said it had underestimated the complexity of the software required to operate the integrated system, which increased total program costs. It reported difficulty in hiring enough contractor and government staff to complete the software work, hiring staff in time to perform planned work, and finding staff with needed expertise. The program updated its Army-approved cybersecurity strategy in June 2018, before its production decision. In 2019, CIRCM completed cooperative and adversarial cybersecurity assessments and obtained short-term authority to operate allowing the program to proceed ahead based on evaluation of cybersecurity-related risks. The program has other cybersecurity events planned during 2020 and must successfully conclude them before CIRCM can gain full authority to operate. The program considers achievement of this authorization a risk and expects to retire it in June 2020, when CIRCM is due to begin full-rate production.

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, CIRCM completed a comprehensive initial operational test and evaluation, with oversight by DOD’s Director, Operational Test & Evaluation. The program office stated that this testing concluded 6 months of independent evaluation and consisted of threat hardware and soldier testing as well as reliability and maintainability and missile flight testing. The program office said that CIRCM accumulated 900 flight hours during the testing, including in cold weather, littoral, and “clutter” conditions, and that the system exceeded its full-rate production entrance reliability requirement of 214 hours. The program office also stated that it complied with all DOD regulatory and statutory requirements for demonstrating technology and manufacturing readiness to ensure a stable system design and production maturity. These achievements, it said, are critical to a full-rate production decision. Lastly, it stated that CIRCM achieved first unit equipped status three months earlier than its May 2020 objective and is on schedule for initial operational capability.

Source: U.S. Army.

Handheld, Manpack, and Small Form Fit Radios (HMS)

The Army's HMS program is procuring software-defined radios that will connect with existing radios and increase communications and networking capabilities. The program continues efforts begun under the former Joint Tactical Radio System to procure multiple radios, such as the Handheld (Leader and Rifleman) and the Manpack. A subset of Manpack radios will operate with the Mobile User Objective System (MUOS)—a worldwide, multiservice Navy satellite communication system. In 2017, the Army deferred acquisition of one-channel Rifleman radios in favor of two-channel Leader radios.

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

- **04/04** Program/development start
- **06/11** Initial low-rate decision
- **04/15 and 02/16** Contract awards—Rifleman and Manpack radios
- **09/18** Contract modification—Leader radio
- **06/19** Sixth low-rate decision—Leader and Manpack radios
- **01/20** GAO review
- **08/20** Start operational test
- **02/21** Full-rate decision—Manpack radio

Program Essentials

Milestone decision authority: Army
Program office: Aberdeen Proving Ground, MD
Prime contractor: General Dynamics C4 Systems, Inc.; Harris Corporation; Collins Aerospace; Thales Defense and Security
Contract type: FFP/IDIQ (low-rate initial and full-rate production)

Next major milestone: Start of operational testing (August 2020)

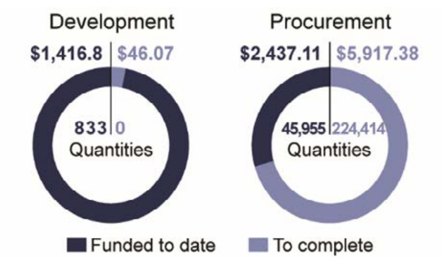
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (05/2004)	Latest (08/2019)	Percentage change
Development	$627.62	$1,462.87	+133.1%
Procurement	$10,938.05	$8,354.49	-23.6%
Unit cost	$0.04	$0.04	+3.8%
Acquisition cycle time (months)	85	124	+45.9%
Total quantities	**328,674**	271,202	-17.5%

Total quantities comprise 833 development quantities and 270,396 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Attainment of Product Knowledge

As of January 2020

Resources and requirements match	Status at Development Start	Current Status
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, because the Army is now procuring the system as a non-developmental item.

Software Development

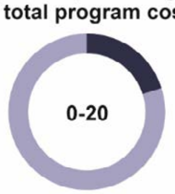
(as of January 2020)

Approach: Non-developmental

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

The program procures non-developmental items and does not have its own software development approach.

HMS Program

Technology Maturity, Design Stability, and Production Readiness

The HMS program is acquiring Leader and Manpack radios as non-developmental items, which has precluded the program's use or tracking of critical technologies and design drawings. Although both radios are now in production, the program has yet to demonstrate that its critical manufacturing processes are in statistical control—an approach inconsistent with best practices.

When the HMS program began development in 2004, it did not assess the maturity of the technologies it had then deemed critical. In addition, the program completed less than half of its planned design drawings at its 2008 critical design review (CDR), which did not meet best practices criteria for design stability. The program's persistent technology immaturity between 2004 and 2011, including at CDR, contributed to radio designs that did not fully accommodate the final form, fit, and function of critical technologies as they matured.

With the move to a non-developmental acquisition in May 2014—and later the Army's decision to acquire two-channel Handheld (Leader) radios and add a commercially available waveform for the newer generation of Manpack radios—the program developed a new test plan in 2017. In accordance with the new test plan, the program has started working with its prime contractors to perform customer and qualification testing to ensure their radios meet Army specifications. These tests will support preparations for operational testing, which is scheduled to begin in August 2020.

According to officials, the HMS program completed its production readiness assessments for the two Manpack radio contractors, and found them to be on track to support production decisions. Officials report that in September 2018, the program modified its existing indefinite-delivery/indefinite-quantity contracts to acquire two-channel Handheld (Leader) radios. Program officials said that they plan to assess the two contractors' readiness to produce the Handheld (Leader) radios in fiscal year 2020.

Software and Cybersecurity

In August 2019, the Navy completed MUOS operational testing and found the waveform to be operationally effective, suitable, and cyber survivable. This positive development followed several years of MUOS deficiencies that repeatedly delayed the waveform's availability for use with certain Army and Marine Corps Manpack radios that will rely on it.

However, operational testers from DOD's Office of the Director of Operational Test and Evaluation identified cyber survivability concerns involving various threats to the waveform. According to an operational test official, some of these concerns can be addressed through operator training and awareness. The HMS program plans to test the newer generation of affected Manpack radios with the MUOS waveform during operational testing that will begin in August 2020. Program officials identified radio accreditation and MUOS certification as critical to HMS's entry into operational testing.

Program officials stated that the HMS hardware and software are designed to prevent unintended recipients from receiving radio signals. They identified additional steps that operators can take to reduce risk of compromise to secure communications. The program plans to have an approved cybersecurity strategy by the end of fiscal year 2020, more than 9 years after the start of production. Our past work has shown that waiting to focus on cybersecurity until late in the development cycle or after a system has been deployed leads to more challenges than designing for cybersecurity from the beginning.

Other Program Issues

The Army has initiated a middle-tier acquisition program to enhance the commercially available waveform used by the Manpack radios. The Army expects that these enhancements will provide warfighters the capability to communicate on a secure network. Program officials said that the Army Combat Capabilities Development Command is responsible for this program, while the HMS program is responsible for incorporating the completed waveform to the affected radios.

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, in December 2019, the Army directed the program to meet a new requirement for 104,496 single-channel data radios, removed requirements for all Small Form Fit radios, and reduced one-channel Rifleman radios from 93,279 to the previously procured amount of 21,579. The program said that, based on the Army Network Review, it amended the Leader radio document capturing production elements to address threshold radio waveforms, weight, and size. The program stated it is also amending the equivalent Manpack document to address waveform clarifications. According to the program, these documents will validate and stabilize requirements consistent with current non-developmental item capabilities and the HMS acquisition strategy. The program also said that it awarded low-rate initial production delivery orders to procure 3,800 Leader radios and an additional low-rate delivery order to procure 2,258 Generation 2 Manpack radios.

Source: Dynetics.

Integrated Air and Missile Defense (IAMD)

The Army's IAMD program plans to network sensors, weapons, and a common battle command system across an integrated fire control network. Its purpose is to support the engagement of air and missile threats. The IAMD battle command system will provide 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 and Raytheon

Contract type: CPIF/CPFF/FPI (development)

Next major milestone: Low-rate initial production (September 2020)

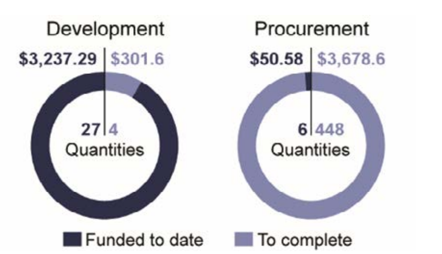
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (12/2009)	Latest (07/2019)	Percentage change
Development	$1,837.99	$3,538.89	+92.5%
Procurement	$3,956.10	$3,729.18	-5.7%
Unit cost	$19.57	$15.27	-22.0%
Acquisition cycle time (months)	80	148	+85.0%
Total quantities	296	479	+61.8%

Total quantities are comprised of 31 development quantities and 454 production quantities. Six of the development quantities will be refurbished into production units and are counted as both development and production quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Attainment of Product Knowledge

As of January 2020

Resources and requirements match	Status at Development Start	Current Status
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 because the system has not reached production.

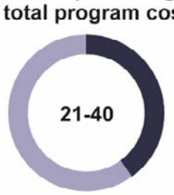
Software Development

(as of January 2020)

Approach: Agile

Average time of software deliveries (months)

Software percentage of total program cost



Software type

10 percent
Commercial

0 percent
Modified commercial

90 percent
Custom software

IAMD Program

Technology Maturity and Design Stability

The IAMD program has demonstrated that its four critical technologies are mature and that its system design is stable. The program completed developmental tests in August and December 2019 in preparation for a second limited user test in the third quarter of fiscal year 2020. The program is conducting the second test because it demonstrated an unsatisfactory performance of the IAMD battle command system software in 2016 during the initial limited user testing. Program officials stated that as of January 2020, the user is evaluating the program for suitability to enter operational testing. In the meantime, the program office began battle command system qualification testing in mid-2019 and plans to follow it with integration testing of the most recent major software build in early fiscal year 2021.

Production Readiness

As we previously reported, the program plans to conduct a manufacturing readiness assessment in fiscal year 2020, in preparation for the September 2020 low-rate initial production decision. However, the program has allotted only about 2 months between the planned completion of the limited user test and the September 2020 production decision. We also previously reported that this strategy places the program's schedule and performance at risk should issues arise because the program will have limited time to address serious deficiencies should they arise during testing.

Software and Cybersecurity

Program officials reported they were challenged in finding and hiring government and contractor staff with required expertise in time to perform planned software development work, and that software development has been more difficult than planned. Hardware design changes have also required additional software development that have led to software cost increases.

We reported in last year's assessment that the IAMD battle command system software performance indicated the need for several improvements, including more soldier training. Since that time, the program's software releases have provided additional capability, allowing IAMD to communicate with hardware and software from other programs. Program officials stated that, to help further reduce the risk of battle command system deficiencies during the 2020 limited user test, the contractor is testing battle command system software with tactical network and weapon/sensor interfaces prior to government acceptance.

The IAMD program recently transitioned to an Agile software development approach to develop command and control and other mission software. According to the program office, the program's Agile development processes produce usable software after each quarterly increment, and soldiers play an integral role in the planning, testing, and verification for each increment in order to facilitate early and continuous feedback and to assist in prioritization of software requirements. The program stated that software will be released to soldiers annually to minimize the training impact on the force and to enable independent testing of each fielded software build.

The program has an approved cybersecurity strategy and has updated the strategy at its acquisition milestones. In addition, the program has completed cooperative and adversarial assessments during its developmental testing and has additional cybersecurity testing planned in summer 2020. Program officials stated that IAMD was designed with cybersecurity concerns in mind as it will be connected to other programs' hardware and software.

Other Program Issues

Since our last assessment, the program has experienced over $100 million in development cost growth due to additional requirements, software development and tests to support future capabilities, as well as accelerated integration. Conversely, the program updated its cost methodology, which has led to a decreased procurement cost estimate compared to its base estimate. The program plans to update its acquisition program baseline at the time of the low-rate initial production decision in September 2020 and a new independent cost estimate will also be available.

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 developmental testing completed in December 2019 used production-representative hardware and provided an early look at hardware and software performance prior to the limited user test. According to the program office, it successfully completed new equipment training in December 2019 and executed a successful developmental test flight effort from August through December 2019. The program also stated that it began training groups of soldiers in January 2020 and expects to conclude that training in April 2020.

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 program office intends the design of the new engine to provide increased power, performance, and fuel efficiency; enhanced reliability; increased service life; and a lower maintenance burden. The Army plans to field the new engine in fiscal year 2027.

CONCEPT
- 08/16 Program start

SYSTEM DEVELOPMENT
- 01/19 Development start
- 01/20 GAO review
- 04/20 Critical design review

PRODUCTION
- 07/24 Low-rate decision
- 03/26 Start operational test
- TBD End operational test
- 07/26 Full-rate decision
- 07/27 Initial capability

Program Essentials

Milestone Decision Authority: Army
Program office: Redstone Arsenal, AL
Prime contractor: General Electric Aviation
Contract type: CPIF (development)
Next major milestone: Critical design review (April 2020)

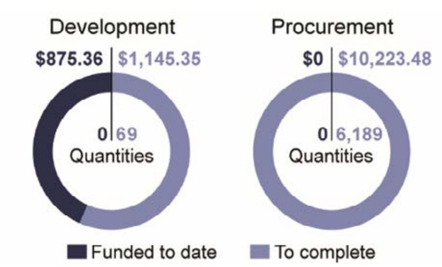
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (01/2019)	Latest (01/2019)	Percentage change
Development	$2,020.71	$2,020.71	0.0%
Procurement	$10,223.48	$10,223.48	0.0%
Unit cost	$1.97	$1.97	0.0%
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.

Funding and Quantities

(fiscal year 2020 dollars in millions)

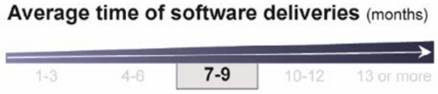


Software Development

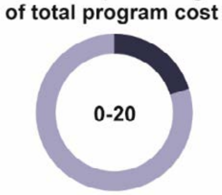
(as of January 2020)

Approach: Agile

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent Commercial
0 percent Modified commercial
100 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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 the ITEP program's design stability because the program had not yet conducted its design review. Additionally, we did not assess the program's manufacturing maturity because it had not yet reached production.

ITEP Program

Technology Maturity

The program entered system development in January 2019 with five critical technologies—the advanced inlet particle separator, compressor advanced aerodynamics, hybrid bearings and two additive manufacturing processes—approaching maturity. The Army plans to further mature all technologies through testing beginning in fiscal year 2021. If the technologies fail to reach maturity prior to the low rate initial production decision in fiscal year 2024, the program office will utilize alternate, mature technologies currently used in the design and repair of gas turbine engines in place of the first three technologies listed above and existing manufacturing capabilities in place of additive manufacturing processes.

Design Stability

The Army selected the General Electric Aviation ITEP engine design to proceed into its engineering and manufacturing development phase. The program held preliminary design reviews of two competing engine designs from General Electric Aviation and the Advanced Turbine Engine Company in March and April 2018. Subsequently, an independent review conducted by the Army in August 2018 concluded that the preliminary design reviews lacked objective and quantifiable entrance criteria. Moreover, subsystem design reviews did not fully inform the system-level review due to a compressed schedule. Despite these findings, the review team concluded that the program was ready to proceed into system development based on the program's efforts to resolve the identified deficiencies, and the Army awarded the contract to General Electric Aviation in February 2019. ITEP's critical design review is scheduled for April 2020.

Production Readiness

ITEP will leverage the Army's existing manufacturing capabilities to utilize additive manufacturing processes. Additive manufacturing creates an object by adding layers of material from three-dimensional data, unlike traditional manufacturing processes where the product is created by cutting away material from a larger piece. ITEP's goal is to use additive manufacturing in place of traditional manufacturing processes in order to enhance performance and achieve weight savings for component designs. An October 2018 independent review from the Office of the Under Secretary of Defense for Research and Engineering assessed the overall manufacturing risk as low and found that the program had demonstrated all manufacturing processes in a production relevant environment. ITEP plans to begin low rate production in July 2024.

Software and Cybersecurity

The program office has identified software development as a risk area following hardware design changes that prompted additional software development efforts. Additionally, obsolescence of the multicore computing component used in the preliminary design has led to a software-related schedule risk. Both factors are contributors to the program's anticipated challenges in completing software efforts needed to successfully conduct developmental and operational testing. According to program officials, ITEP is mitigating software risks by initiating post design review efforts with the contractor and by covering these risks in its recent integrated baseline review.

The ITEP program is using an Agile software development methodology, with software deliveries planned every 7 to 9 months. This approach differs from industry's Agile practices, which encourage the delivery of working software to actual users on a continuing basis—as frequently as 1 to 6 weeks. Officials said that working software is not deployed to end users at the end of each cycle due to the rigorous avionics software standards required to ensure air-worthiness.

The program has an approved cybersecurity strategy. According to program officials, the program office has worked closely with the vendor on cybersecurity issues.

Other Program Issues

ITEP's schedule relies on concurrent development and integration between the engine manufacturer and original Black Hawk and Apache manufacturers. To address integration risks, the program is overseeing the generation of an interface control document with the engine contractor and the airframe manufacturers that will be used for development trade studies and to inform future requirements.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. According to the program, a 2018 Office of the Secretary of Defense review stated that ITEP met system development entrance criteria and had completed a preliminary design review. The program office stated that these events demonstrated ITEP's high likelihood of accomplishing its intended mission. The program also said it had established a baseline, had completed an integrated baseline review, and is ready to begin detailed design. It said it conducted other events as planned in January and February 2020, including mockup engine fit checks into the Apache and Black Hawk airframes and a cybersecurity exercise. According to the program, these efforts provided insights into risk mitigation for integration and cyber vulnerabilities. The program stated that the contractor is executing to a 12-month accelerated schedule that permits an earlier production decision. The program also noted that this report uses fiscal year 2020 dollars while its baseline uses base year 2019 dollars, so development, procurement, and unit cost appear higher in this assessment than in the program baseline.

Source: U.S. Army.

Joint Air-to-Ground Missile (JAGM)

The Joint Air-to-Ground Missile is an Army-led program with joint requirements from the Navy and Marine Corps. The missile is designed to be air launched from helicopters, such as the Apache helicopter, and unmanned aircraft systems to target tanks, light armored vehicles, missile launchers, bunkers, and buildings. It is intended to provide precision attack capabilities no matter the time of day or weather conditions. JAGM will replace all Hellfire missile variants.

Program Essentials

Milestone decision authority: Army

Program office: Redstone Arsenal, AL

Prime contractor: Lockheed Martin

Contract type: FPI (low-rate initial production)

Next major milestone: Full rate production (May 2020)

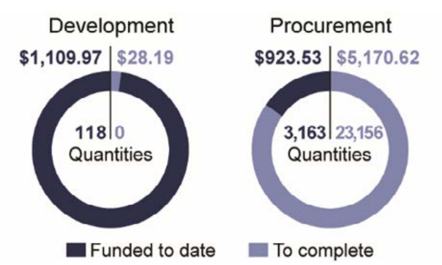
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (09/2015)	Latest (08/2019)	Percentage change
Development	$1,070.80	$1,138.16	+6.3%
Procurement	$5,133.95	$6,094.15	+18.7%
Unit cost	$0.23	$0.28	+17.3%
Acquisition cycle time (months)	38	44	+15.8%
Total quantities	26,437	26,437	+0.0%

Total quantities comprise 118 development quantities and 26,319 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

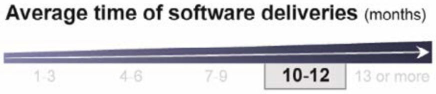


Software Development

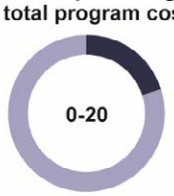
(as of January 2020)

Approach: Incremental

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent
Commercial

0 percent
Modified commercial

100 percent
Custom software

Attainment of Product Knowledge

As of January 2020

	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

JAGM Program

Technology Maturity, Design Stability and Production Readiness

The JAGM program has matured its three critical technologies, stabilized its system design, and begun production. However, the program has yet to demonstrate statistical control of manufacturing processes—an approach inconsistent with best practices. The JAGM program has fully completed design and testing of JAGM components for integration with the existing Hellfire missile, thereby decreasing manufacturing risks.

Program officials stated that JAGM had a stable design at its January 2016 critical design review. In our 2019 assessment of the program, we reported that an increase in JAGM total design drawings resulted in the program falling just short of meeting best practices criteria, which recommend release of 90 percent of design drawings by critical design review. The program has now released 100 percent of its design drawings.

JAGM entered low-rate initial production in June 2018, but it has only achieved manufacturing readiness at the level recommended by DOD guidance, which is below the industry best practice. 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. The program reported it will not assess full manufacturing readiness of its facilities until the second quarter of fiscal year 2020.

Program officials reported that they made minor adjustments to the production line since the beginning of low-rate initial production. Officials noted they expect to encounter some obsolescence issues with items such as microelectronics, but will proactively work to overcome those issues using an Obsolescence Integrated Product Team to monitor component issues and avoid a break in the production line.

The program exercised contract options at the end of fiscal year 2018 and beginning of fiscal year 2019 for low-rate initial production totaling 1,423 missiles. Production deliveries began in the first quarter of fiscal year 2019. The program exercised a final contract option for 825 low-rate production missiles in the first quarter of fiscal year 2020—a delay from its planned exercise in the fourth quarter of fiscal year 2019 due to contract negotiations. The program expects these missiles to be delivered by the second quarter of fiscal year 2023. Program officials stated they intend to proceed with a full-rate production decision in May 2020.

Software and Cybersecurity

JAGM officials stated that a change to software was necessary to address deficiencies discovered with the Apache helicopter during 2019 initial operational testing. They also said that the Pilot Vehicle Interface software, which allows pilots to launch the missile from the Apache helicopter, has completed testing and works as expected. Additionally, they reported that the JAGM system successfully engaged all eight targets during initial operational testing. To conduct the live fire tests, the Army executed different missions using two different Apache helicopter variants to engage ground targets. According to program officials, they have completed all testing with the Army's current version of the Apache helicopter. This testing included an additional 14 test shots of the missile from Apache helicopter.

The Navy plans to begin integrated testing of missile and platform software necessary to launch JAGM from the AH-IZ helicopter in the second quarter of fiscal year 2020. Other platforms, including an unmanned aerial system are also planned for software integration with the missile. The JAGM program office stated that they will provide the missiles to these programs, and the programs are responsible for managing their respective software and platform integration schedules.

The program completed its first cyber adversarial assessment of the missile launcher in January 2018 and completed its second assessment in June 2019. The program did not identify any critical vulnerabilities from either assessment. The program also conducted a cybersecurity vulnerability and penetration assessment in June 2019 and found no issues. Program officials stated that the program experienced minor cost growth due to program security 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. The program stated that initial manufacturing assessments occurred in September and October 2019, and that re-assessment prior to one year would be premature. With regard to testing, the program office stated that JAGM completed testing from December 2019 through February 2020 to support a full-rate production decision. The program office also told us that JAGM completed Apache platform integration testing in December 2019, including four launches from a fully integrated Apache helicopter. It deemed the launches successful and described them as occurring in realistic conditions.

Source: Graphic & Multimedia Design Support, US Special Operations Command.

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. According to the Army, FLRAA is expected to deliver speed, range, agility, endurance, and sustainability improvements as compared to the Black Hawk helicopters that it is intended to replace. The Army also expects the program to provide combatant commanders with tactical capabilities at operational and strategic distances.

Program Essentials

Milestone decision authority: Army

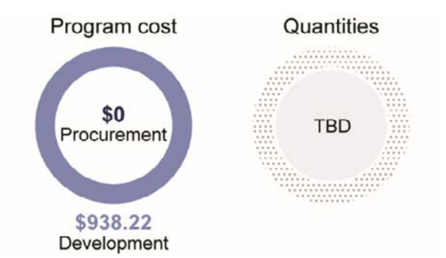
Program office: Huntsville, AL

Prime contractor: TBD

Contract type: TBD (using other transaction authority)

Next major event: Competitive Demonstration and Risk Reduction Contract Award (March 2020)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)

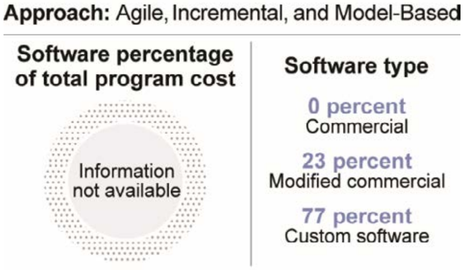


As of February 2020, the estimated cost increased to $1.61 billion for fiscal years 2018-2024.

Software Development

(as of January 2020)

Approach: Agile, Incremental, and Model-Based



The Army has identified some system software, but costs have yet to be determined due to the early stage of the program.

Current Status

In 2019, the Army completed an analysis of alternatives and approved draft FLRAA requirements. The program is using information from the Joint Multi-Role Technology Demonstrator—an air vehicle and mission systems architecture demonstration program begun in 2013—to validate new vertical lift capabilities. To support demonstration and risk reduction activities, the Army is planning for competitive awards in 2020 to two vendors using other transaction authority. These awards and associated activities are intended to deliver initial conceptual prototype aircraft designs.

The program office stated the conceptual design information will be combined with other government and industry input to inform continued development efforts and competitive award of up to two contracts in 2022. According to the program office, these contract awards will support preliminary design reviews and virtual prototype development, activities which will be conducted through either the rapid prototyping middle-tier acquisition pathway or the technology maturation and risk reduction phase of the major capability acquisition pathway. The program plans to subsequently transition to system development as a tailored acquisition program using the major capability acquisition pathway, and intends to equip its first operational unit in 2030.

Attainment of Technology Maturation Knowledge

As of January 2020

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

The program has not set the date of its capability development documentation event, so we could not assess requirements validation.

Program Office Comments

We provided a draft of this assessment to the program office for review and incorporated its technical comments where appropriate. The program office said it is developing multiple acquisition approaches to accelerate FLRAA delivery, and additional funding authorized for 2020 sets the foundation for continued acceleration efforts. The program anticipates final approval of its acquisition approach from Army acquisition leadership in mid-2020.

Source: U.S. Army.

Indirect Fire Protection Capability Increment 2 (IFPC Inc 2)

The Army's IFPC Inc 2 is a follow-on effort 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 separate subsystems—an existing sensor, interceptor (missile), fire control system, and a new multi-mission launcher. We assessed the first phase of Inc 2, which the Army expects will provide interim capability for fixed-site cruise missile defense.

CONCEPT
- 03/14 Program start
- 08/19 Interim system contract award
- 01/20 GAO review
- 09/20 First delivery of interim system
- 11/20 Second delivery of interim system
- 07/21 Interim system start operational test
- 09/21 Interim system initial capability

Program Essentials

Milestone decision authority: Army
Program office: Huntsville, AL
Prime contractor: Rafael Advanced Defense Systems
Contract type: FFP (procurement of interim system)
Next major event: First delivery of interim system (September 2020)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

Approach: Waterfall

Software percentage of total program cost	Software type
Information not available	0 percent Commercial 0 percent Modified commercial 100 percent Custom software

Estimated development costs and software data are for testing and evaluating the Iron Dome systems prior to fielding. Program officials said they do not know software cost because they do not track software work elements.

Current Status

The Army is pursuing a two-phased approach to acquiring IFPC Inc 2 capability. For the first phase, the Army is acquiring two Iron Dome Defense Systems to provide an interim cruise missile defense capability. The Army planned to deploy both systems by September 2020, but delivery of the second system slipped to the fourth quarter of fiscal year 2020 as a result of a 3-month contract award delay.

Program officials stated that they would provide details to Congress on the second phase—long-term, fixed site cruise missile defense—but would not do so before the second quarter of fiscal year 2020 due to time required for internal staffing coordination. To help inform the long-term solution, the Army had planned to conduct an interoperability event with existing Army systems and Iron Dome components. Program officials said they now intend to conduct this event after the Army recommends a long-term solution, which means the Army's decision may not be informed by the interoperability exercise. Program officials acknowledge they have an aggressive schedule, with little margin for error, for fielding a long-term solution by 2023.

Attainment of Technology Maturation Knowledge

As of January 2020

Conduct competitive prototyping	NA	**Complete independent technical risk assessment**	NA
Validate requirements	NA	**Complete preliminary design review**	NA

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

We assessed knowledge attainment for the first phase of IFPC Inc 2, for which the program is procuring mature technology in response to legislation and for which the program will not hold milestone reviews. We plan to assess the Army's longer-term solution when it determines what that capability will be.

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. After our review's cut-off date for assessing new information, the program stated it had submitted a report to Congress in February 2020 detailing its plans to award a contract for its long-term solution using a competitive two-phase process beginning in fiscal year 2021.

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 at planned ranges of 400 to 499 kilometers. The Army anticipates that each PrSM missile container will hold two missiles for launch. The Army plans to design PrSM, as one of a family of munitions, to be compatible 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

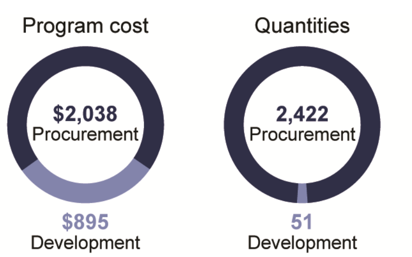
Program office: Redstone Arsenal, AL

Prime contractor: Lockheed Martin; Raytheon

Contract type: CS, CPIF (technology maturation and risk reduction) (using other transaction authority)

Next major event: Development start (June 2021)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)

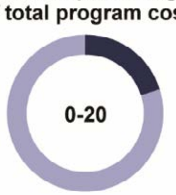


Software Development

(as of January 2020)

Approach: Agile

Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Current Status

The Army has identified PrSM as a priority, and according to program officials, they continued competitive prototyping during 2019 in order to field an early capability in 2023. Program officials stated that the Army provided PrSM with additional fiscal year 2020 funding necessary to maintain the program's plans to continue competitive prototyping until development start to reduce risk.

The Army plans to conduct an independent technical risk assessment prior to PrSM's expected development start in June 2021. Army officials report that in the meantime, they are taking steps to mitigate technology risk. For example, the Army conducted a prototype missile test to a range of 240 kilometers in December 2019. The Army plans to demonstrate the objective range of 499 kilometers at a later date, but program officials said that they have yet to schedule that test.

The Army initially tested the missile with the M142 rocket launcher. Demonstrations with the M270A2 launcher are dependent on completion of upgrades to that system. According to program officials, the Army will complete these upgrades by fiscal year 2023 to support the missile's early capability.

Attainment of Technology Maturation Knowledge

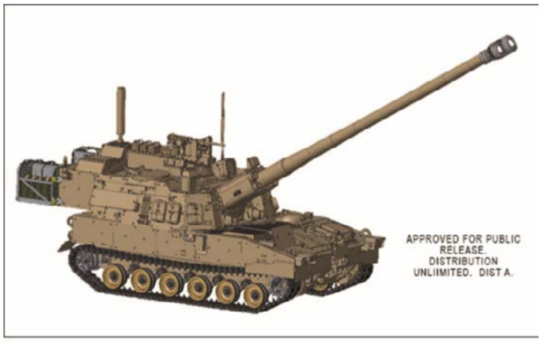
As of January 2020

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 also provided technical comments, which we incorporated where appropriate. Program officials stated that the Army continues efforts to maintain competition and accelerate the program for fielding of an early capability in 2023 and full rate production in 2024. According to the program office, it will continue efforts to accelerate PrSM's integration with the M270A2 launcher.



Source: U.S. Army.

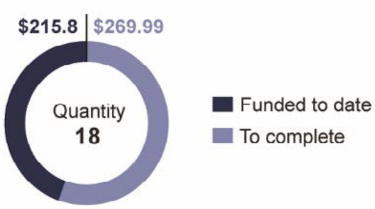
Extended Range Cannon Artillery (ERCA) Increment 1C

The Army's ERCA program is an upgrade to the M109 self-propelled howitzer intended to improve its lethality, range, and reliability. ERCA Increment 1C, a middle-tier rapid prototyping effort, will add equipment to the existing M109 vehicle to mature the design of the upgrade. The Army also plans an Increment 2 effort that will include additional vehicle enhancements. We assessed the Increment 1C rapid prototyping effort.

Program Essentials

Decision authority: Army
Program office: Warren, MI
Prime contractor: BAE Systems
MTA pathway: Rapid prototyping
Contract type: CPFF (development) (using other transaction authority)
Next major event: Critical design review (September 2020)

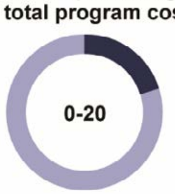
Estimated Middle-Tier Program Cost and Quantities (fiscal year 2020 dollars in millions)



Software Development
(as of January 2020)

Approach: Agile

Software percentage of total program cost



Software type

30 percent Commercial
5 percent Modified commercial
65 percent Custom software

Program Background and Expected Results

The Army initiated ERCA Increment 1C as a middle-tier acquisition rapid prototyping effort in September 2018 with an objective of building 18 prototypes equipped with new armament, electrical systems, and other upgrades beginning in fiscal year 2021. The Army plans to issue the prototypes to a battalion for operational testing by fiscal year 2023. The rapid prototyping effort is projected to end in October 2023 with the 18 prototypes issued to the battalion to gather information for future ERCA increments. In July 2019, the program made an award using other transaction authority to BAE Systems for Increment 1C engineering analysis, prototype hardware fabrication and integration, and power updates. The Army also plans to make multiple additional awards in the future using other transaction authority for integration support, prototype fabrication, steel gun mount, and loader assist prototypes.

The Army plans a separate Increment 2 effort, which it expects will leverage the cannon and other components designed in Increment 1C. The Army currently expects to also use the middle-tier rapid prototyping pathway for this effort, and plans to build and issue 18 prototype vehicles starting in fiscal year 2024.

Attainment of Middle-Tier Acquisition Knowledge
As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	●	●
Approved middle-tier acquisition strategy	○	●
Technology, Cost, and Schedule Assessed		
Formal technology risk assessment	○	●
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

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

ERCA Program

Key Elements of Program Business Case

The ERCA program had an approved requirement at the time of program initiation, but not several other key elements of its business case—including an acquisition strategy, a cost estimate informed by independent analysis, or a formal schedule or technology risk assessment. Our prior work has shown that this type of information is important to help decision makers make well informed decisions about middle-tier program initiation, including whether the program is likely to meet the statute-based objective of fielding a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of an approved requirement.

The Army considers the howitzer range requirement from the M109 Family of Vehicles capability production document, which was approved in November 2016, to be the approved requirements document for the ERCA Increment 1C program. However, the Army has yet to develop requirements specific to this program. Program officials told us they will finalize requirements for Increment 1C when the program completes prototype development.

The program did not have its acquisition strategy approved at the time of program initiation, but in April 2019, the Program Executive Officer approved the simplified acquisition management plan to utilize two middle-tier acquisition efforts for Increment 1C—an initial rapid prototyping effort to mature the design and a rapid fielding effort to field initial battalions. However, in August 2019, the program decided that Increment 1C would be a rapid prototyping effort only. This decision was driven by the planned acquisition strategy for Increment 2, in which a rapid prototyping effort would transition to either a rapid fielding effort or the traditional acquisition system. The program plans to revise the simplified acquisition management plan to reflect this change.

The program also did not have a cost estimate informed by independent assessment or formal schedule risk assessment at the time of program initiation. The program has developed and maintained interim cost estimates to inform funding decisions and other program planning efforts, and officials said they involved an Army-level cost and economic analysis office in that process to validate the estimates. The Army currently expects Increment 1C to cost approximately $486 million.

The Army assessed schedule risk in March 2019 in preparation for the program's next major milestone—critical design review—currently scheduled for September 2020. This assessment identified risks to an Increment 1C first unit issuance date of September 2023. For example, a type of precision-guided projectile technology may not be ready by the time testing needs to occur to achieve that first unit issuance date. The assessment also identified mitigation steps for this risk, such as excluding that technology from initial fielding if necessary.

Technology

The Army has identified nine technologies critical for ERCA Increment 1C development, including the gun mount and projectile, and their respective, current maturity levels. According to program officials, all nine critical technologies are currently immature. While the Army is still developing its plan to mature these technologies, it intends to demonstrate that they will near maturity in early 2020. The Army expects all to be mature upon the completion of the rapid prototyping effort in 2023.

Software Development and Cybersecurity

The primary focus of the program's software effort—and the largest component of one of its critical technologies—is the ERCA fire control software. The program is using Agile development with plans to deploy software on an 18- to 24-month cycle. Officials said that working software is not released until code modifications are merged into the main code, which occurs after testing that can take a few sprints to complete. 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 two weeks—so that feedback can focus on efforts to deploy greater capability.

The program's cybersecurity strategy is predicated on the system security plan, approved in July 2017, for the howitzer being upgraded under this effort. The program has also completed a number of cybersecurity assessments, including cooperative and adversarial assessments.

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 the program has met all document requirements, is on track to issue a residual operational capability as required for a middle-tier rapid prototyping effort, and is employing best practices to enable program success. The program office stated that it is using approved objective requirements, has a signed acquisition decision memorandum and a signed simplified acquisition management plan, is tracking schedule and technical risks with a formalized risk tracking tool, and has had the program cost estimates verified by the Army-level cost and economic analysis office. Finally, the program office said that it is using the middle-tier acquisition process to demonstrate capabilities to inform requirements and reduce risk as the system transitions into a fieldable production configuration.

Source: U.S. Army.

Integrated Visual Augmentation System (IVAS)

The Army's IVAS, a new middle-tier acquisition rapid prototyping program, seeks to improve warfighter close combat capabilities. IVAS is expected to provide a single platform that allows the soldier to fight, rehearse, and train with the use of augmented reality head gear. The IVAS system includes a heads up display, sensors, an on-body computer, and other elements intended to improve warfighter sensing, decision making, target acquisition, and target engagement through a next generation, 24/7 situational awareness tool.

- **09/18** MTA initiation
- **09/18** MTA funds obligated
- **11/18** Contract award
- **03/19** Demonstration of first capability set
- **10/19** Demonstration of second capability set
- **01/20** GAO review
- **07/20** Demonstration of third capability set
- **09/20-04/21** Rapid fielding decision
- **03/21** Demonstration of fourth capability set/expected MTA completion
- **09/23** 5 years since MTA initiation/ MTA funds obligated

Program Essentials

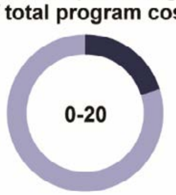
Decision authority: Army
Program office: Fort Belvoir, VA
Prime contractor: Microsoft
MTA Pathway: Rapid prototyping
Contract type: FFP (development) (using other transaction authority)
Next major event: Demonstration of third capability set (July 2020)

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

Approach: Agile and DevOps

Software percentage of total program cost	Software type
	Information not available

Officials said the program is in development stages and it is premature to identify types of software code.

Program Background and Expected Results

The Army initiated IVAS as a middle-tier acquisition rapid prototyping program in September 2018 with an objective to complete prototyping in two years. In November 2018, the Army used other transaction authority to award an agreement to Microsoft for IVAS system development and integration. According to officials, this agreement is intended to deliver a total of 2,550 prototypes in four capability sets, with each set providing increasing capabilities. Microsoft delivered the initial 50 systems demonstrating a commercial proof of concept in March 2019 and an additional 300 modified commercial systems in October 2019. Two additional capability set deliveries are planned to follow. The Army expects the final delivery of 1,600 systems by March 2021. The prototype quantity was selected to test manufacturing feasibility for a full Army formation size. Program officials said that the prototype units are not expected to be fielded, but will be used for future development including integration testing with vehicle and aircraft platforms.

The Army plans to initiate a follow-on middle-tier rapid fielding program as early as fourth quarter of fiscal year 2020, prior to the demonstration of the fourth capability set. The Rapid Fielding program is projected to procure roughly 100,000 units over a 4-year period, ending in fiscal year 2024.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	●	●
Approved middle-tier acquisition strategy	○	●
Technology, Cost, and Schedule Assessed		
Formal technology risk assessment	●	●
Cost estimate based on independent assessment	○	○
Formal schedule risk assessment	○	○

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

IVAS Program

Key Elements of Program Business Case

While the IVAS program had an approved requirement and a technology risk assessment at the time of program initiation, it did not have several other key elements of its business case—including an acquisition strategy, a cost estimate informed by independent analysis, or a formal schedule risk assessment—approved at that time. Our prior work has shown that this type of information is important to help decision makers make well-informed decisions about middle-tier program initiation, including whether the program is likely to meet the statute-based objective of fielding a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of an approved requirement.

Since program initiation, the IVAS program has completed an acquisition strategy, which was approved by the Army Acquisition Executive in November 2019. The strategy was a combined simplified acquisition management plan for both the IVAS rapid prototyping and rapid fielding programs.

The program developed a cost estimate in July 2018 to support the rapid prototype program and shared it with the Office of the Deputy Assistant Secretary of the Army (Cost & Economics), but it was not independently assessed or approved. A cost estimate is being developed by the program office to support an independent cost estimate for the follow on IVAS Rapid Fielding program and is expected to be completed by June 2020.

Similarly, the program does not plan to conduct a formal schedule risk assessment for the rapid prototyping effort. However, the Office of the Under Secretary of Defense, Research and Engineering (OUSD[R&E]) conducted an Independent Technical Risk Assessment in January 2019 and concluded that the initial 24-month schedule was aggressive and raised concerns that the program may not be able to deliver the full capability as planned. The assessment found that the Army will likely have to trade off performance to meet the aggressive schedule, but noted that the program is still expected to deliver an increased military capability in the 24-month timeframe. The assessment recommended that the Army consider delaying its rapid fielding full rate production decision planned for the fourth quarter of fiscal year 2020 to allow for multiple low rate initial production lots to be demonstrated by the contractor before the decision.

Technology

IVAS relies on the successful development and integration of 15 critical technologies. The Army Research, Development & Engineering Command conducted a technology readiness assessment in August 2018, which concluded that all of these critical technologies were mature or approaching maturity at program initiation.

In contrast, OUSD (R&E) concluded in January 2019 that technology risk is high for IVAS and identified the Color Waveguide Display Module as immature. Specifically, it reported the display module did not have the required contrast or field of view for daytime use. In addition, the display module needs reduced light emissions to ensure light security for night operation. While program officials disagreed with the overall conclusion that technology risk is high for IVAS, they are aware of the Color Waveguide Display Module risks and plan mitigation activities.

Software Development and Cybersecurity

IVAS is using both Agile software development and continuous integration and development. IVAS officials said the program has adopted Microsoft's development practices, which focus on programming and assessing a small segment of functionality during 3-week sprints. This approach is consistent with industry practices, which encourage the delivery of working software to users on a continuing basis—as frequently as every 2 to 6 weeks—so that feedback can focus on efforts to deploy greater capability. If the software segment is not successful, the development rolls into another sprint. The working software is deployed to Army soldiers for evaluation at each of four planned soldier test events. IVAS has completed two soldier testing events as of November 2019.

IVAS is in the process of developing a cybersecurity plan for the program and officials expect it to be complete in the second quarter of 2020. The program's draft plan does not identify how often cybersecurity assessments will be conducted or the scope of the assessments. The program office said initial electronic warfare and cyber testing has been conducted on capability set 3 and further testing is planned for sets 3 and 4. It also stated that it considered cybersecurity design and implementation since IVAS' start.

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 IVAS is one of the Army's first middle-tier acquisition programs, and its strategy is an aggressive schedule to develop and transition a new capability to soldiers. According to the program, it navigated emerging authorities, policies, stakeholders, and partnerships to successfully develop and demonstrate the first two capability sets on schedule and with expected performance. The program said IVAS is on-track to complete its first fully militarized version with capability set 3 in 2020, demonstrate production capability with capability set 4, and achieve first unit equipped status in the fall of 2021.

Source: U.S. Army.

Lower Tier Air and Missile Defense Sensor (LTAMDS)

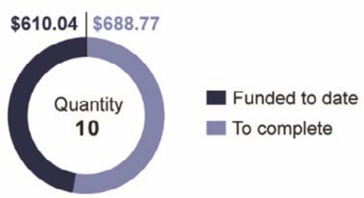
The Army's LTAMDS, a middle-tier acquisition program, is planned as a multi-function radar that will replace the legacy PATRIOT radar. The legacy radar faces changing threats, growing obsolescence, and increasing operational costs. The Army expects that the LTAMDS, as the lower tier component of the 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.

- **07/17** Concept definition start
- **09/18** MTA initiation
- **11/18** MTA funds obligated
- **09/19** Concept definition end
- **10/19** Contract award
- **01/20** GAO review
- **07-09/21** Qualification testing start
- **09/22** Expected MTA completion/ initial capability
- **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)
Next major event: Start of qualification testing (July-September 2021)

Estimated Middle-Tier Program Cost and Quantity (fiscal year 2020 dollars in millions)



Software Development

(as of January 2020)

Approach: Information not available

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

According to program officials, software information is not yet available.

Program Background and Expected Results

The Army initiated LTAMDS as a middle-tier acquisition in September 2018 with an objective of completing prototyping by the fourth quarter of fiscal year 2022. The Army originally intended the program to be conducted under the traditional DOD acquisition system but determined that using the rapid prototyping pathway would facilitate achieving initial capability by the end of 2023. In October 2019, the Army awarded Raytheon a contract to develop and test six production representative prototype sensors. Program officials expect to field a prototype that can be demonstrated in a realistic environment and provide a residual operational capability by the end of the rapid prototyping effort.

The LTAMDS program has yet to determine if it will use the middle-tier rapid fielding pathway or major capability acquisition pathway for production when the middle-tier rapid prototyping effort is complete. According to program officials, the prototypes will establish the initial LTAMDS requirements baseline, which will inform requirements for 16 additional radars.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	○	●
Approved middle-tier acquisition strategy	○	●
Technology, Cost, and Schedule Assessed		
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	○	○
Formal schedule risk assessment	○	○

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

LTAMDS Program

Key Elements of Program Business Case

The LTAMDS program did not have the key elements of its business case—including requirements, an acquisition strategy, a cost estimate informed by independent analysis, and schedule and technology risk assessments—approved at the time of program initiation. Our prior work has shown that this type of information is important to help decision makers make well-informed decisions about middle-tier program initiation, including whether the program is likely to meet a statute-based objective of fielding a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of an approved requirement.

Since program initiation, the program completed an acquisition strategy and requirements development. In July 2019, the Army Acquisition Executive approved the LTAMDS middle-tier acquisition strategy after three vendors tested lower-tier radar capabilities at the White Sands Missile Range. These tests demonstrated the scalability of LTAMDS components and were part of a competition using other transaction authority through which the Army selected a single vendor to develop the prototypes. On September 4, 2019, the Army Capabilities Board approved the program office requirements.

The Army has not yet completed a cost estimate. The first cost estimate is expected in February 2020 and will be independently assessed no later than March 2020. The Army requested about $1.6 billion for the LTAMDS program for fiscal years 2018 through 2024 and has begun working on a life cycle cost estimate. According to program officials, a formal assessment of schedule risk was completed in February 2020, 3 months after contract award. Without this type of information at the time of initiation, decision makers lacked assurance that they had accurate cost and schedule expectations for the program to use to as a starting point to monitor program performance. The subsequent risk assessment provides business case information to help decision-makers make well-informed decisions for a middle-tier acquisition such as whether the program can complete a prototype with a residual capability within 5 years of an approved requirement.

Technology

The program office has identified four technologies critical for LTAMDS development and their respective, current maturity levels. The technologies identified relate to various amplifications and limitations. According to the program office, the Georgia Technology Research Institute assessed all four technologies as mature, meaning they have been integrated with other key subsystems of the prototype and demonstrated in a realistic environment. Program officials will further mature these technologies to complete LTAMDS development, which requires proving that they work in their final form and under expected conditions.

The program office stated that it does not plan to conduct a formal technology risk assessment because the LTAMDS technology has been successfully demonstrated in existing radars. However, while reusing existing technologies can reduce technical risk, if the form, fit, or functionality of those technologies changes from one program to another, technology maturity may also change.

Software Development and Cybersecurity

The program expects to deliver its first software increment in March 2020 with a final software release scheduled for the third quarter of fiscal year 2021. Once development begins, the LTAMDS software team will assess progress through weekly teleconferences and quarterly reviews and perform risk assessments for schedule deviations.

According to program officials, the program plans to address cybersecurity throughout LTAMDS development. Officials report that the development contract has several cybersecurity requirements, including a mechanism to enforce vendor compliance with DOD cybersecurity controls. Key performance parameters, system attributes, and the LTAMDS test plan also address cybersecurity. Prior to the vendor testing in May and June 2019, the Army conducted a rapid cyber assessment of the three vendors' equipment. During this assessment, vendors provided network diagrams and architecture, among other things, to officials at the Army's Data and Analysis Center.

Other Program Issues

The Army is leveraging other transaction authorities in conjunction with middle-tier acquisition programs. The Army noted that cost sharing arrangements through other transaction authority agreements helped mitigate cost risk during the concept development phase of this program. The Army anticipates that the planned use of other transaction authority for prototyping and initial production will also promote cost sharing, among other benefits.

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 remains committed to meeting acquisition milestones and initial operational capability dates for fielding a sensor to counter emerging threats.

Source: U.S. Army.

Optionally Manned Fighting Vehicle (OMFV) Increment 1

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 control robotic and semiautonomous ground systems. The OMFV is intended to replace the existing Bradley Fighting Vehicle, a legacy vehicle that no longer has the capacity to integrate new technologies needed by the Army.

Program Essentials

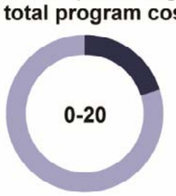
Decision authority: Army
Program office: Warren, MI
Prime contractor: TBD
MTA pathway: Rapid prototyping
Contract type: TBD
Next major event: MTA funds obligated (TBD)

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

Approach: Information not available

Software percentage of total program cost	Software type
	Information not available

Software approach and software type is not yet known because it is contractor design dependent.

Program Background and Expected Results

The Army initiated OMFV Increment 1 as a middle-tier acquisition in September 2018 with an objective to complete prototyping by the third quarter of fiscal year 2023. The program planned to award contracts to up to two vendors in March 2020 for delivery of 14 prototype vehicles each by 2022. In January 2020, the program canceled its solicitation for these contracts. Officials stated that Army leadership is still committed to moving forward with the program, but they will need to reassess the achievability of their requirements within the desired timeframe. At the completion of the middle-tier acquisition, the program plans to leverage lessons learned from the prototyping effort to finalize program requirements and begin initial production under a traditional acquisition approach. Prior to the cancellation, the program office anticipated a competition for the initial production contract award in the third quarter of fiscal year 2023 and planned to field the initial vehicle in early fiscal year 2026. However, following the cancellation, these dates are uncertain as of the time of our review.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	○	●
Approved middle-tier acquisition strategy	○	●
Technology, Cost, and Schedule Assessed		
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

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

OMFV Program

Key Elements of Program Business Case

The OMFV program did not have key elements of its business case—including approved requirements, an acquisition strategy, a cost estimate informed by independent analysis, or a formal schedule or technology risk assessment—approved at the time of program initiation. Our prior work has shown that this type of information is important to help decision makers make well-informed decisions about middle-tier program initiation, including whether the program is likely to meet the statute-based objective of fielding a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of an approved requirement.

Since program initiation, the Army has completed all of these business case elements except a formal technology risk assessment. The program office finalized a cost estimate in March 2019 that was reviewed by the Army's cost agency. Further, the program's acquisition strategy was approved by the Army in July 2019. The program also completed a formal schedule risk assessment in July 2019. The program found that the schedule was high risk, in part because of the time it would take to develop some required components. The program expected to mitigate some of this schedule risk through communication with industry and by planning to provide certain components to vendors as government furnished equipment. However, program documents noted that if schedule issues arise, there was a distinct chance the program would not meet its overall goal of equipping the first unit with the OMFV in 2026. In response to the January 2020 cancellation of the solicitation, officials stated that this goal will be revised.

The Army has established a broad set of requirements for the rapid prototyping effort, which were approved in March 2019. The Army Futures Command has also developed more detailed draft requirements that it plans to finalize after completion of the rapid prototyping effort before entering the traditional acquisition system for production. In response to the January 2020 cancellation of the solicitation, officials stated that these requirements may need to be adjusted.

Technology

The program does not plan to identify its critical technologies or formally assess their associated risks until the completion of the middle-tier effort. According to Army officials, the program intends to use the prototyping effort to identify new technologies that may expand the capabilities of the program, and then assess the maturity of those technologies as it transitions into initial production.

To mitigate risks associated with this approach, Army officials told us that, if necessary, they can move forward with a baseline vehicle based on mature technologies that have already been successfully integrated into other vehicles. The Army plans to encourage potential prototyping vendors to propose solutions that would advance the technological development beyond this baseline. Army officials told us that even if proposed technological advancements remain immature at the end of the prototyping effort, the Army will still procure a baseline OMFV more advanced than the current Bradley system.

However, we have previously found that while reusing existing technologies can reduce technical risk, if the form, fit, or functionality of those technologies changes from one program to another, technology maturity may also change. The program may also face integration challenges since the sub-systems will require integration onto a new platform, one different than for which they were originally designed.

Officials also identified capabilities requiring network integration with other Army systems as an area of risk outside the program's control, because network technology development is coordinated through the Army's Network cross-functional team. To mitigate this risk, OMFV officials indicated they are using a modular design that allows for easy component replacement.

Software Development and Cybersecurity

The rapid prototyping program will require software development, but details of this effort have yet to be determined since they are dependent on the design(s) selected. Program officials said they have incorporated cybersecurity requirements and plan to include these requirements in the request for proposals. The program plans to develop and finalize a cybersecurity strategy, but will not do so until its planned transition into the initial production effort in fiscal year 2023.

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 concurred with our findings on the first iteration of the OMFV program. According to the program office, the Army followed applicable regulations and statutes, but the circumstances leading up to the Army's decision to cancel the rapid prototyping solicitation showed that more emphasis needed to be placed on competition. The program office stated that the Army remains committed to competition and innovation to deliver operational capability to the warfighter.

Source: U.S. Army.

Mobile Protected Firepower (MPF)

The Army's MPF, a middle-tier acquisition program, is intended as a new direct fire capability for the infantry brigade combat team. Infantry brigades are expected to employ MPF across a range of military operations in direct support of infantry. MPF is required to be air-transportable to enable initial entry operations. MPF is expected 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 (NGCV) portfolio.

Program Essentials

Decision authority: Army

Program office: Warren, MI

Prime contractors: BAE Systems, General Dynamics Land Systems

MTA pathway: Rapid prototyping

Contract type: FFP

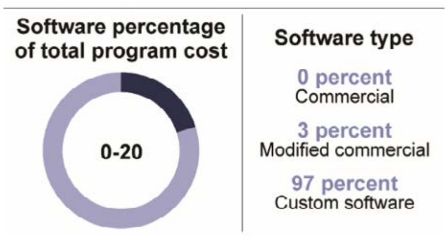
Next major event: Pre-production test (May 2020)

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

Approach: Incremental



Program Background and Expected Results

The Army initiated MPF as a middle-tier rapid prototyping effort in September 2018 with an objective to complete prototyping by June 2022. The Army initially approved MPF under the traditional DOD acquisition system in November 2016. In December 2018, the program awarded contracts to two companies to each develop 12 pre-production prototypes for test and evaluation. The program plans for these 24 prototypes to demonstrate nearly all capabilities in an operational environment by the end of the middle-tier effort. However, some capabilities will be demonstrated on initial production vehicles after the prototyping effort.

At the completion of the middle-tier effort, planned for June 2022, the program intends to select a single vendor and begin initial production using the major capability acquisition pathway. The Army's goal is to equip the first unit in fiscal year 2025.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	●	●
Approved middle-tier acquisition strategy	●	●
Technology, Cost, and Schedule Assessed		
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

MPF Program

Key Elements of a Program Business Case

The MPF program had all the elements of its business case approved by the time it was initiated as a middle-tier program. Because MPF was originally approved under the traditional DOD acquisition system, some business case documentation was developed for that approach. The Joint Requirements Oversight Council approved requirements in June 2018. The program office considers these requirements to be the basis for the rapid prototyping effort, although officials stated that these requirements could change as a result of testing or soldier input. The Army Cost Review Board approved the results of the MPF Army Cost Position in September 2018. In October 2018, the Army approved a middle-tier program strategy for competitive prototyping leading to the planned transition to the major capability acquisition pathway for production.

The Army conducted a formal schedule risk assessment prior to program initiation as part of an analysis of alternatives, and program officials stated that following program initiation as a middle-tier effort, another was conducted by a Source Selection Evaluation Board. The assessment found that the schedule was aggressive and that being able to meet it depended on whether the program had the ability to contract for technically mature designs. Program officials reported that both vendors underwent design maturity reviews 6 months after contract award to provide a design status and demonstrate progress to achieve programmatic requirements and are progressing toward prototype deliveries in calendar year 2020.

Technology

An Army Independent Review Team completed a formal technology assessment in June 2018 and determined that MPF does not have any critical technologies. According to the assessment results, the technologies selected for the program are all existing technologies that are approaching maturity or are mature. However, program officials identified integration of the different technologies as a significant risk to the program and are monitoring contractor integration efforts. While reusing existing technologies can reduce technical risk, if the form, fit, or functionality of those technologies changes from one program to another, technology maturity may also change.

Officials also identified capabilities requiring network integration with other Army systems as an area of risk outside the program's control, because network technology development is coordinated through the Army's Network cross-functional team. This network integration is a key capability for communicating with other systems. These officials noted that they regularly communicate with Network cross-functional team staff to facilitate coordination.

Software Development and Cybersecurity

The majority of MPF's software is reused since the program chose to utilize existing technologies rather than develop new ones. The program is monitoring software development efforts using progress reporting and scheduled software deliverables. However, according to program officials, MPF's accelerated acquisition process limits government oversight into software development.

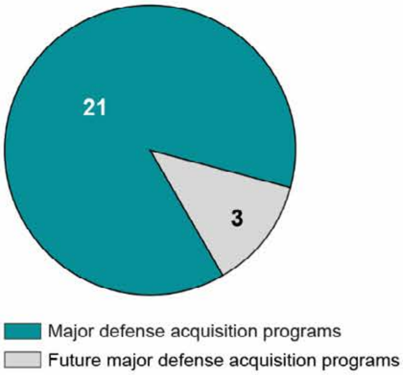
The Army Chief Information Officer approved the program's cybersecurity strategy in July 2018 and the Army subsequently performed a cyber-attack exercise to assess the program. Some network components that the program will rely on are still under development by the Network cross-functional team. The Army plans to perform full MPF cybersecurity testing in an operational environment after the program transitions to initial production. The program plans to perform a subset of these tests during the rapid prototyping effort.

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, MPF was well-prepared to capitalize on the advantages of designation as a middle-tier program since the program had already developed regulatory and statutory documentation required of a major defense acquisition program prior to middle-tier designation. In addition, the program office said it has captured required acquisition knowledge, including requirements, an acquisition strategy, and assessments for technology, cost, and schedule. The program office stated that schedule risk has remained high since the inception of the program, but that it has a mitigation plan that includes use of competition, fixed-price contracts, and use of mature low risk technologies. According to the program office, a highlight of the program schedule will be the execution of a 5-month unit-led Soldier Vehicle Assessment event that provides a soldier touch point to assess the competitive vehicle prototypes.

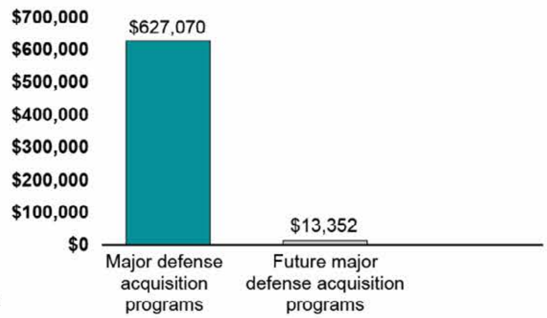
NAVY AND MARINE CORPS PROGRAM ASSESSMENTS

GAO Assessed 24 Navy Weapon Acquisition Programs



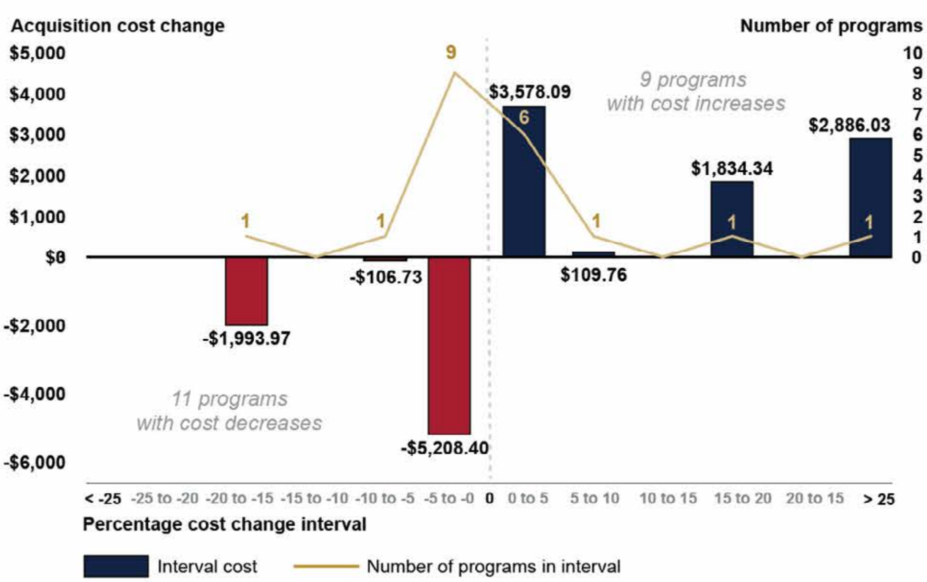
The Navy Programs GAO Reviewed Have a Combined Estimated Total Acquisition Cost of $640 Billion

(Fiscal Year 2020 dollars in millions)

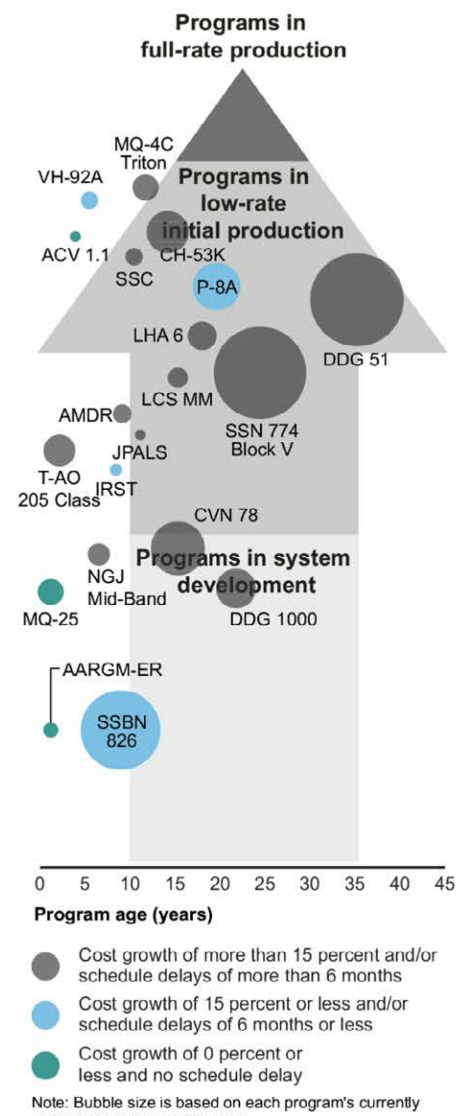


Most Navy Major Defense Acquisition Programs GAO Assessed Had Cost Decreases Since Last Year

(Fiscal Year 2020 dollars in millions)



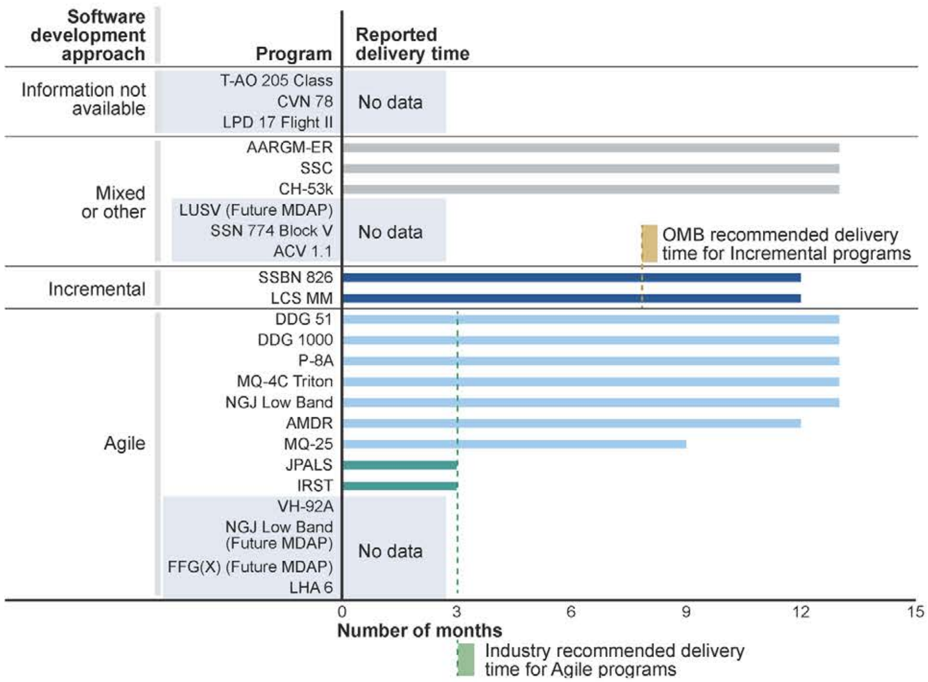
Most Navy Major Defense Acquisition Programs GAO Assessed Have Had Cost Growth, Schedule Delays, or Both since First Full Estimate



- Figures with titles that do not reference major defense acquisition programs provide information for the entire group of Navy major defense acquisition programs and future major defense acquisition programs that GAO assessed. Figures with titles that do reference major defense acquisition programs provide information for only the Navy major defense acquisition programs that GAO assessed.
- GAO excluded the LPD 17 Flight II program from the estimated total acquisition cost, acquisition cost change, and cost growth and schedule delay analyses because, as a new increment to a pre-existing program, LPD 17 Flight II did not submit a selected acquisition report or defense acquisition executive summary.
- Cost and schedule analyses are primarily based on estimates from December 2018 selected acquisition reports. This information may differ from information reported in the Program Performance table and Funding and Quantities figures in individual assessments, which are based on more recent program estimates in some cases. Please see appendix II for details.

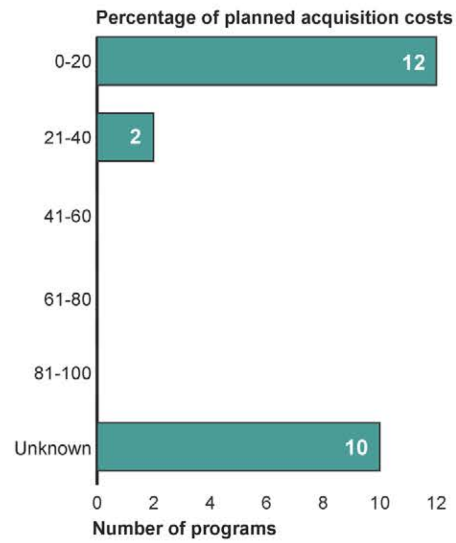
NAVY AND MARINE CORPS PROGRAM ASSESSMENTS

Navy Programs that GAO Assessed Often Reported Software Delivery Times Greater than Industry Recommendations



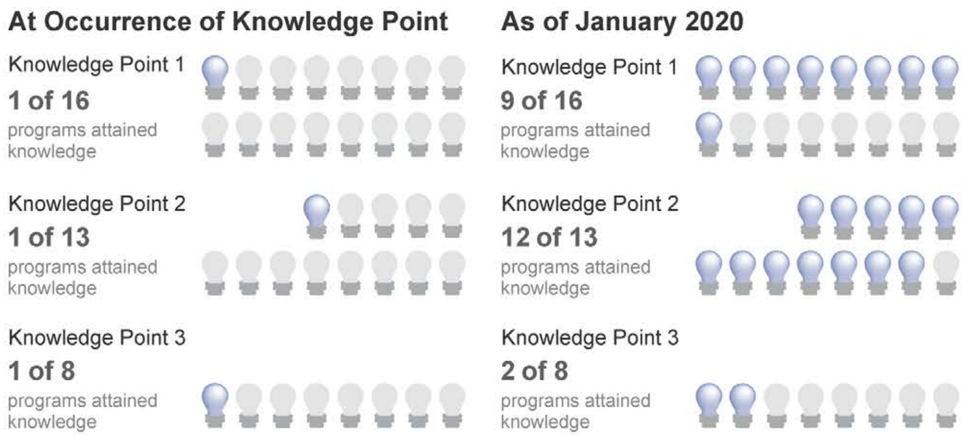
- Industry recommends deliveries on a continuing basis, as frequently as every 2 to 6 weeks for Agile programs. The Office of Management and Budget (OMB) guidance recommends deliveries every 6 months for Incremental programs. Programs reported deliveries to GAO in 0-3 month increments.

Most Navy Programs GAO Assessed Reported that Less than 20 Percent of Planned Acquisition Costs are Specifically for Software



Navy Major Defense Acquisition Programs GAO Assessed Generally Did Not Attain Knowledge at Key Points, but Some Attained Knowledge Later

- Note: For each knowledge point, GAO assessed the major defense acquisition programs that had reached that point as of January 2020. GAO excluded programs for which it determined that the practice was not applicable.



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.

Program Essentials

Milestone decision authority: Navy

Program office: Patuxent River, MD

Prime contractor: Alliant Techsystems Operations, LLC

Contract type: CPIF (development)

Next major milestone: Critical design review (February 2020)

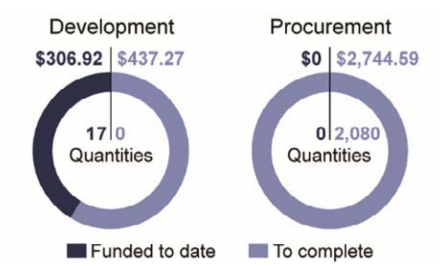
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (12/2018)	Latest (12/2018)	Percentage change
Development	$763.57	$744.19	-2.5%
Procurement	$2,747.35	$2,744.59	-0.1%
Unit cost	$1.67	$1.66	-0.6%
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.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Attainment of Product Knowledge

As of January 2020

Resources and requirements match	Status at Development Start	Current Status
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 AARGM-ER design stability or manufacturing processes because the program has not yet reached, respectively, critical design review or production start.

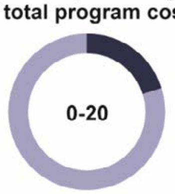
Software Development

(as of January 2020)

Approach: Spiral

Average time of software deliveries (months)

Software percentage of total program cost



Software type

14 percent Commercial

0 percent Modified commercial

86 percent Custom software

AARGM-ER Program

Technology Maturity

The AARGM-ER program entered system development in March 2019 with its one critical technology immature, contrary to best practices. Based on our past work, programs that fail to fully mature their critical technologies—demonstrate them in their final form, fit, and function within a realistic environment—before starting development are generally less likely to meet cost, schedule, and performance objectives. According to program officials, the critical technology—a flame retardant insulation for the solid rocket motor—has been demonstrated in other motors and completed a key environmental test in November 2019, which means it is nearing maturity. In addition to the one critical technology, a Navy technology readiness assessment also identified the rocket motor propellant, rocket motor casing, insensitive munitions requirements, radome, and temperature regulation of internal components as technology areas the program should monitor.

Design Stability

The AARGM-ER program does not plan to fully demonstrate that the product's design is stable by its critical design review, scheduled for February 2020. While the AARGM-ER reuses sections of the AARGM, it requires an increased missile diameter, a new rocket motor, and a control system for the missile fins. According to program officials, all of the missile's design drawings will be releasable by its critical design review. However, contrary to best practices, the Navy will not test a system-level integrated prototype by then, an approach that could present risks for design changes when system-level integration testing takes place. Instead, a program official said testing prior to the design review will be limited to ground tests of the AARGM-ER's guidance and controls, rocket motor, and control actuation system, which will not be integrated with one another. According to program officials, the first flight test will occur over 1 year after the design review and just prior to the program's planned production decision. The program is also developing a new warhead and fuze, both of which it hopes to integrate into the missile before production. While the program expects these new components to improve safety and reliability, the timing of their development also poses risk to the schedule by likely prolonging the time needed for safety certification.

Production Readiness

The AARGM-ER program has leveraged production knowledge from the AARGM program and plans to demonstrate its critical manufacturing processes prior to a production decision in March 2021, which would be consistent with best practices. However, the program office has not yet scheduled a production-representative prototype test, and it does not plan to complete system-level developmental testing until after production starts. DOD policy allows some concurrency between developmental testing and initial production, but we have previously found that starting production before demonstrating that a system will work as intended increases the risk of deficiencies that require costly design changes.

Software and Cybersecurity

In its December 2018 selected acquisition report, the AARGM-ER program reported there were no significant software-related issues. However, the program reported to us that it has experienced challenges hiring enough government and contractor staff with the required expertise to complete software development in time to perform planned work, and that software engineering staffing plans were not realized as planned.

The ARGM-ER program is working to assess cybersecurity. According to officials, the AARGM-ER program recently completed a cybersecurity exercise. A DOD independence assessment found that AARGM-ER's development schedule provides margin to address any risks prior to operational testing and evaluation.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that in February 2020, it conducted a system-level design review with the prime contractor and government subject-matter experts, as well as reviews with ordnance safety boards. It also said results from subsystem-level testing show technical maturity and design stability.

According to the program office, it successfully completed design verification tests of production-representative rocket motors at the most environmentally stressing conditions. It also said the results demonstrated rocket motor performance, design maturity, and technology readiness, and that the first test of the warhead demonstrated lethality. In addition, the program stated that it has started aircraft integration testing and completed the first instrumented measurement vehicle, which will be used for aircraft integration flight test events.

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 and Land Armaments LP; Science Applications International Corporation (SAIC)
Contract type: FPI/FFP/CPFF (development—SAIC) (development and low-rate initial production—BAE Systems and Land Armaments LP)
Next major milestone: Start of operational testing (June 2020)

Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (05/2016)	Latest (08/2019)	Percentage change
Development	$845.65	$841.67	-0.5%
Procurement	$1,123.46	$1,148.80	+2.3%
Unit cost	$8.42	$8.43	+0.0%
Acquisition cycle time (months)	57	57	+0.0%
Total quantities	240	240	+0.0%

The Navy has yet to develop a baseline for the merged Family of Vehicles, so cost and cycle time estimates only reflect ACV 1.1. Since our last assessment, the program updated its development estimate to include past costs it did not previously report. Total quantities comprise 36 development quantities and 204 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

Attainment of Product Knowledge

As of January 2020

	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

Software Development

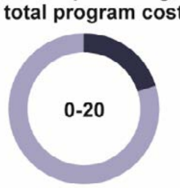
(as of January 2020)

Approach: Waterfall

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Officials stated the last software delivery was June 2019. There were four software deliveries in 10 months during development.

ACV Program

Technology Maturity, Design Stability, and Production Readiness

The ACV program has matured its critical technologies and stabilized its system design but has continued to have problems over the past year meeting reliability goals. Additionally, although the program began production in 2018, it has yet to reach the level of manufacturing readiness that acquisition best practices recommend programs achieve before production start.

During 2019, the program worked to address ongoing challenges related to the ACV not meeting some reliability growth targets during its most recent testing. Program officials reported that the majority of failures continue to be related to the government-furnished remote weapon station. To address this issue, the program initiated an assessment to identify the root cause and determined that the issue was related to the reliability of the weapons themselves. As a result, it has incorporated design changes it considers minor, such as developing a shield to deflect spent casings. Program officials said, overall, they made approximately 40 to 50 design changes to improve reliability. These officials added they are completing the last round of reliability testing for the prototypes and that the next test results will be available in the third quarter of 2020. The program will conduct the remaining reliability testing with the first production vehicles, which will include design changes based on previous testing on the prototypes. The program office stated that it had completed testing of a system-level integrated prototype and provided associated documentation. Based on this information, we have updated our attainment of product knowledge graphic to reflect this change from our previous assessment.

Officials reported that in October 2019 the program exercised an option for the third lot of low-rate initial production, which includes 30 vehicles. The program also reported that the first two low-rate initial production lots included a total of 60 vehicles, of which the contractor has delivered 13 vehicles, including four that will be used exclusively for testing. However, the program has yet to achieve manufacturing readiness levels recommended by acquisition best practices, which increases the likelihood of costly rework. Program officials said that they plan to complete the next manufacturing readiness assessment in March 2020.

The Marine Corps has delayed the estimated start of initial operational test and evaluation by 4 months to June 2020 and the full-rate production decision 3 months to September 2020. The program office attributed these schedule slips to delays in ACV deliveries by the contractor due in part to supply chain challenges and an overly-optimistic learning curve. The program still plans to achieve initial operational capability before the end of fiscal year 2020.

Software and Cybersecurity

According to program officials, the purpose of software development was primarily to modify existing software. The contractor delivered the last vehicle software delivery in June 2019 as updates to the ACV vehicle management system and driver display panel components. The contractor made a previous software delivery in October 2018 to correct problems with headlights and radios. During development, the contractor provided four software deliveries in 10 months after design review and before initial vehicle acceptance. The program noted that it has not experienced any software related changes to the program cost estimate.

The program stated that it has an approved cybersecurity strategy in place and has completed several types of cybersecurity assessments, including an adversarial assessment and penetration testing. Program officials noted that they completed an evaluation for potential cybersecurity vulnerabilities in March 2018.

Other Program Issues

According to program officials, the Marine Corps is moving forward with plans to increase the production quantity of ACVs as well as develop new variants of the standard ACV model with different mission profiles. The variant mission profiles include command and control, maintenance and recovery, and a variant with a medium caliber lethality upgrade. The Marine Corps ultimately plans to produce 1,122 ACVs total and held a critical design review in March 2019 for the command and control variant. Officials reported that in June 2019, the program executed a contract modification with BAE Systems to develop the ACV variants. The program plans to update its cost and schedule estimates as well as other acquisition planning documents for the full rate production decision in September 2020 to reflect the additional variants and expanded production quantities.

Since our last assessment, program officials said that they updated the reported development funding to include past costs it did not report in 2017 due to inconsistencies in how cost data were reported in the selected acquisition report for that year.

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.

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.

CONCEPT
- 09/10 Program start

SYSTEM DEVELOPMENT
- 09/13 Development start
- 04/15 Critical design review
- 05/17 Low-rate decision
- 01/20 GAO review

PRODUCTION
- 08/20 First production radar delivered
- 05/23 Start operational test
- 08/24 End operational test/Initial capability

Program Essentials

Milestone decision authority: Navy

Program office: Washington Navy Yard, DC

Prime contractor: Raytheon

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

Next major milestone: First production radar delivery (August 2020)

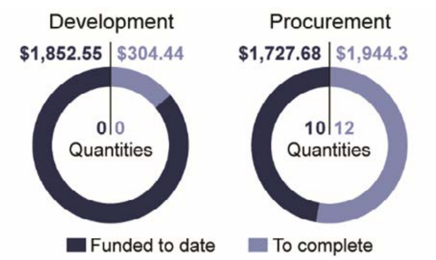
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (10/2013)	Latest (07/2019)	Percentage change
Development	$2,088.71	$2,156.99	+3.3%
Procurement	$4,319.93	$3,671.98	-15.0%
Unit cost	$292.77	$266.41	-9.0%
Acquisition cycle time (months)	156	161	+3.2%
Total quantities	22	22	+0.0%

Total quantities comprise 0 development quantities and 22 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Attainment of Product Knowledge

As of January 2020

	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

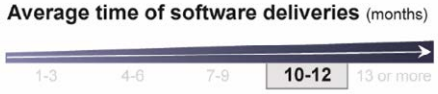
We did not assess AMDR's demonstration of critical processes on a pilot production line because the program considers this metric not applicable. According to program officials, the program does not have any critical manufacturing processes.

Software Development

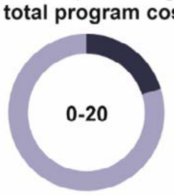
(as of January 2020)

Approach: Agile

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

AMDR Program

Technology Maturity, Design Stability, and Production Readiness

In April 2019, the Navy approved AMDR to procure its 10th low-rate initial production radar in fiscal year 2020. According to the program, it has mature critical technologies, a stable design, and production processes in control. However, we continue to disagree that the technologies are fully mature. While the Navy continues to demonstrate some technologies through land-based testing at its Pacific Missile Range Facility (PMRF) and plans to integrate AMDR with the Aegis combat system at a separate land-based site for simulation and testing, AMDR's critical technologies cannot be assessed as fully mature until the Navy integrates AMDR and Aegis on the lead DDG 51 Flight III ship in 2022 during the Aegis Light Off (ALO) event. Following ALO, the Navy will operationally test AMDR and Aegis in a realistic, at-sea environment on the lead DDG 51 Flight III ship in 2023. While AMDR's design is currently stable, it remains at risk for disruption until the Navy completes this testing. In part, this risk is driven by the fact that the Navy is procuring more than two-thirds of its 22 total radars prior to completing operational testing. Any deficiencies the Navy discovers during at-sea testing could require revisions to existing design drawings or retrofitting to already built radars, which would likely increase costs or delay radar deliveries.

In order to support initial radar integration and testing with Aegis beginning in 2020, the Navy plans to install production radar components at the Aegis combat system land-based test site in New Jersey. Program officials said this is the first opportunity for AMDR and Aegis contractors to integrate the systems to test interfaces and software compatibility. The land-based tests will inform software development and integration of AMDR and Aegis in support of ALO on the lead DDG 51 Flight III ship in 2022.

AMDR is well into low-rate initial production but has yet to demonstrate statistical control of its critical manufacturing processes—an approach inconsistent with acquisition best practices. In December 2019, the program exercised contract options that brought the number of low-rate production units purchased to nine. However, the contractor continues to experience cost and schedule growth on production radars due to issues with its Digital Receiver Exciter (DREX)—a critical technology—and price variances on component materials, which could affect the program's procurement cost estimate if issues are not resolved. Officials said a DREX subcomponent does not meet its vibration specifications, despite a recent contractor redesign. The program is exploring multiple mitigation options. The contractor reported that these issues have delayed delivery of the first radar to at least August 2020, 4 months later than the contract's delivery date. Program officials said they could mitigate the issue by delivering the radar to the ship without the DREX unit and installing the unit later with minimal impact to the schedule. However, delays have already consumed schedule margin and may threaten the first DDG 51 Flight III installation in 2020 as well as AMDR/DDG 51 Flight III operational testing in 2023.

Software and Cybersecurity

AMDR has completed six of its nine software deliveries to support core radar capabilities, but additional development remains to add capabilities, integrate cybersecurity measures, and integrate AMDR with Aegis. Software is incrementally released every 4 months for testing before the final build is delivered to the end user every 10-12 months. Program officials said this aligns with Aegis software development, which is being developed concurrently. AMDR and Aegis software development will continue through 2021 while both systems integrate and test software.

The Navy has conducted some initial cybersecurity testing with AMDR but will not fully test cybersecurity capabilities with Aegis until at least 2023. However, the program reports some cost growth due to implementing cybersecurity controls. If cybersecurity issues arise during testing, additional software development may cause further cost growth or disrupt operational testing.

Other Program Issues

The program is developing an Advanced Distributed Radar (ADR) capability that leverages existing Navy technologies. The ADR capability increased the program's cost estimate, and the Navy projects it will require additional development funds through 2027. ADR is expected to improve AMDR capability through radar enhancements. ADR will be integrated on existing AMDR systems through software upgrades. The Navy plans to finalize ADR requirements and begin development in 2020. Full ADR capability will not be fielded until after the first AMDR-equipped DDG 51 Flight III is fielded in 2024.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. It stated that AMDR design is stable but software deficiencies might be discovered during testing; AMDR's demonstrated performance exceeded its performance thresholds during land-based testing; and initial radar and Aegis integration began in 2016 and is on track to support ALO and operational testing. The program office also said the contract type for the low-rate initial production units minimizes the impact of component price variances and some radar components have been delivered to support DDG 51 Flight III construction schedules. According to the program office, initial cybersecurity updates are on track to complete in 2021.

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 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, General Electric

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

Next major milestone: Start of operational testing (May 2021)

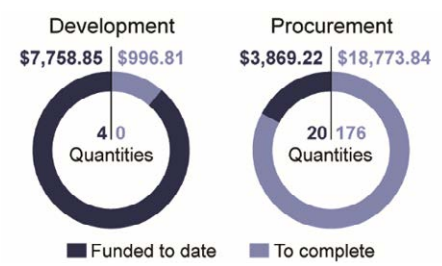
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (12/2005)	Latest (09/2019)	Percentage change
Development	$5,045.21	$8,755.66	+73.5%
Procurement	$14,031.45	$22,643.06	+61.4%
Unit cost	$122.29	$157.06	+28.4%
Acquisition cycle time (months)	117	189	+61.5%
Total quantities	17	200	+28.2%

Total quantities comprise 4 development quantities and 196 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

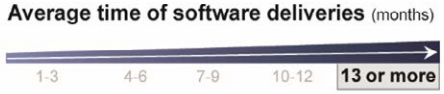


Software Development

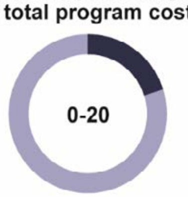
(as of January 2020)

Approach: Waterfall

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Attainment of Product Knowledge

As of January 2020

Resources and requirements match	Status at Development Start	Current Status
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

The CH-53K program has continued to have challenges and delays with initial production over the past year. The program entered production in March 2017 with mature critical technologies and a stable design but with undemonstrated production processes. Since then, the program office has reported over 100 technical issues identified during developmental testing, including exhaust gas re-ingestion in the aircraft and high stress on the main gear rotor box. Technical issues have caused delays in the testing schedule and increased program costs due to ongoing design changes. For example, the Navy requested a reprograming of an additional $158 million to resolve technical issues in time to support operational testing, which is planned to start June 2021.

In February 2019, the Navy approved a Joint Program Plan, which accounts for time needed to resolve technical issues and complete testing before reaching initial operating capability, currently scheduled for September 2021. According to program officials, all technical issues will be resolved by mid-2020. However, in July 2019 the program reported additional testing delays and low test execution rates related to two issues. First, problems with the fuel cells required the Navy to delay testing while a solution was identified. Program officials stated this design issue is unique to the developmental aircraft and is not present in production ready models. Second, according to program officials, an engine compartment overheated because maintenance procedures were not followed. As a result, the Navy stopped flight tests for several weeks to conduct intensive training on maintenance procedures.

The CH-53K production line has not demonstrated that its critical manufacturing processes are in statistical control—an approach inconsistent with acquisition best practices. While DOD guidance does not require statistical control of production processes until the full rate production decision, best practices show the production line should be in statistical control prior to production start in order to ensure manufacturing processes are repeatable, sustainable, and capable of consistently producing parts within quality standards.

Planned delivery of the first two low-rate production aircraft has been delayed over a year from July 2020 to September 2021. Program officials stated they have intentionally stalled production in order to incorporate changes needed to fix technical issues found in testing. Despite testing and production delays, the program office has not adjusted the schedule for purchasing low-rate production aircraft. The program office has awarded or plans to award 20 out of 38 low-rate production aircraft prior to the completion of developmental testing. Our prior work has shown that making additional low-rate procurements of systems before key capabilities are proven and test events are completed increases the risk that purchased systems will require costly modifications after delivery.

Software and Cybersecurity

The program office worked toward solutions for software related technical issues discovered in developmental testing. For example, the program office discovered a failure in software to detect the transition from ground to flight causing increased safety concerns. The program has determined the cause of this issue and is implementing a path forward that includes an upcoming software delivery. However, the program reported it has experienced difficulty hiring enough government and contractor staff with required expertise to complete software development.

In February 2017, the program testing plan was expanded, to include additional cybersecurity testing requirements. Since then the program conducted several cybersecurity assessments during developmental testing, which did not provide the data needed to support cybersecurity planning to reach initial operating capability. According to officials, the program plans 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. Our past 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.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, it is continuing to execute to the Joint Program Plan and has demonstrated solutions for many of the technical issues identified to date. In addition, the program office expects to make up any delays in the testing schedule by mid-2020 and complete that testing on time to support initial operational test and evaluation. The program office stated that to reduce concurrency risk and ensure adequate demonstration that manufacturing processes are within statistical control, the Navy approved an updated acquisition strategy in November 2019 and added two low-rate production lots before full-rate production.

According to the program office, software staffing is currently adequate and development is on track. The program stated there were no cybersecurity requirements when development began in 2005, but requirements were added in 2017. The program said it is now addressing these requirements through both government engineering analysis and contractor assessment and testing.

Source: U.S. Navy.

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.

CONCEPT
- 06/00 Program start

SYSTEM DEVELOPMENT
- 05/04 Construction preparation contract award

PRODUCTION
- 07/07 Production decision
- 09/08 Detail design and construction contract award
- 06/15 Second ship contract award
- 05/17 Lead-ship delivery
- 01/20 GAO review
- 03/21 Initial capability
- 08/22 Start operational test

Program Essentials

Milestone decision authority: Navy
Program office: Washington, DC
Prime contractor: Huntington Ingalls Industries
Contract type: CPFF/CPIF (CVN 79) construction preparation; FPI (CVN 79) detail design/construction; FPI (CVN 80) detail design/construction; FPI (CVN 81) detail design/construction
Next major milestone: Initial operational capability (March 2021)

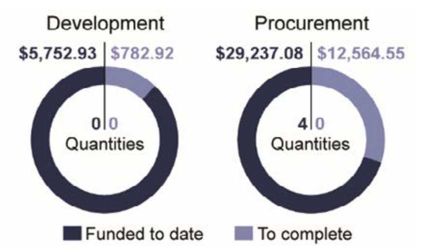
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (04/2004)	Latest (09/2019)	Percentage change
Development	$5,534.56	$6,535.85	+18.1%
Procurement	$35,455.44	$41,801.63	+17.9%
Unit cost	$13,663.33	$12,146.07	-11.1%
Acquisition cycle time (months)	137	203	+48.2%
Total quantities	3	4	+33.3%

Total quantities comprise 0 development quantities and 4 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Attainment of Product Knowledge

As of January 2020

Resources and requirements match	Status at Construction Preparation Contract Award	Current Status
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.

Software Development

(as of January 2020)

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 program offices.

CVN 78 Program

Technology Maturity, Design Stability, and Production Readiness

This year the Navy reported that all 12 of the Ford Class's critical technologies were fully mature, an increase from the nine technologies that were mature at delivery. However, while the Navy assessed the advanced weapons elevators as mature, it ended the first post-delivery maintenance period in October 2019 with only four of the 11 elevators certified to operate. Further, none of the elevators that operate between the main deck and the lower decks are currently operational, which means the elevators are still not capable of bringing munitions to the flight deck. The Navy is working with the shipbuilder to complete all elevator work by Spring 2021—an 18-month delay from the schedule we reported last year. The Navy also constructed a land-based site to test the performance and reliability of the elevators, which is expected to be ready in early 2021.

Despite maturing its critical technologies, the Navy is still struggling to demonstrate the reliability of key systems, including the electromagnetic aircraft launch system (EMALS); Advanced Arresting Gear (AAG); and dual band radar (DBR). The Navy is continuing shipboard testing for these systems but has delayed operational testing by 18 months while it revises the test schedule to coordinate test schedules and complete deployment preparations. Although the Navy is testing EMALS and AAG on the ship with aircraft, the reliability of those systems remains a concern. If these systems cannot function safely by the time operational testing begins, CVN 78 will not be able to demonstrate it can rapidly deploy aircraft—a key requirement for these carriers.

Challenges in maturing CVN 78's critical technologies has led to their redesign or replacement on later ships in some cases. CVN 79 repeats the CVN 78 design with some modifications and replaces DBR with the Enterprise Air Surveillance Radar (EASR), which is in development. The Navy plans to procure two EASR units for CVNs 79 and 80 and install the CVN 79 unit during that ship's second phase of delivery. CVNs 80 and 81 will repeat the design of CVN 79.

Software and Cybersecurity

Software development for CVN 78's critical technologies is managed through separate program offices. For example, a separate program office manages AAG and EMALS, which rely on a mix of commercial and custom software. According to program officials, the Navy assessed these systems for cybersecurity vulnerabilities in August and October 2019. According to CVN 78 program officials, other ship systems have also undergone, or are scheduled to undergo, cybersecurity penetration or adversarial testing. The 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

In September 2019, the Navy increased the CVN 78 cost cap by $197 million to $13.2 billion in part to correct deficiencies in the advanced weapons elevators. This is the Navy's third adjustment to the cost cap since 2017. CVN 78's procurement costs increased by over $2.7 billion from its initial cost cap. Continuing technical deficiencies mean the Navy may still require more funding to complete this ship.

Further, the Navy is unlikely to obtain planned cost savings and construction efficiencies on the next three ships in the Ford class. We previously reported on the optimistic cost and labor assumptions for CVN 79, based on a projected 18 percent labor hour reduction compared to hours to construct CVN 78. In 2019 the shipbuilder increased the estimated cost at completion due to using more labor hours for CVN 79 than expected. In addition, the Navy awarded a contract to buy two carriers simultaneously—CVNs 80 and 81—based on the assumption that this strategy will save the Navy over $4 billion. However, the Navy's cost analysis showed that CVN 80 and 81 have a high likelihood of experiencing cost overruns, and it is uncertain whether the Navy can achieve the expected savings. The Navy assumed a further reduction in labor hours compared to CVN 79—about 25 percent fewer labor hours than CVN 78—will contribute to cost savings for these ships.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that CVN 78 is in an 18-month post-delivery testing phase; completed over 2,000 aircraft launches and recoveries since delivery in May 2017; and completed numerous test events and certifications. According to the program office, the Navy certified four elevators and plans to certify two more in April and September of 2020, and five remaining elevators are on track for certification in fiscal year 2021. The program stated that the Navy launched CVN 79 2 months ahead of schedule in December 2019, and construction is 70 percent complete. It also said Navy leadership approved a change for CVN 79 from a two-phase acquisition to a single phase delivery strategy and released a request for proposals for this new approach in January 2020. Additionally, the program stated that the Navy awarded the CVNs 80 and 81 detail design and construction contract in January 2019 and projected savings of over $4 billion compared to a single ship contract; CVN 80 construction is 3 percent complete and scheduled for delivery in 2028; and CVN 81 has begun material procurement and is scheduled for delivery in 2032.

Source: BAE Systems San Diego.

DDG 1000 Zumwalt Class Destroyer (DDG 1000)

The DDG 1000 destroyer 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 (HM&E) 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, D.C.

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

Contract type: FPI/FFP/CPFF (ship construction); CPFF/CPAF (mission systems equipment)

Next major milestone: Lead-ship final delivery (March 2020)

Funding and Quantities

(fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

Approach: Agile and DevOps

Average time of software deliveries (months)

Software percentage of total program cost

Software type

0 percent Commercial

13 percent Modified commercial

87 percent Custom software

According to program officials, the program does not track software cost elements.

Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (01/1998)	Latest (09/2019)	Percentage change
Development	$2,624.96	$12,140.48	+362.5%
Procurement	$37,476.80	$14,008.14	-62.6%
Unit cost	$1,253.18	$8,716.20	+595.5%
Acquisition cycle time (months)	128	285	+122.7%
Total quantities	32	3	-90.6%

Total quantities comprise 0 development quantities and 3 procurement quantities.

Attainment of Product Knowledge

As of January 2020

	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 has fully matured most, but not all, of its nine original current critical technologies and reports a stable design. According to the Navy, the vertical launch system, infrared signature, and total ship computing environment are each continuing to approach maturity. The Navy expects to fully mature these systems as it completes ship construction, certification, and testing over the next 2 years. In addition to these nine technologies, the Navy has now added three critical technologies to meet its new mission: a communication system, an intelligence system, and the seeker on an offensive strike missile. These technologies are planned to be mature when they are integrated onto the ship, but this integration will not occur until several years after the ship undergoes testing. The Navy plans to complete operational testing of the lead ship in September 2021.

As of January 2020, the DDG 1000 program continues to finish construction on all three ships while still maturing the remaining critical technologies and further defining the ship's new mission. The Navy planned to complete delivery of the DDG 1000 with its combat systems in April 2020—a delay of 6 months from last year's review. In total, the lead ship is now 2 years late compared to the Navy's original plans to complete this milestone.

The Navy plans to complete delivery of the DDG 1001 with its combat systems in September 2020. Navy program officials stated that by leveraging lessons learned from DDG 1000 combat system activation, they can complete DDG 1001 combat systems delivery in less than 3 years. Lastly, the Navy plans to deliver DDG 1002 with its combat systems in September 2022—a 9-month delay from last year's estimate.

Software and Cybersecurity

As we reported last year, the Navy plans to complete software development for the class in September 2020—a delay of 24 months since our 2018 assessment largely due to optimistic schedules for development. As a result, the Navy has had to delay some testing that the ship must complete before it is ready to deploy. In addition, although the lead ship was delivered in 2016, the program is still continuing to deliver software builds that achieve some of the promised automation. Since the software is not as capable and does not enable as much automation as originally planned, among other things, the Navy has permanently added 31 sailors to the crew compared to initial estimates, increasing life-cycle costs.

The program plans to complete a cybersecurity vulnerability evaluation in fiscal year 2021 connected with section 1647 of the National Defense Authorization Act for Fiscal Year 2016. The program expects that this evaluation, along with the remainder of a 2-year regimen of certifications and several different tests in September 2020, will demonstrate the full functionality of the ship's systems, including cybersecurity capability. According to program officials, no cybersecurity issues have been identified to date.

Other Program Issues

In January 2018, the Navy changed the ship class's primary mission from land attack to offensive surface strike and updated its requirements document to reflect this new mission in July 2018. To begin to enable the new surface strike mission over the next 5 or more years, the Navy is requesting $160 million for four new systems for the ships: two missile systems, a communications system, and an intelligence system. One missile system is planned to be installed on all three ships by September 2021 at a cost of $66 million. The second missile system is not planned to be installed on any of the ships for at least 5 years and needs significant development at a cost of $45 million—additional funds will be needed to purchase and install the system. The communications system will be installed on all three ships by fiscal 2023 and costs $22 million. Lastly, the intelligence system is not planned to be installed on any of the ships for at least 5 years and needs significant development at a cost of $40 million—additional funds will be needed to purchase and install the system.

The cost to develop and install these four systems is in addition to the program's procurement cost as it is accounted for in other procurement and research and development funding. According to Navy officials, the Navy may continue to add capability to support the new mission.

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 office stated that it is making good progress in delivering DDG 1000 class ships to the fleet. After our date for assessing new information from programs, the office stated that in March 2020 the DDG 1000 had achieved sufficient combat system installation and activation for the Navy to take delivery and transition to the next phase of developmental and integrated at-sea testing. Further, the office said that in 2019, the DDG 1000 spent more than 100 days at sea to maintain crew proficiency, support fleet operations, conduct testing and provide an early opportunity for the ship to engage in operational scenarios. It also said the DDG 1001 completed its combat availability in March 2020 with a successful sea trial and is transitioning to combat systems activation. The office also said the final ship of the class, DDG 1002, is under construction and 93 percent complete, and that integration of the new systems will add offensive capability against targets afloat and ashore across the DDG 1000 class.

Source: U.S. Navy.

Guided Missile Frigate (FFG(X))

The Navy's guided missile frigate program is intended to develop a multi-mission small surface combatant based on a proven ship design that provides enhanced lethality and survivability compared to the Littoral Combat Ship. **In April 2020, the Navy announced the award of the FFG(X) detail design and construction contract, months earlier than scheduled. DOD comments on a draft of this report did not state the Navy planned to accelerate the award. This assessment does not reflect the April 2020 award because it occurred after our review period.**

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

- 05/19 Preliminary Design Review
- 01/20 GAO review
- 02/20 Development start
- 07/20 Lead-ship detail design contract
- 07/22 Lead-ship fabrication start
- TBD Lead-ship delivery
- Initial capability (Future event; the Navy deemed the actual date as not suitable for public release)

Program Essentials

Milestone Decision Authority: Navy

Program office: Washington Navy Yard, DC

Prime contractor: TBD

Contract type: FPI (detail design and construction; planned)

Next major event: Development start (February 2020)

This assessment does not reflect the Navy's recent decision to award the FFG(X) detail design and construction contract on April 30, 2020.

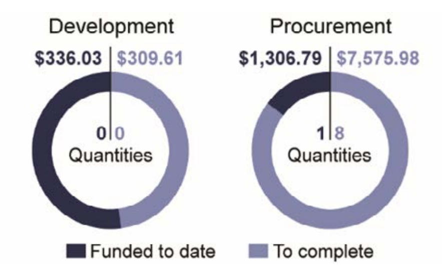
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (N/A)	Latest (10/2019)	Percentage change
Development	N/A	$645.64	N/A
Procurement	N/A	$8,882.77	N/A
Unit cost	N/A	$1,058.71	N/A
Acquisition cycle time (months)	N/A	124	N/A
Total quantities	N/A	9	N/A

We are reporting cost and quantity amounts that align with the program's Future Years Defense Program estimates because the current cost estimate provided by the program does not include a full funding profile beyond fiscal year 2024. The Navy plans to update its full cost estimate following the detail design and construction contract award.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Software Development

(as of January 2020)

Approach: Agile, DevOps, and DevSecOps

Software percentage of total program cost	Software type
Information not available	14 percent Commercial 0 percent Modified commercial 86 percent Custom software

Funding and quantity information is based on Navy estimates through fiscal year 2024. Software data reflects the Aegis program's software development to support FFG(X). The FFG(X) program does not track software cost.

Attainment of Product Knowledge

As of January 2020

	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(X) because the Navy's technology readiness assessment for the program found that the ship does not have any. We also did not assess the ship's design stability because the Navy had not yet to selected a ship design for FFG(X) construction at the time of our review's cut-off date for assessing new information.

FFG(X) Program

Technology Maturity

The Navy completed a technology readiness assessment for FFG(X) in March 2019. The assessment, which Navy officials said included a review of about 150 systems, identified no critical technology elements that pose major technological risk during development. DOD has yet to complete an independent technical risk assessment for FFG(X). An official from the Office of the Under Secretary of Defense for Research and Engineering who is participating in the FFG(X) risk assessment said that delays in obtaining required information from the Navy make it unlikely the assessment will be completed before the program's development start decision. If incomplete, information available to inform decision makers on the sufficiency of the Navy's efforts to account for technical risk factors will be diminished.

The FFG(X) design approach includes the use of many existing combat and mission systems to reduce technical risk. However, one key system—the Enterprise Air Surveillance Radar (EASR)—is still in development by another program. EASR, which is a scaled down version of the Navy Air and Missile Defense Radar program's AN/SPY-6(V)1 radar currently in production, is expected to provide long-range detection and engagement of advanced threats. The Navy is currently conducting land-based testing on an EASR advanced prototype, with FFG(X)-specific testing planned to begin in 2022. The Navy also expects to integrate versions of the radar on other ship classes beginning in 2021, which may reduce integration risk for FFG(X) if the Navy is able to incorporate lessons learned from integration on other ships during FFG(X) detail design activities.

Design Stability

The Navy used the results from an FFG(X) conceptual design phase to inform the program's May 2019 preliminary design review as well as the ongoing contract award process for detail design and construction of the lead ship. In early 2018, the Navy competitively awarded FFG(X) conceptual design contracts to five industry teams. Conceptual design was intended to enable industry to mature parent ship designs for FFG(X)—designs based on ships that have been built and demonstrated at sea—as well as inform requirements and identify opportunities for cost savings. Navy officials said the specific plan for detail design will be determined based on the winning proposal.

Software and Cybersecurity

According to the FFG(X) acquisition strategy, the program is structured to provide mission systems and associated software to the shipbuilder as government-furnished equipment. These systems, which are provided by other Navy programs, include a new version of the Aegis Weapon System—FFG(X)'s combat management system—to coordinate radar and weapon system interactions from threat detection to target strike. Navy officials said FFG(X)'s Aegis Weapon System will leverage at least 90 percent of its software from the Aegis common source software that supports combat systems found on other Navy ships, such as the DDG 51-class destroyers.

The Navy approved the FFG(X) cybersecurity strategy in March 2019. The strategy states the program's cyber survivability requirement was a large driver in the development of network architecture. The Navy's strategy also emphasizes the importance of the ability of the ship to operate in a cyber-contested environment. The Navy will consider cybersecurity for the systems provided by the shipbuilder—which control electricity, machinery, damage control, and other related systems—as part of selecting the FFG(X) design.

Other Program Issues

In October 2019, DOD confirmed that the Navy did not request that prospective shipbuilders include warranty pricing to correct defects after ship deliveries in their proposals for the competitive FFG(X) detail design and construction contract award, as we previously recommended. Instead, the Navy required that the proposals include guaranty pricing with limited liability of at least $5 million to correct defects, which could allow for a better value to the government than has been typical for recent shipbuilding programs. However, warranty pricing could have provided the Navy with complete information on the cost-effectiveness of a warranty versus a guaranty. Our prior work has found that using comprehensive ship warranties instead of guarantees could reduce the Navy's financial responsibility for correcting defects and foster quality performance by linking the shipbuilder's cost to correct deficiencies to its profit.

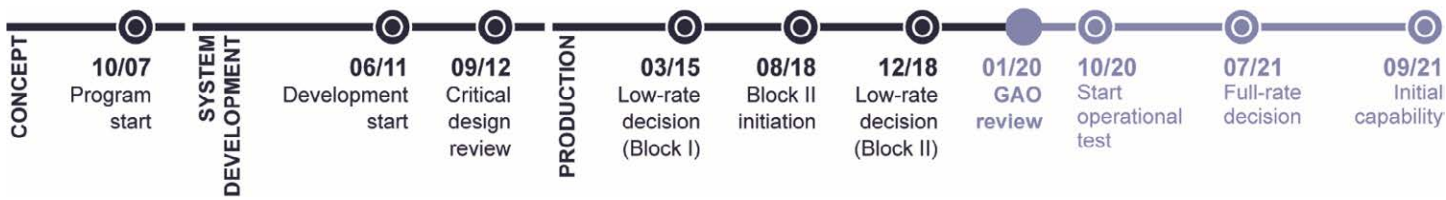
Program Office Comments

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 Navy is working to satisfy the requirement for an independent technical risk assessment requirement prior to development start. Regarding warranties, the program office stated the solicitation allows shipbuilders to propose a limit of liability beyond the $5 million requirement. It said this arrangement represents an appropriate balance between price and risk; ensures that the shipbuilder is accountable for the correction of defects that follow acceptance; and allows shipbuilders to use their own judgment in proposing the value of the limit of liability. The program office also said the Navy will evaluate the extent to which any additional liability amount proposed above the minimum requirement provides a meaningful benefit to the government, and will evaluate favorably a higher proposed limitation of liability value, up to an unlimited guaranty.

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 not effective. The Navy is acquiring IRST with an evolutionary acquisition approach that includes two system configurations or blocks. With Block I, the program integrated an existing IRST system onto the F/A-18 fuel tank. With Block II, it is developing an improved sensor, upgraded processor, and additional software. We assessed Block II.



Program Essentials

Milestone decision authority: Navy

Program office: Patuxent River, MD

Prime contractor: Boeing

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

Next major milestone: Start of operational testing (October 2020)

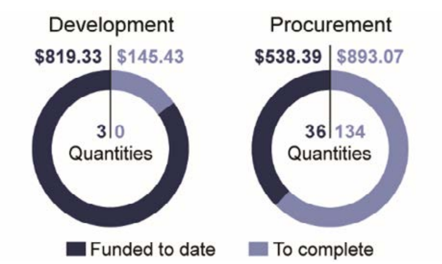
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (02/2017)	Latest (09/2019)	Percentage change
Development	$925.16	$964.76	+4.3%
Procurement	$1,393.32	$1,431.46	+2.7%
Unit cost	$12.95	$13.85	+6.9%
Acquisition cycle time (months)	123	123	+0.0%
Total quantities	179	173	-3.4%

Total quantities comprise 3 development quantities and 170 procurement quantities. Funding and quantities reflect amounts for the full program, consistent with how the program reports these data.

Funding and Quantities

(fiscal year 2020 dollars in millions)



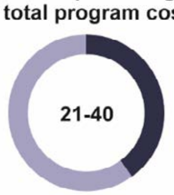
Software Development

(as of January 2020)

Approach: Agile

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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. Program officials said that this software was tested most recently in an operationally representative environment in March 2019. As of October 2019, the program had released about 97 percent of Block II design drawings, which indicates a stable design.

The program initiated production in December 2018, before completing development. According to program officials, this approach was in an effort to achieve initial operational capability by the end of fiscal year 2021. Our previous work has shown that this type of concurrent approach increases risk of program cost growth and schedule delays. Further, although the program said it has tested a system-level integrated prototype, it does not plan to test a production representative prototype until March 2021—about 27 months after entering production. Our prior work has shown that testing such a prototype before starting production reduces the risk of costly design changes and rework. Program officials said the program has accepted the risk of potential rework in order to meet schedule goals. They anticipate any rework would be minor because they have tested hardware and software in configurations similar to those planned for Block II.

The program plans to conduct an informal Test Readiness Review in March 2020 and start Block II flight testing thereafter. According to program officials, the program received approval from DOD's Director, Operational Test and Evaluation (DOT&E) to use six Block II prototypes—which are planned to be delivered by early 2020—to begin operational testing prior to the delivery of production representative articles. These officials said prototypes will have the same interfaces and performance characteristics as production representative articles. However, the start of operational testing has been delayed by about 2 months to October 2020 due to delayed delivery of updated F/A-18 software needed for the testing, according to program officials. Program officials said that they plan for initial capability in September 2021; however, this schedule leaves less time to address deficiencies that may be found in testing.

The program also began production of Block II without both demonstrating critical manufacturing processes on a pilot production line and being within statistical controls—inconsistent with best practices. Program officials stated that they demonstrated critical manufacturing processes through production of prototype hardware. They reported that Block I critical processes are being demonstrated, and they have identified no significant risks for Block II processes. However, the program reported Block II manufacturing readiness to be lower now than at the start of Block II production. Program officials said that manufacturing processes will be mature and within statistical control in early 2021, and plan to conduct a production readiness review by early 2021 as they prepare to ramp up production rates.

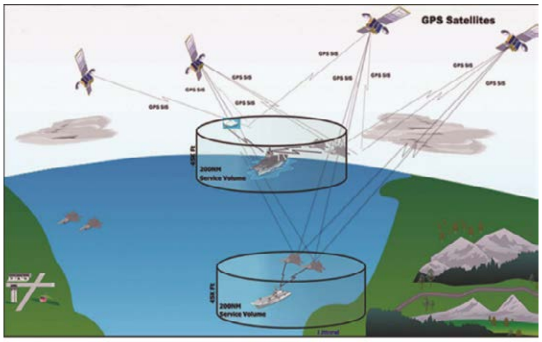
Software and Cybersecurity

Officials said that the program completed most of the planned software development. They stated that any future software changes would be made to improve the tracking system's ability to process additional target motion and aggressive maneuvers and would not require changes to system hardware. They stated that they plan to identify and address software issues during multiple flight testing events. However, a December 2018 independent assessment by officials from the Office of the Under Secretary of Defense for Research and Engineering noted that the program's accelerated schedule will make it challenging to address software deficiencies found during testing.

Program officials said that they plan to start preliminary IRST cyber testing in April 2020 before two sequential cybersecurity tests that a DOT&E official said were needed to satisfy DOT&E cyber testing requirements. In September 2021, the program plans to conduct a cooperative vulnerability and penetration assessment. Program and DOT&E officials indicated the results of this test will inform the design of an adversarial assessment planned for late 2022. Per program officials, the Commander, Operational Test and Evaluation Force (COMOPTEVFOR) will assess IRST cybersecurity based on the results of the adversarial assessment.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program provided technical comments, which we incorporated where appropriate. Program officials said that, based on Block I and Block II system similarities, long lead procurement, and urgency of need, concurrent development is necessary and appropriate. Further, they stated that existing Block I hardware was modified to use a Block II interface and is in use in three fleet squadrons to reduce risk and enable early software maturation. The officials stated that system maturity has been demonstrated with the Block II capital asset on an F/A-18 and flight testing will begin in 2020. They also stated that schedule compression makes addressing software deficiencies found during test challenging, but they expect mitigation measures and established Block I processes will ensure software is mature and stable prior to operational testing. Additionally, they said that based on prototype and production configuration similarities, DOT&E and COMOPTEVFOR agreed to begin operational test with prototypes. They also stated that the program assessed all critical manufacturing processes for Block II as mature and demonstrated through previous IRST production.



Source: U.S. Navy.

Joint Precision Approach and Landing System (JPALS)

JPALS is a program to develop a Global Positioning System (GPS)-based aircraft landing system that will allow aircraft such as the F-35 Lightning II and the MQ-25 Unmanned Aircraft System to operate from aircraft carriers and amphibious assault ships. With JPALS, the Navy intends to provide a reliable, sea-based precision approach and landing capability that is effective in adverse weather conditions. JPALS functionality is primarily software-based, although it will also feature off-the-shelf hardware such as antennas and racks.

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

- 07/08 Development start
- 06/16 Restructured development start
- 05/17 Restructured critical design review
- 04/19 Production decision
- 01/20 Start operational test/GAO review
- 09/20 End operational test
- 11/20 Initial capability

Program Essentials

Milestone decision authority: Navy

Program office: Lexington Park, MD

Prime contractor: Raytheon

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

Next major milestone: End of operational test (September 2020)

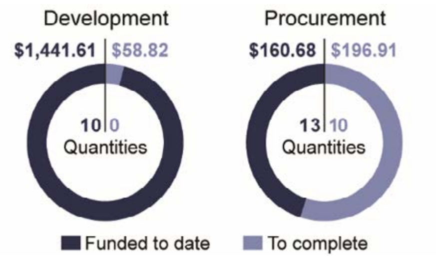
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (07/2008)	Latest (09/2019)	Percentage change
Development	$912.69	$1,500.43	+64.4%
Procurement	$245.70	$357.59	+45.5%
Unit cost	$31.52	$56.55	+79.4%
Acquisition cycle time (months)	74	148	+100.0%
Total quantities	37	33	-10.8%

During this year's assessment, we found that the program's initial estimate differed from the original Acquisition Program Baseline schedule by three months. We updated our analysis to reflect the initial schedule estimate to be consistent with the methodology we use for other programs. Total quantities comprise 10 development and 23 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



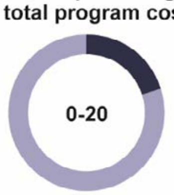
Software Development

(as of January 2020)

Approach: Agile and Waterfall

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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	●	●

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

We did not assess some JPALS manufacturing maturity metrics because the program considers them not applicable. Program officials stated that JPALS does not have any critical manufacturing processes.

JPALS Program

Technology Maturity, Design Stability, and Production Readiness

Program officials reported that JPALS's two critical technologies reached maturity during 2019, and the program has released all of its design drawings, which corresponds with a stable design. JPALS program officials also reported successfully testing production representative prototypes in their intended environment prior to the Navy approving the program to enter into production in April 2019. The program will not reach a full-rate production decision. According to the program, JPALS does not have any critical manufacturing processes because the program is primarily using commercial hardware.

The program is scheduled to take delivery of three production units during fiscal year 2020. Program officials stated that, since the program entered into production, they have been working to address obsolescence issues related to the shipboard GPS sensor unit. They reported awarding a contract modification in May 2019 to produce new sensor units that do not include the obsolescent parts. Until these new sensor units are produced, the functionality of JPALS production units is at risk.

Program officials currently anticipate completing operational testing by September 2020 and achieving initial capability in November 2020. The initial capability date has been delayed by 2 months since our last assessment because the program has experienced scheduling challenges with having Navy ships available for JPALS testing.

Software and Cybersecurity

JPALS achieves its functionality through custom software developed utilizing both Agile and Waterfall software approaches. According to program officials, working software is deployed to users approximately every 1 to 3 weeks, which aligns with industry practices to deliver working software on a continuing basis. Officials reported completing system-level developmental testing in March 2019. Because JPALS is GPS-based, it will need to be compatible with M-code—a new military GPS signal being developed by the Air Force that is designed to improve anti-jamming and secure access for military users. JPALS program officials stated they contracted for a trade study to determine future M-code integration and implementation options. They noted that the contractor completed an initial portion of the study but cannot complete additional portions until there is further development of M-code, putting the future integration of JPALS with M-code at risk.

In June 2018, JPALS issued an updated cybersecurity strategy, and the program has completed cooperative vulnerability and penetration assessments, as well as adversarial assessments, during testing. The program noted that it has not experienced cost or schedule growth as a result of addressing cybersecurity requirements.

Other Program Issues

JPALS originally entered system development in July 2008. The Navy restructured the JPALS program and revised its milestones, with a new development start in June 2016. Because the program was originally started in 2008, our attainment of product knowledge table assesses the program's knowledge at its original development start and original critical design review events. This methodology is consistent with how we have previously assessed JPALS and other programs that have repeated key program events.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that they concur with our assessment, and are continuing activities with the contractor to mitigate any risk to JPALS and M-code integration.

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 from 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.

Program Essentials

Milestone decision authority: Navy

Program office: Washington Navy Yard, DC

Prime contractor: Northrop Grumman

Contract type: CPFF/FFP/FPI (development and production)

Next major milestone: Antisubmarine warfare initial capability (June 2020)

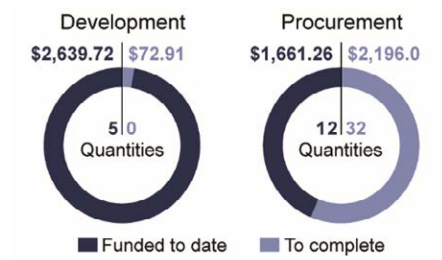
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (08/2007)	Latest (09/2019)	Percentage change
Development	N/A	$2,712.63	N/A
Procurement	$3,755.39	$3,857.26	+2.7%
Unit cost	N/A	$134.80	N/A
Acquisition cycle time (months)	N/A	N/A	N/A
Total quantities	64	49	-23.4%

Total quantities comprise 5 development and 44 procurement packages.

Funding and Quantities

(fiscal year 2020 dollars in millions)



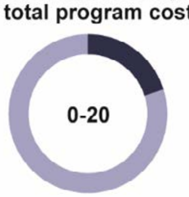
Software Development

(as of January 2020)

Approach: Incremental

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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 has reduced the overarching MCM package's requirements and is still purchasing and preparing to deploy partial packages. Officials stated that the Navy's revised requirements focus on the ability of individual systems to communicate on an LCS rather than achieve mine clearance rates. This is a change from our 2019 assessment, in which the Navy stated that it was only seeking approval to update requirements for deep mine hunting, one kind of MCM capability, because they were too ambitious and the technology had not performed as needed. According to a DOD test official, the revised MCM package requirements are not representative of expected missions and environments. As such, the program may not be acquiring systems that can achieve effective military capabilities.

The program continues to take delivery of systems that have met individual requirements but that have not been tested to ensure they can achieve overarching MCM package requirements. While officials believe that meeting system requirements will satisfy overarching MCM requirements, current operational test plans do not account for the delivery of incomplete packages. Moreover, officials have stated that the program has proposed eliminating some developmental testing and significantly reducing operational testing due to the revised requirements. As a result, the program may not identify problems with how the systems interact on an LCS or confirm if the crew can operate and maintain sufficient systems, which could limit package capability. To close an anticipated MCM capabilities gap, the Navy has continued to request funding for some systems that have not achieved initial operational capability (IOC) or that rely on systems that have not completed operational testing, such as the unmanned surface vehicle. This approach risks buying systems that do not meet operational needs and additional program delays.

The Navy plans to buy 24 MCM packages for 15 MCM-assigned LCS. According to officials, the program is buying more packages than LCS to meet overall Navy MCM mission demand. The Navy has yet to determine how it will deploy all 9 unassigned packages.

Surface Warfare (SUW)

The Navy plans to procure 10 SUW packages for eight SUW-assigned LCS, one for test ships, and one spare. It has begun to field full packages, which include the gun mission module and maritime security module, as well as partial packages. The program has awarded production contracts for the 10th and final gun mission module and maritime security module. The Navy also successfully tested its surface-to-surface missile module (SSMM) using Longbow Hellfire missiles on both LCS variants and declared SSMM IOC in 2019. With SSMM IOC, the SUW package meets threshold requirements for baseline capabilities for the complete mission package.

Antisubmarine Warfare (ASW)

The Navy plans to procure 10 ASW packages for eight ASW-assigned LCS, one for test ships, and one spare. It plans to begin deploying LCS with full ASW packages in 2022. The Navy currently has one preproduction ASW package embarked on LCS 3 for developmental and operational testing. Officials stated that LCS 3 has undergone alterations to test the Escort Mission Module (EMM), which started developmental testing in September 2019. Given the small margin for completing ASW package testing, any delays EMM testing could impact plans for achieving ASW package IOC in 2020.

Software Development and Cybersecurity

Program officials reported that software development efforts have contributed to increased program cost estimates. The program has funded software development teams significantly longer than planned because of schedule delays and the integration of systems that were not originally planned to meet requirements, such as the Longbow Hellfire missile and Unmanned Influence Sweep System.

The program conducted cybersecurity vulnerability and penetration assessments and adversarial assessments during operational testing in 2015. According to the program, repeated vulnerabilities were identified during these tests. The DOD cybersecurity vulnerabilities evaluation is scheduled for completion in March 2021. Our past 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.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program provided technical comments, which we incorporated where appropriate. According to the program, formal testing for the individual systems that comprise the MCM package inform, in part, the production decisions for those systems. The program stated that these systems have completed testing in a realistic environment and that all systems have begun initial production. The program said that the Navy has also physically integrated all MCM modules on LCS variants. Further, the program stated it will operationally test MCM system-of-systems command, control, and integration capabilities, which rely on the same communications link as used in shore-based, system testing. The program stated it will procure systems once they complete system tests and demonstrate performance, and that the Navy and Joint Requirements Oversight Council have endorsed the revised MCM requirements that our assessment identified. The program also said ongoing tests of the ASW package on LCS 3 are on track to complete in fiscal year 2020.

Source: Boeing.

MQ-25 Unmanned Aircraft System (MQ-25 Stingray)

The Navy's MQ-25 is a catapult-launched unmanned aircraft system that will operate from aircraft carriers. The Navy expects MQ-25 to provide a refueling capability for the carrier air wing and the intelligence, surveillance, and reconnaissance capabilities needed to identify and report on surface targets, such as ships. The program is made up of an aircraft segment, a control station segment, and a carrier modification segment. We evaluated the aircraft development segment, which represents about 70 percent of the Navy's planned investment in the MQ-25 program over the next 5 years.

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

- 08/18 Development start
- 01/20 GAO review
- 03/20 System critical design review
- 02/23 Low-rate decision
- 06/24 End operational test
- 08/24 Initial capability
- 12/26 Full-rate production decision

Program Essentials

Milestone decision authority: Navy

Program office: Patuxent River, MD

Prime contractor: Boeing

Contract type: FPI (development)

Next major milestone: System critical design review (March 2020)

Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (08/2018)	Latest (08/2019)	Percentage change
Development	$3,630.15	$1,907.72	-47.4%
Procurement	$9,119.95	$8,520.81	-6.6%
Unit cost	$172.73	$146.24	-15.3%
Acquisition cycle time (months)	72	72	+0.0%
Total quantities	76	76	+0.0%

Total quantities comprise 7 development quantities and 69 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

	Development	Procurement
Funded to date	$1,231.69	$0
To complete	$676.03	$8,520.81
Quantities (funded to date / to complete)	7 / 0	0 / 69

Software Development

(as of January 2020)

Approach: Agile, 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: 0-20

Software type

- 0 percent Commercial
- 0 percent Modified commercial
- 100 percent Custom software

Attainment of Product Knowledge

As of January 2020

	Status at Development Start	Current Status
Resources and requirements match		
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 the MQ-25's design stability because the program has not yet conducted the final system design review or manufacturing process maturity because the MQ-25 has not yet reached production.

MQ-25 Stingray Program

Technology Maturity

The Navy identified no critical technologies for MQ-25. However, the program relies on two critical technologies being developed under the Joint Precision Approach and Landing System program, which are fully mature. Our Attainment of Product Knowledge table accounts for these two technologies.

Design Stability

The program is conducting design activities in advance of its system critical design review, currently planned for March 2020. For example, the program conducts biweekly design reviews to continuously assess maturation and adequacy of the design. The program also tested a system-level integrated prototype of the aircraft from September 2019 through February 2020. According to the program office, the focus of early prototype testing is the basic airworthiness, engine performance, and understanding the aerodynamic challenges posed by the inlet configuration. Program officials said that the current shape of the inlet causes aerodynamic conditions that may result in engine damage. Following the system-level preliminary design review, the program plans to test fixes for the engine inlet to minimize its risk to the aircraft's development.

Production Readiness

The Navy has scheduled the low-rate initial production decision for February 2023—8 months earlier than the date we reported in our 2019 assessment. This change stemmed from a program review of the schedule Boeing developed and provided to the Navy in November 2018 after the development contract award. Program officials acknowledged the schedule is aggressive, but stated that they believe it is achievable. The Navy plans to award the production contract on a sole-source basis to Boeing in the second quarter of fiscal year 2023 for 69 aircraft, 12 of which will be low-rate initial production aircraft. Officials report that, although Boeing is not required under the development contract to provide manufacturing readiness level data, the program office plans to collect pertinent data to determine manufacturing maturity as the production contract award approaches. In connection with this award, the program office also plans to review critical suppliers and their data to assess suppliers' manufacturing readiness. The program plans for suppliers to demonstrate statistical control of manufacturing processes at production start, in line with acquisition best practices.

Software and Cybersecurity

Program officials reported challenges in finding and hiring government and contractor staff with required expertise to perform planned software development work. They also identified shortfalls in software development lab facilities, and software engineering staffing plans were not realized as planned. Program officials now plan to complete software integration by the program's August 2024 initial operational capability date.

The MQ-25 program office has conducted multiple cybersecurity assessments and believes it has mitigated several identified vulnerabilities. The program plans to address the remaining vulnerabilities prior to declaring MQ-25 initial operational capability.

Other Program Issues

At the time of the award, Boeing's development contract included a ceiling price of approximately $805 million for the base, fixed-price incentive development effort—a total much lower than the Navy's initial development cost estimate. According to program officials, the Navy anticipated the submission of strategic low pricing for this contract because of investments made prior to development award. Program officials stated that, among other things, the Navy's potential inability to maintain its schedule commitments could require modifications to the contract that would impact the fixed price terms. Specifically, the Navy faces limited flexibility to install MQ-25 control centers on aircraft carriers. If the Navy misses any of its planned installation windows, the program would have to extend MQ-25 development testing by up to 3 years. According to officials, such a delay could necessitate a delay to initial capability and result in a cost increase.

The development contract includes delivery of four development aircraft, with options for up to three additional test aircraft. The contract does not include options for the 69 planned production aircraft. Program officials said Boeing will provide cost, technical, and programmatic data during the development phase, which the Navy intends to use to help it negotiate the planned sole source award to Boeing for the production aircraft.

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 concurred with the contents of this assessment. After our review's cut-off date for assessing new information, the program office stated that the system-level critical design review concluded in March 2020 and that, in April 2020 the Navy exercised the option to purchase the three additional test aircraft for $84.6 million.

Source: MQ-4C Triton B-5.

MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)

The Navy's MQ-4C Triton is an unmanned aircraft system based on the design of the Air Force's RQ-4B Global Hawk air vehicle. It is intended to provide the Navy with persistent maritime and littoral intelligence, surveillance, and reconnaissance (ISR) data collection and dissemination capability, relaying airborne communications from locations where no other naval forces are present to military personnel stationed at five operational sites worldwide.

Program Essentials

Milestone decision authority: Navy

Program office: Patuxent River, MD

Prime contractor: Northrop Grumman

Contract type: Cost-sharing (development) FPI (low-rate initial production) FFP (low-rate initial production spares)

Next major milestone: Start operational test (December 2020)

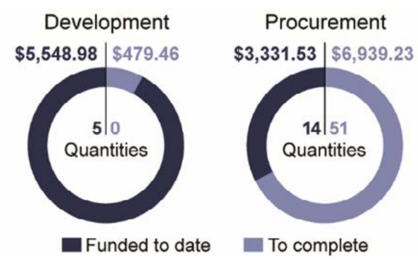
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (02/2009)	Latest (07/2019)	Percentage change
Development	$3,619.88	$6,028.44	+66.5%
Procurement	$10,742.55	$10,270.76	-4.4%
Unit cost	$211.47	$237.81	+12.4%
Acquisition cycle time (months)	92	156	+69.6%
Total quantities	70	70	+0.0%

Total quantities comprise 5 development quantities and 65 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Attainment of Product Knowledge

As of January 2020

Resources and requirements match	Status at Development Start	Current Status
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 some technology metrics because the program stated it no longer has critical technologies, or the current status of manufacturing readiness levels because the program said it no longer tracks these levels.

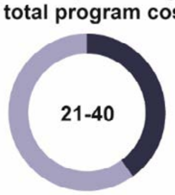
Software Development

(as of January 2020)

Approach: Agile and Incremental

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Commercial

15 percent Modified commercial

85 percent Custom software

MQ-4C Triton Program

Technology Maturity, Design Stability, and Production Readiness

The MQ-4C Triton system relies on no critical technologies and the overall design is stable. Even so, as the Triton transitioned from its earlier Integrated Functional Capability (IFC) 3 software platform to its final, multiple-intelligence capable IFC 4 software and hardware platform, beginning in 2017, program officials identified some necessary redesign of on-board communication systems. They stated an engineering solution for the hardware deficiency of one of these communication systems is being installed on IFC 4 aircraft currently in production. However, a hardware and software solution for the other is still being developed. The program reported that the aircraft's overall design is stable, but these issues mean that some aircraft will require retrofit once the solution is completed.

Although program officials still expect initial operational capability to be achieved in April 2021, program officials now expect to obtain approval to begin full-rate production in November 2021, about 4 months later than it expected last year.

There are 11 manufacturing processes critical to the Triton program, none of which had reached the level of manufacturing readiness that acquisition best practices recommend at the time of production start. Further, program officials explained they are no longer tracking manufacturing readiness levels since there is no difference in the planned production rate between low-rate initial and full-rate production. We have updated our Attainment of Product Knowledge graphic to reflect this change from our previous assessment.

Program officials reported continued improvements to the Triton's wing manufacturing process, which accounts for four of 11 critical processes. Specifically, the number of wing defects reported for each aircraft produced between 2017 and 2019 has fallen by 84 percent. These improvements can be attributed to the wing contractor's continued implementation of root cause corrections, such as designing tools that prevent user error and updating work instructions.

Software and Cybersecurity

The MQ-4C program is using Agile and Incremental development approaches to deliver software to fleet operators every 13 months or more. Office of Management and Budget and DOD guidance both call for regular incremental deliveries to users. We also previously reported that involving users in early stages and obtaining frequent feedback helps reduce risk and is critical to software development success. Program officials reported that they experienced challenges in hiring enough government and contractor staff with the required expertise to perform planned work. Officials said that total program costs increased in part as a result of the software development effort due to defects and rework, personnel turnover, and software and hardware integration issues.

The program has an approved cybersecurity strategy in place and has conducted multiple types of cybersecurity assessments. The program identified unplanned software development efforts to meet cybersecurity needs as contributing to software being an area of risk and reported both cost and schedule growth due to these challenges. A program official stated in January 2020 that the program was in the process of rating cyber risks that have been identified for the program. A cyber-risk assessment debrief is planned for March 2020.

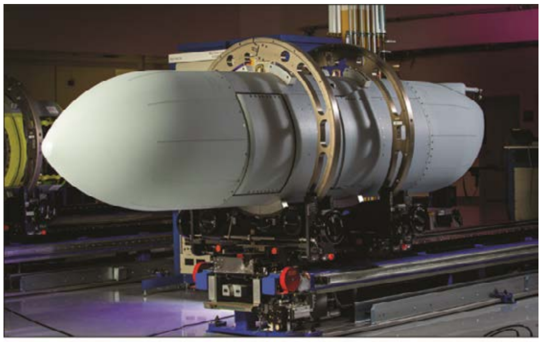
Other Program Issues

Program officials reported that the Triton achieved baseline early operational capability in January 2020, later than the June to September 2019 period that had previously been established for this milestone.

Since our last assessment, the program has experienced $196.2 million in development cost growth. Aside from the unplanned software development efforts noted above, program officials also identified the late discovery and correction of on-board communication system deficiencies and integration of new multiple-intelligence sensors and architecture as contributing factors.

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, along with the MQ-4C prime contractor and the Defense Contract Management Agency, it continues to conduct incremental manufacturing assessments on the retrofit and production of IFC-4 aircraft. It said these assessments identify and evaluate the manufacturing process, including staffing, facilities, tooling, production methods, parts availability, and other manufacturing planning. Additionally, the program office stated that it tracks, mitigates, and reports to senior management any identified manufacturing risks. The program also noted that our assessment uses fiscal year 2020 dollars while the program sets a base year for funds for its reporting, so total and unit costs differ accordingly between our assessment and the program's reporting.



Source: The Raytheon Company.

Next Generation Jammer Mid-Band (NGJ MB)

The Navy's NGJ MB is an external jamming pod system that the Navy plans to integrate on EA-18G Growler aircraft. It 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' use of the electromagnetic spectrum for radar detection, among other purposes. The Navy plans to field the system that jams mid-band radio frequencies in 2022. The Navy has a separate program for low-band frequencies and will roll out a high-band program at a later date. We assessed the Mid-Band program.

Program Essentials

Milestone decision authority: Navy

Program office: Patuxent River, MD

Prime contractor: Raytheon; Boeing

Contract type: CPIF (development – Raytheon) (development and integration – Boeing)

Next major milestone: Low-rate initial production (September 2020)

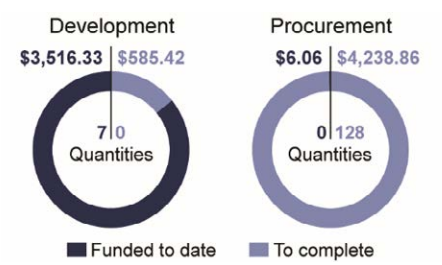
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (04/2016)	Latest (09/2019)	Percentage change
Development	$3,734.97	$4,101.75	+9.8%
Procurement	$4,328.07	$4,244.92	-1.9%
Unit cost	$59.78	$61.88	+3.5%
Acquisition cycle time (months)	98	110	+12.2%
Total quantities	135	135	+0.0%

Total quantities comprise 7 development quantities and 128 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



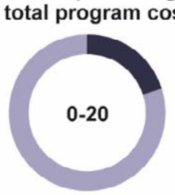
Software Development

(as of January 2020)

Approach: Agile and Waterfall

Average time of software deliveries (months)

Software percentage of total program cost



Software type

22 percent Commercial

11 percent Modified commercial

67 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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 Mid-Band manufacturing maturity because the system has not yet reached production.

NGJ-MB Program

Technology Maturity and Design Stability

The NGJ-MB program has yet to fully demonstrate the maturity of its critical technologies or the stability of its design—an approach inconsistent with best practices. Until the program fully matures its critical technologies—by demonstrating each in a final form, fit, and function within a realistic environment—the program's design faces risk of change. The program plans to demonstrate the maturity of its critical technologies and stability of its design before its planned September 2020 production decision.

The program entered system development in April 2016 with its seven critical technologies, including arrays and a power generation system, approaching maturity. Ground testing of a fully integrated prototype pod began in November 2019. However, the program does not plan to have its critical technologies fully mature, integrated, and in flight testing until March 2020.

As of October 2019, the NGJ MB contractor had released 100 percent of the system's design drawings and delivered the first redesigned pod structure to the Navy for testing. Program officials said that they considered the redesign of the pod structure to be stable, although the contractor continues to make minor changes to it. In April 2017, the program discovered design deficiencies with the pod structure at its critical design review, which contributed to a 1-year schedule delay and an over $400 million increase in the program's development cost. Accordingly, the program updated its cost and schedule in November 2018. The pod structure was redesigned, but according to the program office, the critical technologies, subsystems, and software were not affected. Since our 2018 assessment, the program increased its total number of design drawings. As a result, NGJ-MB released 85 percent of its drawings at the critical design review—an amount that falls short of the 90 percent level recommended by best practices. We have updated our Attainment of Product Knowledge table to reflect this change in design stability at critical design review from our previous assessment.

Production Readiness

The NGJ-MB program's current plans do not call for the program to fully demonstrate the maturity of its manufacturing processes prior to the start of production in September 2020. The program office plans to demonstrate its critical manufacturing processes on a pilot production line, which would be consistent with best practices. However, inconsistent with best practices, the program office does not plan to test a production-representative prototype or complete system-level developmental testing until 7 and 17 months, respectively, after production starts. We have previously found that starting production before demonstrating that a system will work as intended increases the risk of deficiencies that require costly design changes. Program officials told us that they plan to mitigate this risk by gathering data about pod performance during testing in ground test chambers and through flight testing engineering development models. The program must also demonstrate key performance requirements for the power, spatial and frequency coverage, and stability of the pod's jamming beam before it can be approved for production.

Software and Cybersecurity

Program officials identified software development as a risk to the program, stating that the software effort was more difficult than expected. Specifically, officials reported it has been difficult to find and hire government and contractor staff with required expertise in time to perform planned work. In addition, the NGJ-MB program is dependent on the EA-18G aircraft's software. Consequently, as the EA-18G's software upgrade efforts have evolved, the NGJ-MB program has had to evolve with it.

The program has an approved cybersecurity strategy and has conducted limited cybersecurity assessments. The program is scheduled to complete an evaluation for potential cybersecurity vulnerabilities in April 2020.

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. NGJ-MB program officials commented that they plan to deliver one software product to the fleet so the average time of software deliveries we calculated in our software graphic is not applicable. However, as reflected in our graphic, the length of time to develop the one software product is over 13 months. NGJ-MB program officials also told us that as of January 2020, they have tested a system-level integrated NGJ-MB engineering development model, which has been installed on an EA-18G aircraft, in ground test chambers. According to the program office, this testing demonstrates the maturity of the pod's critical technologies and design maturity. Program officials also stated that the testing reduces risk to the pod's first flight on an EA-18G aircraft, which is planned for the third quarter of fiscal year 2020. In addition, the program said it plans to build the production pods in the same facility that the engineering development model pods are manufactured, which it stated 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 2080. According to the Navy's current acquisition plan, the lead ship will make its first patrol in June 2030.

CONCEPT
- 01/11 Technology development start

SYSTEM DEVELOPMENT
- 09/17 Detail design contract award
- 01/20 GAO review
- 05/20 Production readiness review/contract option award first two submarines

PRODUCTION
- 10/20 Lead-ship contract option exercised & fabrication start
- 10/27 Lead-ship delivery
- 06/30 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/CPFF (design and development)
Next major milestone: Production readiness review (May 2020)

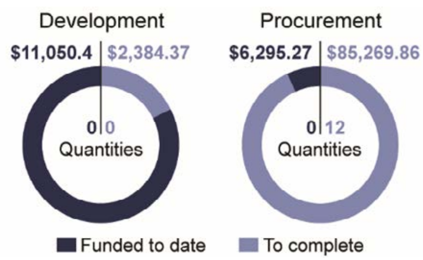
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (01/2017)	Latest (07/2019)	Percentage change
Development	$13,448.27	$13,434.77	-0.1%
Procurement	$92,957.47	$91,565.12	-1.5%
Unit cost	$8,880.20	$8,763.81	-1.3%
Acquisition cycle time (months)	231	237	+2.6%
Total quantities	12	12	+0.0%

Total quantities comprise 0 development quantities and 12 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

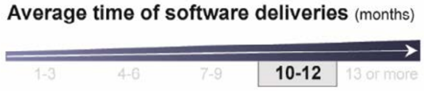


Software Development

(as of January 2020)

Approach: Incremental

Average time of software deliveries (months)



Software percentage of total program cost

Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Officials said they are not tracking software in their cost reporting system.

Attainment of Product Knowledge

As of January 2020

	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	NA	NA

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

The program stated that it had achieved basic and functional design for SSBN 826, but we did not credit them for this metric because the program has not yet reached its formal fabrication start date of October 2020.

SSBN 826 Program

Technology Maturity and Design Stability

The Columbia class program continues to monitor one critical technology—the stern area system, which it anticipates will reach maturity in mid-2022. The Navy reports that another technology it previously identified as critical—a carbon dioxide removal system—has matured to the point it is no longer considered critical. In December 2017, we reported that the nuclear reactor, integrated power system, propulsor and shafting met GAO's definition of critical technologies, but the Navy did not identify them as such.

Navy officials reported that the nuclear reactor is mature as of late 2018 based on its evaluation of test data, but several other technologies we previously identified as critical remain immature. Manufacturing challenges delayed the delivery of the integrated power system's first production-representative motor by 2 years, from 2017 to 2019.The Navy still plans to concurrently test the motor, update its design, and build the lead submarine's motor, then deliver the integrated power system to the shipyard in October 2022 as scheduled despite the compressed timeframe created by this delay. Finally, the Navy does not expect the propulsor and shafting to reach maturity until after the lead submarine is delivered in fiscal year 2026, because the Navy does not plan to test all components together in their final form, fit, and function prior to delivery. If deficiencies in these immature technologies emerge during testing, they could cause costly and time-intensive design changes and re-work, jeopardizing the lead submarine's first patrol date.

As of September 2019, the shipbuilder had completed 100 percent of the basic and functional design of the submarine—consistent with best practices, but risks to design stability remain. Design stability is based on assumptions about the final form, fit, and function of critical technologies and how those technologies will perform in a realistic environment, which the program has not fully demonstrated. Further, a key tenet of the program's cost and schedule goals assumes that the shipbuilder will complete 83 percent of detail design by October 2020. Over the past year, the shipbuilder missed its monthly detail design goals due to inefficient design software. Program officials report the shipbuilder increased its design staff in an effort to recover its schedule. However, delayed detail designs are impacting material orders, slowing construction progress, and jeopardizing the design completion goal.

Production Readiness

The Navy plans to begin construction in October 2020, but already began some work starting in December 2018. Through its advance construction efforts the Navy believes that the shipbuilder can achieve the lead submarine's aggressive 84-month construction schedule. For example, the Navy has been constructing missile tubes for the common missile compartment since 2014 to prove production capabilities. However, in 2018 and 2019 the shipbuilder found that some tubes the Navy planned to install on the lead submarine had weld defects. As a result, the shipbuilder will produce a replacement missile tube section for the lead submarine. Navy officials report they are still assessing the cost and schedule impacts of this change due to repair delays and issues with a second tube vendor.

Software and Cybersecurity

The program involves a software development effort, but it does not track software development as part of its cost and schedule reporting structure. According to program officials, they do not track costs in part because some of their software was developed by another Navy program, and other software is reused from other ships with minor modifications.

The program has an approved cybersecurity strategy and has completed several cybersecurity assessments, including adversarial assessments during developmental and operational testing. The program is scheduled to complete an evaluation for potential cybersecurity vulnerabilities in December 2020.

Other Program Issues

Supplier quality and capacity continue to pose a risk to the lead submarine's delivery schedule. After discovering defective missile tube welds, the Navy and shipbuilder reviewed supplier quality assurance practices and found weld quality problems throughout the industrial base due to increased demand from shipbuilding programs and a reduction in independent supplier oversight. The Navy is increasing oversight of high-risk suppliers and investing in improving quality. At the same time, the Navy has accelerated its plans to finalize negotiations and award the shipbuilder a contract option for the first two submarines from October to May 2020. The Navy plans to exercise the option in early 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. The program office stated that an updated cost estimate is being finalized to inform lead submarine funding. According to the program, the Navy recognizes that its supplier base remains high risk and is committed to increased oversight on manufacturing issues and readiness assessments. The program said it complies with all Navy, DOD, and statutory requirements for managing critical technologies, and that proving the technologies in a relevant environment would add costs and delay building the lead submarine.

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) CPFF (long lead materials and early production)

Next major milestone: Start of operational testing (April-June 2021)

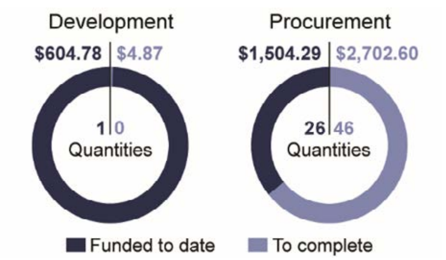
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (07/2012)	Latest (08/2019)	Percentage change
Development	$641.33	$609.65	-4.9%
Procurement	$3,892.32	$4,206.89	+8.1%
Unit cost	$62.40	$66.21	+6.1%
Acquisition cycle time (months)	135	147	+8.9%
Total quantities	73	73	+0.0%

Total quantities comprise 1 development quantity and 72 procurement quantities.

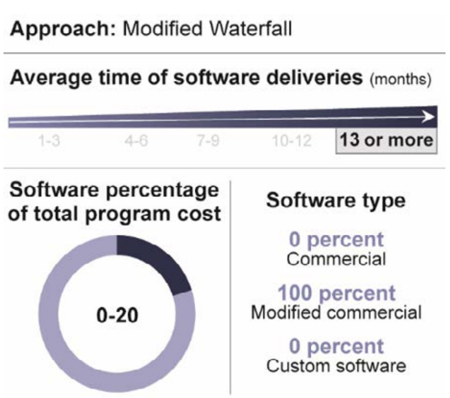
Funding and Quantities

(fiscal year 2020 dollars in millions)



Software Development

(as of January 2020)



Attainment of Product Knowledge

As of January 2020

Resources and requirements match	Status at Development Start	Current Status
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 now mature. However, the craft's gearbox, which is part of both the propulsion and lift drivetrains, is currently experiencing its third iteration of design problems. Specifically, after design changes to address previous issues, the gearbox showed signs of premature wear in pre-delivery testing of the first prototype craft. A redesigned gearbox—intended to address the premature wear—was delivered to the prime contractor in January 2020. This new gearbox is currently undergoing testing. In the meantime, the program has outfitted some of the craft currently on the production line with an interim gearbox that will need to be replaced later with the final design, which will impact the program's production schedule.

The program has also identified other design problems during pre-delivery testing. For example, the rudder mechanism was not strong enough to direct the force of the propellers. Additionally, the craft also experienced electrical system problems, such as on-board generators not powering up properly. According to program officials, the contractor has addressed both problems through design changes. The program will incorporate the rudder changes on future craft and is working to retrofit completed craft and those currently in production, potentially affecting the production schedule.

Officials report that nine SSC craft are currently under contract, but technical problems—particularly the gearbox issues—have created uncertainty in the production schedule. The program entered low-rate initial production in May 2015, and officials report that the contractor delivered the first craft in February 2020, a 7-month delay compared to the planned delivery date reported in last year's assessment. However, officials reported that the Navy's acceptance was contingent on the contractor agreeing to make subsequent fixes to address several outstanding issues, including the gearbox.

Software and Cybersecurity

Software development for SSC has faced delays due primarily to several factors. According to program officials, the initial design called for reuse of 90 percent of code from other programs, but the current percentage of reused code will be much lower. They also stated that software modules were developed separately, without sufficient attention to interactions between different software modules, leading to problems that had to be corrected. Finally, officials report there was a dispute between the prime contractor and the software subcontractor. However, program officials do not believe that software challenges have contributed to the current delays in craft delivery and testing because other delays—particularly with the gearbox—had larger schedule impact.

Other Program Issues

The program has yet to award the follow-on sole-source contract for the production of craft funded in fiscal years 2017, 2018, and 2019. According to program officials, the uncertainty created by technical problems and continuing negotiations between the program and the prime contractor have delayed award. Additionally, according to program officials, the gearbox subcontractor is not interested in participating in the follow-on contract due to the ongoing problems with the gearbox. While the program office and prime contractor are in discussions regarding another firm that may submit a proposal, program officials stated that they anticipate additional production delays for the program overall because of the startup time required for the new subcontractor.

The design and production challenges facing SSC—particularly the gearbox problems—led the program to delay initial capability by a year, with plans to deploy the first craft now set for August 2021. Despite this delay, initial operational testing will not occur until shortly beforehand, starting in the third quarter of fiscal year 2021, following post-delivery testing on the first craft. Operational testing is the program's first opportunity to verify in realistic operational conditions that it has fully addressed all known deficiencies. Should the Navy discover deficiencies during operational testing, it may have to further delay initial capability or deliver SSC craft that are operationally ineffective or unsuitable.

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 SSC program has made significant progress correcting first-in-class technical challenges. It stated that, though challenges remain, the Navy continues to work with the contractor to resolve all issues. The program office said that gearbox issues have been rectified: an interim gearbox design solution was successfully used to complete the first craft's builder's trials and acceptance trials; and the final gearbox has passed factory acceptance testing and is scheduled to undergo a 100-hour test in spring 2020. In addition, the program said that the final gearbox is being installed on craft in the production line and will be incorporated into all craft. It noted that the Navy anticipates a contract award in the third quarter of fiscal year 2020 for the craft funded in fiscal years 2017, 2018, 2019, and 2020.

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 one to two ships per year until 2033.

CONCEPT
- 02/11 Program initiation

SYSTEM DEVELOPMENT /PRODUCTION
- 09/17 Development/ Production start
- 03/18 Critical design review
- 09/18 Construction start
- 01/20 GAO review
- 06/21 Lead-ship delivery
- 01/22 Start operational test
- 03/22 End operational test
- 08/22 Initial capability/ full-rate decision

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)

Next major milestone: Lead-ship delivery (June 2021)

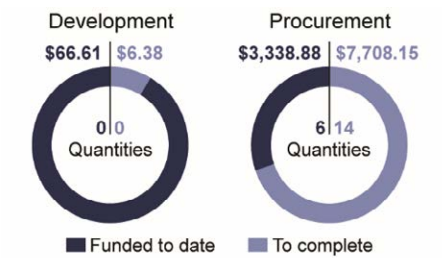
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (09/2017)	Latest (08/2019)	Percentage change
Development	$73.10	$72.99	-0.2%
Procurement	$9,165.12	$11,047.04	+20.5%
Unit cost	$543.42	$556.00	+2.3%
Acquisition cycle time (months)	46	59	+28.3%
Total quantities	17	20	+17.6%

Total quantities comprise 0 development quantities and 20 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Software Development

(as of January 2020)

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 is using off-the-shelf software systems and did not collect information on software timeframes, cost, or type.

Attainment of Product Knowledge

As of January 2020

Resources and requirements match	Status at Detail Design Contract Award	Current Status
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

All Lewis class critical technologies are mature and the design is stable. The critical technologies were all determined to be mature based on prototype testing conducted before detail design contract award—an approach consistent with best practices.

Lead ship construction began in September 2018 with 95 percent of the ship's total design effort, including the basic and functional design, complete—also consistent with best practices. Throughout detail design and now into construction, the Navy has not changed the Lewis class program's performance requirements. The Navy also leveraged commercial vessel designs to minimize design and construction risks. The Lewis class features a modern double-hull construction, an environmental-based design standard for commercial tankers, to ensure the ships can dock at ports-of-call.

According to the program office, as of January 2020, lead ship construction was 65 percent complete and second ship construction was less than 10 percent complete. Both ships experienced cost growth primarily due to quantity increases but also due to higher-than-forecast overhead and labor costs; increasing costs of steel and vendor components; and, according to officials, a small amount of cybersecurity related design cost growth.

Delivery of the lead ship has slipped by 7 months from November 2020 to June 2021. Program officials stated that the delay is primarily due to late delivery of the ship's main reduction gear and delays by the subsidiary of the contractor. A tool for transporting reduction gears from a heat treatment cracked and needed to be replaced, causing the reduction gear delay. According to program officials, the flooding of a graving dock in 2018 shifted ship construction schedules and accelerated construction in certain trades, such as pipefitting. This increased production demand for additional pipes and vents that one subsidiary has been unable to meet and has negatively impacted the schedule for both the lead and second ships. In addition, while repairs are being planned and implemented, the graving dock's unavailability has disrupted the contractor's schedule for future ships. According to the program office, the flooding incident resulted in an average of 5- to 12-month delays to the delivery dates for ships two through six. As a result of these delays, the Lewis class will not meet its initial operational capability (IOC) date of January 2022. The revised IOC date is now August 2022.

Software and Cybersecurity

The program is using off-the-shelf software systems tailored for the T-AO 205 design and did not collect details of its software development costs or activities.

With regard to cybersecurity, the program conducted its first cyber tabletop test—an exercise used to assess the probability of success for attackers—in January 2018. Based on the results, the program has another cyber test scheduled in January 2020, which will include several of the ship's linked subsystems. The program reported it has experienced increases in costs related to meeting cybersecurity requirements. Specifically, officials reported that in March 2019, the program began making modifications to the contract to address cyber requirements that were not in effect at the 2016 contract award. The changes are expected to cost approximately $7.4 million over the first six ships, an amount that will be reflected in the program's forthcoming revised acquisition program baseline.

Other Program Issues

As part of the Navy's plan to expand the fleet, the Navy concluded in fiscal year 2019 that it would need an additional three Lewis class ships. To date, the Navy has procured six of the 20 ships the Navy plans to purchase. In addition to these six ships, the Navy plans to add one more ship to the low-rate initial production phase via a modification to what it refers to as the "block buy" contract. Program officials stated they plan to competitively award the remaining 13 ships, likely awarding contracts to more than one contractor. The program plans to use the same design for these 13 remaining ships.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that the lead ship's delivery initially slipped due to the late delivery of main engines and reduction gear, but was further impacted by the late delivery of outfitting material. The program office also stated the fiscal year 2021 President's budget submission removes the planned procurement of one ship each in fiscal years 2021 and 2022 but does not impact the six-ship "block buy" contract. The program office noted that the Navy plans to procure a seventh ship through the existing six-ship "block buy" contract in fiscal year 2022. The program office further noted that the revised acquisition program baseline is complete and reflects the planned update to the total number of ships.

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, which 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.

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)

Next major milestone: Start of operational testing (June 2020)

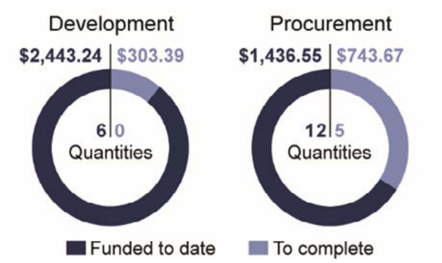
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (04/2014)	Latest (08/2019)	Percentage change
Development	$2,883.49	$2,746.63	-4.8%
Procurement	$2,260.87	$2,180.22	-3.6%
Unit cost	$223.67	$214.21	-4.2%
Acquisition cycle time (months)	75	81	+8.0%
Total quantities	23	23	+0.0%

Total aircraft quantities comprise 6 development quantities and 17 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Attainment of Product Knowledge

As of January 2020

	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.

Software Development

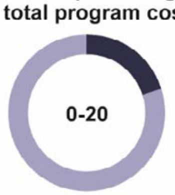
(as of January 2020)

Approach: Agile and Waterfall

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

80 percent Commercial

13 percent Modified commercial

7 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 fleet aircraft.

VH-92A is a registered trademark of the United States Navy.

VH-92A Program

Technology Maturity, Design Stability, and Production Readiness

The VH-92A program entered production in June 2019 with a stable design and a developmental version of the government-developed mission communications system (MCS). The MCS replaces the current fleet's communications and is expected to provide VH-92A passengers, pilot, and crew with simultaneous short- and long-range secure and non-secure voice and data communications capabilities. While the MCS is not in use on any other aircraft, the VH-92A program reports no critical technologies.

The Navy, using two development VH-92As and a developmental MCS software version, conducted an operational assessment from March to April 2019 to inform its production decision. This assessment confirmed MCS-related performance shortfalls, some of which led to inconsistent and unreliable communications. According to program officials, many of these MCS issues were known deficiencies. Upgraded software intended to address those limitations is to be evaluated during the initial operational test and evaluation scheduled to be conducted between June and September 2020. The program has delayed initial fielding by 3 months to January 2021, in part to provide more time to address MCS-related challenges. The MCS-upgraded software's effectiveness remains an area of concern.

As of November 2019, the contractor has delivered to the Navy five of six aircraft produced in the program's development phase. The contractor is making progress installing an additional multifunctional display in the cockpit and increasing the height of the upper portion of the new forward aircraft door onto the last production representative aircraft, which is expected to be delivered in May 2020. These post-production enhancements will be retrofitted onto already-built VH-92As. The program continues to identify the landing zone suitability key system attribute as high-risk. The Navy has yet to demonstrate that it can meet the requirement to land on the White House South Lawn without causing damage. Heat from the auxiliary power unit and/or engine exhaust continue to damage the lawn under certain conditions. The program is studying solutions including aircraft design changes, lawn surface treatments, and operational procedural changes to minimize landing zone risks. Due to concurrency in the program, which entered production while simultaneously 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.

Software and Cybersecurity

MCS software performance and capability limitations affected the reliability of the aircraft, along with the mission and maintenance data computer, which repeatedly sent out false warning alarms. According to program officials, the program has identified software solutions that are now being tested on production representative VH-92As. The program reports it is utilizing Agile software development to build the operational software load for initial operational tests and to sustain the MCS software once operational. Officials said that working software deployment is aligned with software upgrade releases. This approach may differ 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 that feedback can focus on efforts to deploy greater capability.

The program has an approved cybersecurity strategy and stated that it conducts cybersecurity testing on an ongoing basis, to include initial operational test and evaluation for potential cybersecurity vulnerabilities.

Other Program Issues

In May 2019, the Navy approved the VH-92A acquisition strategy for the production phase. The strategy replaces full-rate production with a third low-rate initial production lot. A key reason for the change is that the planned full-rate production run of five aircraft was too small to achieve the potential cost benefits of full-rate production—a decrease in unit cost. This approach creates a time-savings opportunity; LRIP lot III approval is scheduled to occur 4 to 7 months earlier than the original planned date for the full-rate production decision and according to program officials, this approach enables an uninterrupted production flow between Lot II and Lot III. However, by eliminating the full-rate production decision milestone, the Navy's new approach means the program may not have the benefit of incorporating complete information from a subsequent evaluation by Director, Operational Test and Evaluation on the adequacy of testing and effectiveness and suitability of the system into the decision to buy the remaining quantities. Before obligating funding for the last two lots, the program office must brief the Navy on various elements of the VH-92A's performance, including the status of testing results to date.

Program Office Comments

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

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 multi-mission ship designed to operate against air, surface, and underwater threats. Compared to existing Flight IIA ships of the same class, the new Flight III ships are expected 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 20 Flight III ships.

Program Essentials

Milestone decision authority: Navy

Program office: Washington, DC

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

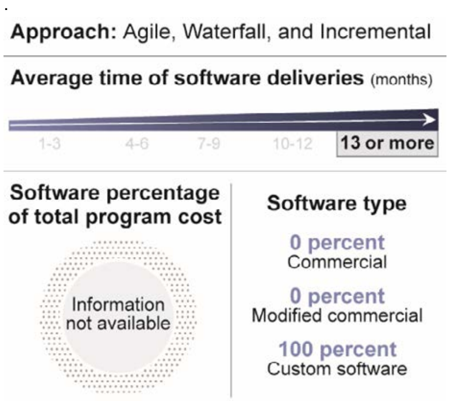
Contract type: FPI (construction)

Next major event: Aegis combat system activation (January 2022)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)



Software data reflects Aegis software development for DDG 51. Software costs are similarly included in program cost estimates.

Current Status

Flight III ships include considerable changes to DDG 51's design to incorporate the AN/SPY-6(V)1 radar and restore ship weight and stability safety margins. The program delayed the start of power and integration testing for the AN/SPY-6(V)1 radar from January 2019 to April 2020 due to software-related deficiencies that, according to program officials, are now resolved. Despite this delay, the Navy plans to deliver equipment, complete testing and installation on the ship, and activate the combat system for shipboard testing by January 2022. Further, it expects both the radar and software developed for the ship's combat system to be delivered before the power and integration testing is completed at the combat system development site, limiting opportunities to fix any issues prior to activation.

The Navy plans to complete an integrated test and evaluation master plan for the ship, AN/SPY-6(V)1 radar, and the Aegis combat system by the time of combat system activation in January 2022. The plan, according to Navy officials, will not include the use of an unmanned self-defense test ship, although DOD's Director, Operational Test and Evaluation and the Navy previously disagreed on whether an unmanned ship was necessary to validate the end-to-end performance of Flight III ships—including the self-defense capability—during operational testing.

The Navy continues construction on the lead Flight III ship, DDG 125, with plans for delivery in fiscal year 2023. Construction of the second ship is planned to start in April 2020. Officials report that the Navy has procured 11 ships using multiyear procurement authority and plans to award a contract for a 12th ship in fiscal year 2020. The current acquisition strategy includes 22 ships but, according to Navy officials, the total number of Flight III ships depends on the Navy's plans for its future large surface combatant ships.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program stated it has delivered 67 ships and is on track for delivery and initial capability of the first Flight III ship. According to the program, it rebaselined the radar test and delivery schedule to better align production and testing and is on track to complete radar testing prior to the start of shipboard testing. Further, the program said the development of the radar and software are on track to support integration.

Source: U.S. Navy.

LHA 8 Amphibious Assault Ship (LHA 8)

The Navy's LHA 8, the third LHA 6 class ship, will help replace retired LHA 1 Tarawa-class amphibious assault ships. The LHA 8 incorporates significant design changes from earlier ships in the LHA 6 class and is intended to provide enhanced aviation capabilities and a well deck that can accommodate two landing craft. The ship is designed to transport about 1,350 Marines and their equipment onto hostile shores. The LHA 8 is under contract and is scheduled to be delivered in January 2024.

Program Essentials

Milestone decision authority: Navy

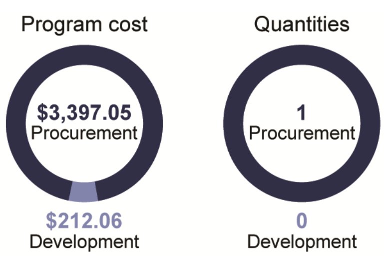
Program office: Washington, DC

Prime contractor: Huntington Ingalls Industries

Contract type: FPI (detail design and construction)

Next major event: Enterprise Air Surveillance Radar delivery (August 2024)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)



Software Development
(as of January 2020)

Approach: Agile

Average time of software deliveries (months)

Information not available

Software percentage of total program cost

Information not available

Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Program officials said they do not know software cost because they do not track software work elements.

Current Status

The Navy began construction in October 2018 with about 61 percent of the LHA 8 product model completed—an approach inconsistent with shipbuilding best practices, which call for the completion of modeling before construction begins. Ninety-nine percent of the product model is now complete, with the exception of the mast and two other compartments on the top of the ship. LHA 8 construction is now 5 percent complete.

The LHA 8 program office has not identified any critical technologies, but has identified risks from its reliance on technology from another Navy program. Specifically, LHA 8 program officials identified the use of the Enterprise Air Surveillance Radar (EASR)—a rotating radar system derived from the preexisting Air and Missile Defense Radar program—as the program's highest development risk. EASR is planned to be delivered in August 2021 and provide self-defense and situational awareness capabilities for LHA 8. Officials stated that during EASR development, they found that the mast blocked EASR's field of view. They said that to reduce the obstruction and electromagnetic interference from EASR, they have to reconfigure the mast and nearby antennas, which may affect the ship's planned delivery date of January 2024. Officials said they would test the configuration in a laboratory environment to determine the impact of EASR prior to its delivery to the ship.

The program has also encountered construction challenges that have increased schedule risk. Program officials said that the subcontractor manufacturing the ship's Main Reduction Gears (MRG) encountered quality issues that delayed their delivery. Officials report that the contractor had been following a more aggressive construction schedule for ship delivery, but that the delay to the MRGs pushed them back to the contract's 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. Officials stated that LHA 8 is progressing well and is 12 percent complete as of March 2020. Officials stated that the Navy has reduced risk in the topside design changes and finalized them with the contractor, and that EASR remains a development risk that the Navy is managing closely.

Source: U.S. Navy.

LPD 17 San Antonio Class Amphibious Transport Dock, Flight II (LPD 17 Flight II) [formerly LX(R)]

The Navy's LPD 17 Flight II program will replace retiring 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 will include a larger hull, but the Navy expects them to provide similar capabilities. The Navy is implementing Flight II incrementally over two ships and then plans to acquire 13 Flight II ships beginning with LPD 30 in fiscal year 2019.

Program Essentials

Milestone decision authority: Navy

Program office: Washington Navy Yard, DC

Prime contractor: Huntington Ingalls Incorporated (HII)

Contract type: CPFF (long lead material purchasing) FPI (detail design and construction) CPFF (life cycle and engineering support; planned)

Next major event: Production Readiness Review/Design Review (March 2020)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)

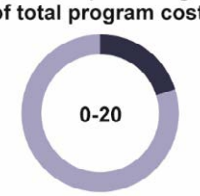
Software Development
(as of January 2020)

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 it has no software work elements.

Current Status

The Navy purchased the first Flight II ship—LPD 30—in March 2019 and plans to begin construction in April 2020 after a production readiness review in the first quarter of fiscal year 2020. It made about 200 design changes from the first to second flight, including replacing the composite mast with a steel stick, which the Navy plans to complete prior to lead ship construction. Program officials stated that the updated design does not rely on any new technologies. However, the Navy plans to install the new Enterprise Air Surveillance Radar (EASR), which is still in development, on Flight II ships. Live radar system testing on an EASR prototype is underway. Although program officials consider this low risk, the Navy will begin ship construction with little time to incorporate any lessons learned from radar testing, which could require the Navy to absorb costly changes and rework during ship construction if test results require design changes.

Program officials stated that they have sufficient funding for LPD 30 construction, but that without multi-year procurement authority to buy multiple ships across up to 5 years with a single contract, they will be challenged to achieve the current cost requirement and complete construction of ships. Statute requires programs requesting multi-year authority to have a realistic cost estimate, among other things. The LPD 17 program does not have an independent cost estimate for Flight II ships nor plans to establish a cost baseline specific to Flight II. Consequently, the Navy does not have an accurate and credible estimate of Flight II costs.

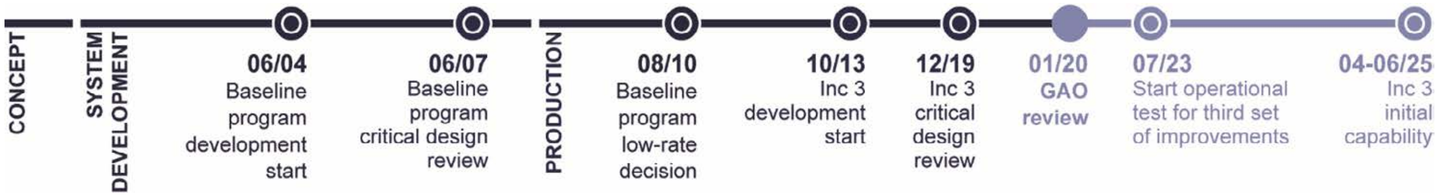
Program Office Comments

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. Program officials said the Navy has subsumed LPD 17 Flight II into the LPD 17 program and existing cost baseline. Program officials also stated that EASR testing is ongoing as of March 2020. Further, these officials stated that the Navy acquired LPD 30 under a sole source contract with Huntington Ingalls Incorporated. In addition, program officials reported they have completed LPD 30 critical design and production readiness reviews and intend to begin construction as planned.

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, which will be incorporated into the existing P-8A architecture. The following sets will 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

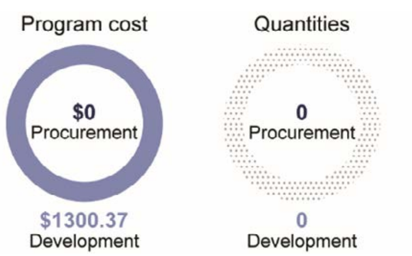
Program office: Patuxent River, MD

Prime contractor: Various

Contract type: CPFF (design and integration)

Next major event: Start of operational testing for the third set of improvements (July 2023)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)



Software Development
(as of January 2020)

Approach: Agile, Waterfall, and DevOps

Average time of software deliveries (months)

Software percentage of total program cost

Software type

0 percent
Commercial

0 percent
Modified commercial

100 percent
Custom software

Officials said they have not yet developed documents that provide information on software costs.

Current Status

The P-8A program has delivered the first of four sets of Increment 3 capability improvements, is currently working on the second and third sets, and is scheduled to field the last set in fiscal year 2025. Since our 2019 assessment, Increment 3 development costs have increased by more than $90 million. Program officials attributed the cost increase to their need to extend the schedule because they received less funding than requested in fiscal year 2018 and prior years. The program also delayed the fielding of the second set of capabilities by 1 year until August 2020 to allow it more time to fully integrate a new targeting capability that depends on another system. Program officials stated that they expect to experience funding constraints, leading to further delays in development and testing activities for the last two sets of capabilities and increases in the total development cost. The explanatory statement accompanying the Consolidated Appropriations Act, 2020, reflects approximately 20 percent less in development funds than the program requested for fiscal year 2020.

As a part of the third set of Increment 3 improvements, the Navy is integrating new hardware and software on the aircraft to upgrade the P-8A combat system. The program office conducted a critical design review for the combat system upgrade in December 2019. According to program officials, the design review largely focused on integration, and the design was approaching stability as measured by the percentage of drawings released. Another Navy program, the Air Anti-submarine Warfare Systems Program, is developing the software for the fourth set of improvements, which are dependent on the combat system upgrades. Any delays in the completion and delivery of the third set of improvements will impact completion of the last set.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that it did not receive the funding needed for increment 3 development. According to the program, funding issues have lengthened the schedule and increased costs as well as contributed to a 9-month delay in fielding the last capability set, pushing initial operational capability to fiscal year 2025.

Source: U.S. Navy photo courtesy of Huntington Ingalls Industries.

SSN 774 Virginia Class Submarine Block V (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 mid-body section called the Virginia Payload Module (VPM).

Program Essentials

Milestone decision authority: Navy

Program office: Washington, DC

Prime contractor (planned): General Dynamics Electric Boat

Contract type: FPI (construction)

Next major event: Block V lead ship delivery (June 2025)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)

Software Development
(as of January 2020)

Approach: Waterfall

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 does not track software cost, type, or deliveries because software is developed or acquired by individual program offices of the submarines systems.

Current Status

In December 2019, the Navy awarded a multiyear contract valued at approximately $22 billion for construction of nine VCS Block V submarines, with options for three more. According to program officials and a Navy report, Block IV construction challenges stemming from poor Navy oversight and an optimistic schedule made it difficult for the Navy to negotiate the Block V contract in line with initial plans.

The Navy plans for all of Block V to include acoustic superiority improvements, and VPM will be added starting with the second Block V sub. Program officials said that the Block V design will differ from Block IV by approximately 20 percent. The program office previously planned to largely complete basic and functional designs for VPM by construction start. However, the shipbuilders are currently behind schedule. The program now plans to complete 75 percent of the basic and functional design by construction start—compared to the 86 percent it initially planned—despite having an additional 6 months due to contract award delays. This lag in design progress is partly due to shipbuilders’ challenges in using a new software design tool. The Columbia class program (CLB) has already experienced challenges converting its design into instructions to build the CLB. If the VCS starts construction prior to maturing its design, it will place itself at greater risk of cost growth and schedule delays.

The Navy and its shipbuilders will also face challenges in simultaneously building Block V while starting construction on the CLB in 2021. The Navy and shipbuilders will need to manage staffing and other resources across both programs. Program officials said that the CLB is a higher Navy priority, which could mean delays to the Block V to keep the CLB on 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 office stated that poor Block IV construction performance is improving. It said that the focus is now on modular outfitting followed by final assembly and test. The program office stated that completing 75 percent of the VPM design prior to starting construction will be adequate to build the first hull within cost and schedule. The program said shipbuilders and the VCS and CLB programs are actively working to minimize any impacts stemming from CLB construction start.

Source: U.S. Navy.

Large Unmanned Surface Vessel (LUSV)

The Navy's LUSV is planned to be a long-endurance, unmanned ship capable of conducting warfare operations with varying levels of autonomy. It is expected to integrate anti-ship and land-attack capabilities onto a modified commercial vessel at least 200 feet long. The LUSV is planned to autonomously execute some capabilities, such as ship navigation and limited payload employment, but it is expected to need a crew for certain operations and will not autonomously employ lethal payloads. The Navy plans for the LUSV to deploy independently or with other surface combatant ships.

CONCEPT
- 01/20 GAO review
- TBD Request for proposal release

SYSTEM DEVELOPMENT
- 04-06/22 Prototype detail design and construction contract award
- TBD Prototype critical design review
- TBD Lead ship detail design and construction contract award

PRODUCTION
- TBD Start of lead ship fabrication
- TBD Start operational test
- TBD End operational test
- TBD Initial capability

Program Essentials

Milestone decision authority: TBD

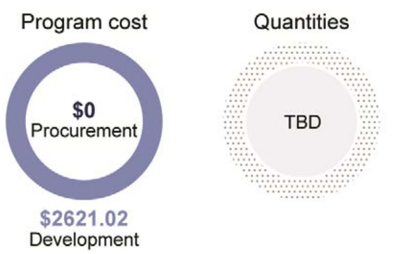
Program office: Washington Navy Yard, DC

Prime contractor: TBD

Contract type: TBD

Next major event: Request for proposal release (TBD)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)



Software Development
(as of January 2020)

Approach: information not available

Software type

0 percent Commercial

70 percent Modified commercial

30 percent Custom software

According to program officials, they have yet to determine the software approach and timing.

Current Status

The Navy planned to award multiple conceptual design contracts in 2020 and award a detail design and construction contract in 2021 for the first two ships. However, due to reductions in funding levels and design adjustments, officials stated the program may not award detail design and construction contracts until fiscal year 2023. Through an experimental DOD program, the Navy is already operating two commercially modified Unmanned Surface Vessels (USVs), which have completed initial at-sea testing. The Navy also plans for officials to exercise the DOD program's options for two additional USVs. The Navy intends to use these experimental USVs to reduce LUSV technical risk, improve reliability, and mature complex key enablers, including autonomy and remote operation of sensors and weapon systems.

Program officials previously stated that there was no planned release date for LUSV operational requirements, including ahead of a request for proposals for the detail design and construction contract. However, in February 2020 officials stated that they had completed an analysis of trade-offs of cost, schedule, and capabilities in 2019 as part of the Navy's new mix of surface combatant ships and now anticipate releasing operational requirements by the end of 2020.

Attainment of Technology Maturation Knowledge
As of January 2020

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 knowledge metrics because the program has yet to establish its development start date.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. After our review's cut-off date for assessing new information, the program reported it now plans to acquire six total experimental USVs, has established an acquisition strategy, and expects to award a prototype detail design and construction contract in 2022.

Source: AVIAN and KBRWyle CSS.

Next Generation Jammer – Low Band (NGJ Low-Band)

The Navy's NGJ-Low-Band is an external jamming pod system that will be fitted on EA-18G Growler aircraft. It is expected to replace the ALQ-99 jamming system and provide enhanced airborne electronic attack capabilities to disrupt adversaries' use of the electromagnetic spectrum for radar detection, among other purposes. The Navy plans for this program to field a system that jams low-band radio frequencies. The Navy expects separate programs will field mid- and high-band systems. We assessed the low-band program.

CONCEPT
- 10/18 Program start

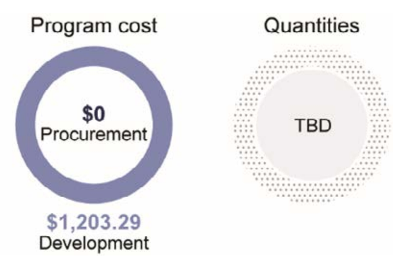
SYSTEM DEVELOPMENT
- 01/20 GAO review
- 07-09/20 Development start
- 01-03/21 Critical design review

PRODUCTION
- 07-09/24 Low-rate decision
- 07-09/25 Operational prototypes fleet delivery
- 04-06/27 End operational test
- 07-09/27 Initial capability
- 01-03/28 Full-rate decision

Program Essentials

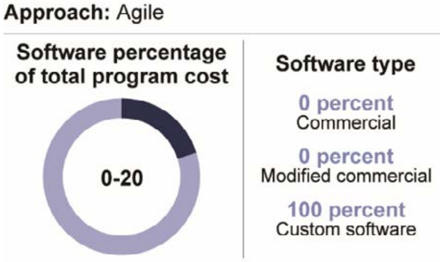
Milestone Decision Authority: Navy
Program office: Tactical Aircraft Programs, Patuxent River, MD
Prime contractor: TBD
Contract type: TBD
Next major event: Development start (July-September 2020)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)



Software Development
(as of January 2020)

Approach: Agile



Current Status

The NGJ Low-Band program is currently a future MDAP, but the Navy is planning to transition the program to a middle-tier acquisition based upon the maturity of technology to support the capability. In October 2018, the program awarded two demonstration contracts to assess the maturity of existing technologies, identify potential materiel solutions, and inform acquisition strategy development. These contracts require both contractors—L3 Technologies and Northrop Grumman—to provide technology demonstration prototypes and demonstrate technology maturity in a relevant test environment. In July 2019, an independent Navy assessment team conducted technology maturity assessments of both contractors' prototype designs and confirmed the technology is available to support fielding the NGJ Low-Band capability. Based in part on these assessments, the NGJ Low-Band program confirmed plans to move forward as a middle-tier acquisition.

In September 2019, the Navy released a request for proposal to design, develop, build, integrate, and test an initial NGJ Low-Band capability. The planned contract would include eight operational prototype pods with a target fielding date of 2025. The Navy plans to award the contract by the end of fiscal year 2020. According to program officials, they anticipate a decision memorandum formally approving the middle-tier approach 30 days prior to award.

Attainment of Technology Maturation Knowledge
As of January 2020

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

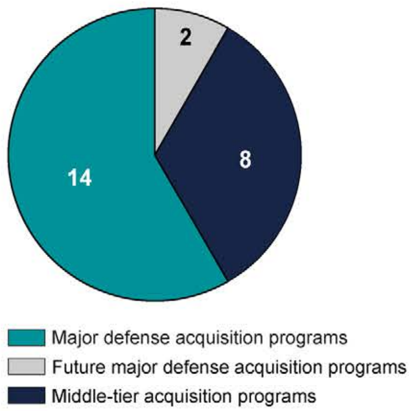
● Knowledge attained, ◐ Knowledge planned, ○ Knowledge not attained, … Information not available, NA Not applicable

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.

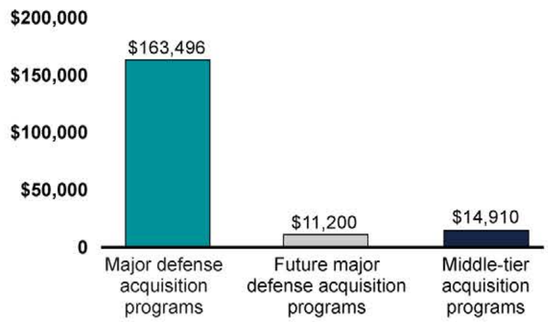
AIR FORCE PROGRAM ASSESSMENTS

GAO Assessed 24 Air Force Weapon Acquisition Programs



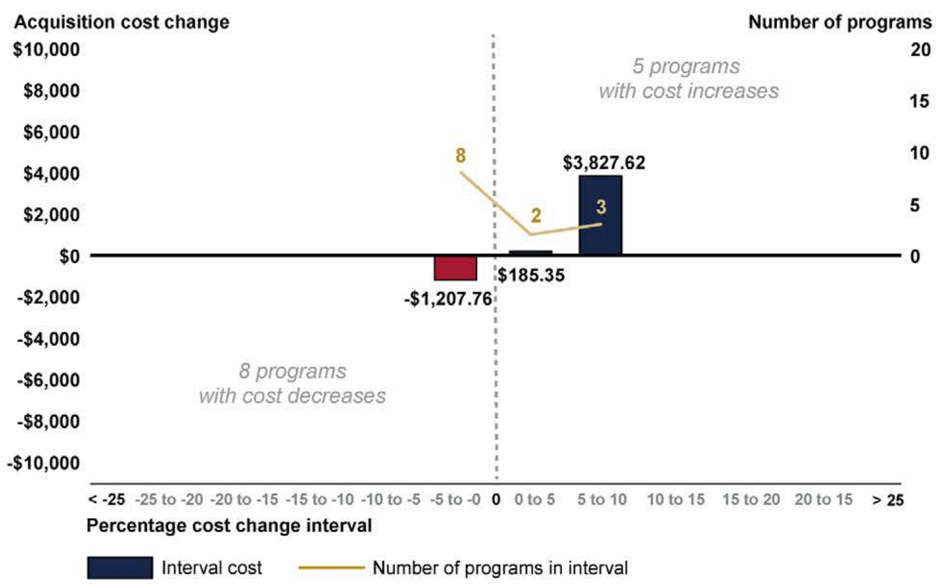
The Air Force Programs GAO Reviewed Have a Combined Estimated Total Acquisition Cost of $190 Billion

(Fiscal Year 2020 dollars in millions)

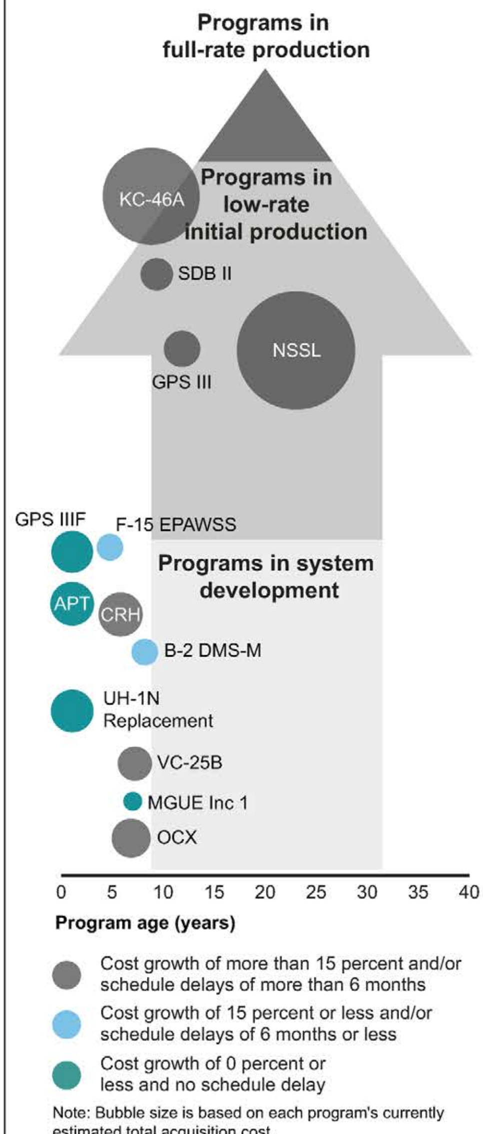


Most Air Force Major Defense Acquisition Programs GAO Assessed Had Cost Decreases Since Last Year

(Fiscal Year 2020 dollars in millions)



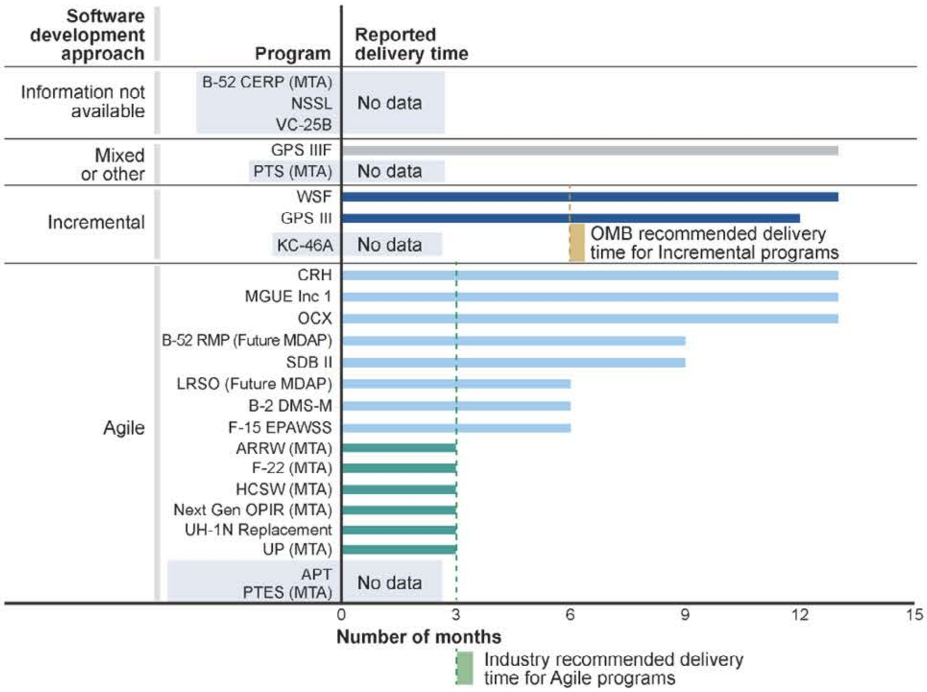
Most Air Force Major Defense Acquisition Programs GAO Assessed Have Had Cost Growth, Schedule Delays, or Both Since First Full Estimate



- Figures with titles that do not reference major defense acquisition programs or middle-tier acquisition programs provide information for the entire group of Air Force major defense acquisition programs, future major defense acquisition programs, and middle-tier acquisition programs that GAO assessed. Figures with titles that do reference major defense acquisition programs or middle-tier acquisition programs provide information for only the Air Force major defense acquisition programs or middle-tier acquisition programs that GAO assessed.
- GAO excluded the Weather System Follow-On program from the estimated total acquisition cost, acquisition cost change, and cost growth and schedule delay analyses because the program had not yet reported cost and schedule data as of the issuance of the December 2018 SARs.
- Cost and schedule analyses are primarily based on estimates from December 2018 selected acquisition reports. This information may differ from information reported in the Program Performance table and Funding and Quantities figures in individual assessments, which are based on more recent program estimates in some cases. Please see appendix II for details.

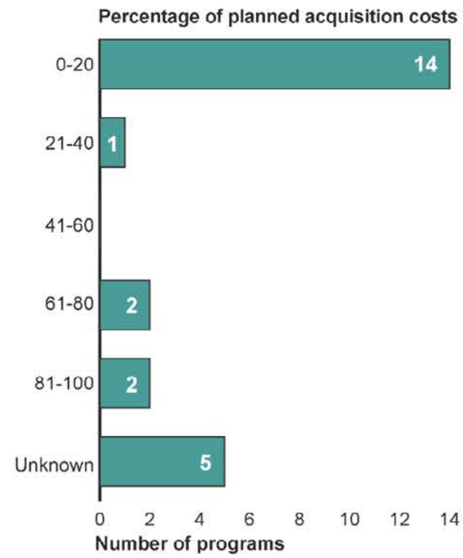
AIR FORCE PROGRAM ASSESSMENTS

Air Force Programs that GAO Assessed 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. The Office of Management and Budget (OMB) guidance recommends deliveries every 6 months for Incremental programs. Programs reported deliveries to GAO in 0-3 month increments.
- The Next Gen OPIR and UP programs reported alternative timeframes to deliver working software to users, including delivery schedules negotiated with users, and continuous capability delivery, respectively.

Most Air Force Programs GAO Assessed Reported that Less than 20 Percent of Planned Acquisition Costs are Specifically for Software



Air Force Major Defense Acquisition Programs GAO Assessed Generally Did Not Attain Knowledge at Key Points, but Some Attained Knowledge Later

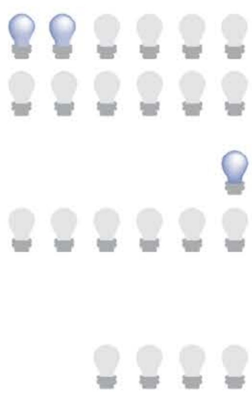
- Note: For each knowledge point, GAO assessed the major defense acquisition programs that had reached that point as of January 2020. GAO excluded programs for which it determined that the practice was not applicable.

At Occurrence of Knowledge Point

Knowledge Point 1
2 of 12
programs attained knowledge

Knowledge Point 2
1 of 7
programs attained knowledge

Knowledge Point 3
0 of 4
programs attained knowledge

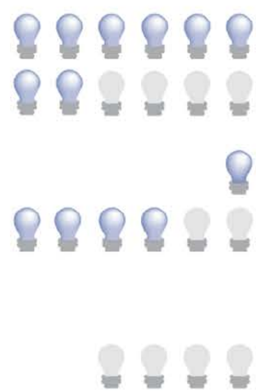


As of January 2020

Knowledge Point 1
8 of 12
programs attained knowledge

Knowledge Point 2
5 of 7
programs attained knowledge

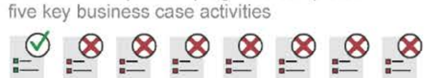
Knowledge Point 3
0 of 4
programs attained knowledge



Air Force Middle-Tier Acquisition Programs GAO Assessed Generally Completed Business Case Activities and Assessments, but Some Did Not by Program Initiation

At initiation

1 of 8
middle-tier acquisition programs completed five key business case activities



As of January 2020

5 of 8
middle-tier acquisition programs completed five key business case activities

Source: The Boeing Company, St Louis MO.

Advanced Pilot Training (APT)

The Air Force APT 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 APT—the air vehicle and an associated ground-based training system. The APT program responds to 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: Indefinite-delivery indefinite-quantity with delivery orders: FFP (development and production)

Next major milestone: Critical design review (March 2020)

Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (09/2018)	Latest (07/2019)	Percentage change
Development	$1,287.35	$1,285.48	-0.2%
Procurement	$6,938.20	$6,922.80	-0.2%
Unit cost	$23.94	$23.89	-0.2%
Acquisition cycle time (months)	85	85	+0.0%
Total quantities	351	351	+0.0%

Total quantities comprise 5 development quantities and 346 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

Attainment of Product Knowledge

As of January 2020

	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	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 APT critical technologies because the program stated that it does not have any; design stability because the full-program critical design review had yet to occur at the time of our review; and manufacturing maturity because the program has yet to reach production.

Software Development

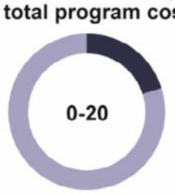
(as of January 2020)

Approach: Agile

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

The program did not report software delivery times.

APT Program

Technology Readiness

The APT program does not rely on critical technologies, consistent with its acquisition strategy. The strategy acknowledged, however, that some new APT capabilities, such as embedded training systems, cockpit displays, and software, might need to be developed or integrated during the program's development phase. In September 2018, the Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics approved a waiver for the statuatory requirement to conduct an independent technical risk assesment prior to the start of development. According to the waiver, the APT is a low techical risk platform that involves technology that is much more mature than is typical for a program approaching the start of development.

In August and September 2019, the program completed two, separate preliminary design reviews (PDR) for the ground based training system and air vehicle, respectively. These reviews were completed nearly a year after the program started development, timing that is inconsistent with best practices. As we reported last year, in September 2018 the Assistant Secretary of the Air Force (Acquisition, Logistics, and Technology) waived the statutory requirement to conduct PDR before the start of development, which allowed the program to delay the PDR. The waiver stated that conducting PDR-related activities prior to development start would delay transition of pilots to fourth and fifth generation fighter aircraft. We have observed in prior work that a PDR conducted prior to development start helps ensure a system's design is feasible, which in turn contributes to a match between customer needs and available time, funding, and other resources.

Design Stability

The Air Force plans to hold a final critical design review (CDR) for the Air Vehicle and Ground Based Training System (GBTS) in March 2020. In the meantime, the APT program conducted a combined. PDR/CDR in September 2019 for the air vehicle only. At that time, the program released 90 percent of the design drawings for the air vehicle. According to the program office, it reviewed 13 subsystems and 5,500 drawings in support of the air vehicle PDR/CDR. The program also conducted a PDR for the GBTS in August 2019. According to Air Force officials, 27 subsystems were reviewed as part of the GBTS PDR; however, no drawings were required for the PDR.

Software and Cybersecurity

The program is using an Agile framework to develop custom software for communication, flight vehicles, mission planning, and training, among other domains. Program officials reported that software costs have remained the same and the program has not experienced software-related staffing challenges to date.

According to the program office, the APT program has an approved cybersecurity strategy but has yet to complete a cybersecurity assessment. The program is scheduled to complete an evaluation for potential cybersecurity vulnerabilities.

Other Program Issues

The program is experiencing uncertainties in developmental test and evaluation planning, which could potentially create planning, schedule, or workload challenges for the program. According to Office of the Secretary of Defense developmental test officials, the prime contractor is trying to accomplish some of the early stages of flight testing on prototype aircraft; however, the Air Force will not know how much of that testing will count toward developmental testing because the government aircraft has a slightly different configuration. Air Force officials stated that weekly sessions with the testing stakeholders and test working groups are ongoing to address these challenges. Program officials further stated that developmental testing being conducted by the contractor will greatly reduce risk to program cost and schedule earlier than in typical aircraft development programs.

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.

B-2 Defensive Management System Modernization (B-2 DMS-M)

The Air Force's B-2 DMS-M program plans to upgrade the aircraft's 1980s-era defensive management system to a more capable system. This system detects and locates enemy radar systems to provide threat warnings and avoidance information. This upgrade is expected to improve the system's frequency coverage and sensitivity, update pilot displays, and enhance in-flight rerouting capabilities. It is also intended to improve the reliability and maintainability of the DMS system and the B-2's mission readiness.

Program Essentials

Milestone decision authority: Under Secretary of Defense, Acquisition and Sustainment
Program office: Wright-Patterson Air Force Base, OH
Prime contractor: Northrop Grumman
Contract type: FFP (development)
Next major milestone: Full Software Certification (December 2020)

Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (05/2016)	Latest (08/2019)	Percentage change
Development	$1,970.05	$2,292.17	+16.4%
Procurement	$794.01	$791.20	-0.4%
Unit cost	$138.20	$154.17	+11.6%
Acquisition cycle time (months)	124	153	+23.4%
Total quantities	20	20	+0.0%

Total quantities comprise 4 development quantities and 16 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

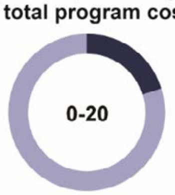
Software Development

(as of January 2020)

Approach: Agile, Incremental, and DevOps

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Commercial
0 percent Modified commercial
100 percent Custom software

Custom software includes contractor-developed code from existing military platforms.

Attainment of Product Knowledge

As of January 2020

Resources and requirements match	Status at Development Start	Current Status
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 B-2 DMS-M manufacturing maturity metrics because the program has not yet reached production.

B-2 DMS-M Program

Technology Maturity and Design Stability

The B-2 DMS-M program has fully matured its critical technologies and stabilized its design. The program entered system development in March 2016 with four critical technologies approaching maturity. Since then, the program has decided to leverage an alternative system with the same critical technologies. It now considers all four technologies mature because they have been tested on an existing program. In November 2018, the program completed a critical design review with 90 percent of its drawings released to manufacturing, consistent with acquisition best practices. However, the program did not test a system-level integrated prototype before its critical design review, which could present risks if deficiencies are found during developmental testing.

Software and Cybersecurity

The program continues to struggle with software development, which has resulted in significant program delays and presents risk for additional delays. Last year, we reported on risks in software development and potential delays in certification of the software block (PD 7.1) that the program required to begin developmental flight testing in June 2019. In February 2019, the B-2 DMS-M contractor identified a very high likelihood that it would not meet the PD 7.1 certification milestone. Ultimately, the program reported an acquisition program baseline schedule breach and did not begin flight testing as planned. In response, a joint contractor and government team revised the program schedule. The Air Force now estimates a nearly 18-month delay in PD 7.1 certification; delays in the start of production and operational testing of over 1 year; and that required assets will not be available until May 2024—more than 2 years later than planned.

According to program officials, PD 7.1 development delays are the result of delays in software development activities stemming from the contractor's inaccurate estimate of the amount of software work and insufficient staffing. In response to an April 2019 DOD report on the program's software development efforts, the contractor has committed additional experienced software developers and revised its software development and test program to build and flight test incremental capabilities. Program officials noted that the additional testing will take more time, but believe it will mitigate software development risk by enabling the contractor to identify and address deficiencies more quickly.

Although the contractor is now developing and testing software using a more incremental and iterative approach, the program continues to face software-related development and schedule risk. Program officials stated that while they planned to flight test the first software increment by September 2019, continued discovery of software deficiencies delayed testing until November 2019. These deficiencies have exacerbated the substantial overlap in the planned development of software increments, which could lead to risk as deficiencies in earlier blocks are identified and addressed at the same time other blocks are in development.

Despite starting development in 2016, the program does not have an approved cybersecurity strategy, and does not plan to complete one until February 2020. Per DOD guidance, programs generally must submit a cybersecurity strategy for review and approval prior to all milestone decisions or contract awards. Our past 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.

Other Program Issues

As we reported last year, the Air Force updated its service cost position in June 2018 to reflect a 12.5 percent increase over the program baseline. Officials said the position included an estimate for additional developmental flight testing under the new software development and test approach.

Program Office Comments

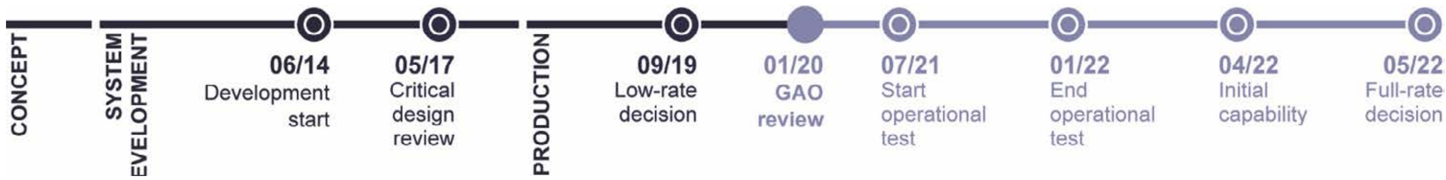
We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. Following our receipt of the program's initial comments, the Air Force's fiscal year 2021 President's budget request indicated it intended to restructure the program to continue as a displays-only modification. The Air Force said it chose this approach because DMS-M provides insufficient return on investment and timing due to program challenges The Air Force said it continues to obligate over $1.3 billion in other B-2 modernization efforts.

In comments provided prior to the release of the fiscal year 2021 President's budget request, the program office stated that certification of the first software increment occurred in November 2019 and that DMS-M successfully executed a majority of tests for first flight. It said schedule remains a challenge and physical aircraft restoration is the critical path to first flight. The program office also said the later software increments were complete or nearly complete, and contractors are addressing defects. It noted schedule pressure to full software certification but stated the pressure can be mitigated. The office also stated that the cyber security strategy was last updated in October 2019.

Source: Sikorsky Aircraft Co.

Combat Rescue Helicopter (CRH)

The Air Force's CRH program will replace the Air Force's aging HH-60G Pave Hawk rescue helicopter fleet. It will provide 113 new air vehicles, related training systems, and support for increased personnel recovery capability. CRH uses 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, armor for crew protection, a gun mount system, and situational awareness enhancements.



Program Essentials

Milestone decision authority: Air Force

Program office: Wright-Patterson Air Force Base, OH

Prime contractor: Sikorsky Aircraft

Contract type: FFP (low-rate initial production)

Next major milestone: Start of operational testing (July 2021)

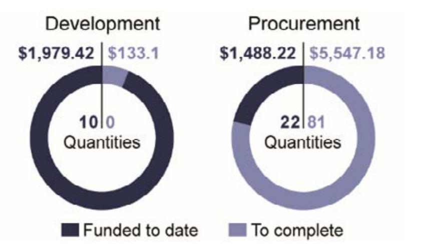
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (06/2014)	Latest (09/2019)	Percentage change
Development	$2,167.29	$2,112.52	-2.5%
Procurement	$6,757.83	$7,035.40	+4.1%
Unit cost	$79.92	$81.45	+1.9%
Acquisition cycle time (months)	82	94	+14.6%
Total quantities	112	113	+0.9%

In prior years we assessed cycle time based on Required Asset Availability to align with program reporting to DOD. This year, we became aware that the program is tracking an initial operational capability date, which we used to be consistent with our methodology. Total quantities comprise 10 development quantities and 103 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

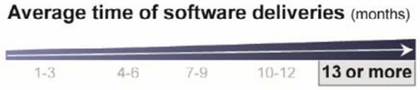


Software Development

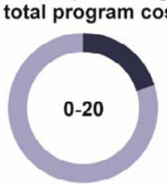
(as of January 2020)

Approach: Agile, Waterfall, and Incremental

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent Commercial

18 percent Modified commercial

82 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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

CRH Program

Technology Maturity, Design Stability, and Production Readiness

The CRH program's one critical technology has yet to be demonstrated as fully mature in a realistic (in-flight) environment. Program officials declared the critical technology—a radar warning receiver—as mature based on ground-based testing completed in May 2018. However, a September 2019 independent review conducted by officials from the Office of the Under Secretary of Defense for Research and Engineering (OUSD [R&E]) assessed the radar warning receiver as only nearing maturity until it is flight tested. Program officials stated they plan to begin verifying the receiver's maturity and other CRH requirements in flight testing starting in February 2020.

The CRH program reported a stable design, although OUSD(R&E) review found moderate technical risk associated with the CRH's weight. Program officials stated that early flight test results demonstrated that the helicopter meets requirements for airworthiness, hover performance, combat radius, and fuel burn rate. Yet OUSD(R&E) reported that continued attention to weight control is needed to ensure performance is not degraded. Equipment added for new capabilities could increase this risk. If future capabilities cannot be integrated within maximum weight limits, then some redesign or requirements trade-offs may be necessary. The program did not test a system-level integrated prototype to demonstrate its design. However, best acquisition practices state that such a prototype should be tested by critical design review.

The Air Force approved production start in September 2019, with the first production aircraft to be delivered in 2021. This approval includes the milestone decision authority's approval to fund over half of the planned procurement—61 out of 103 helicopters—as low-rate initial production (LRIP) units during the first 4 years of procurement instead of proceeding to full-rate production in the third year as originally planned. Program officials reported that the desire to avoid a production break contributed to the LRIP quantity increase. Procuring additional systems in LRIP means these systems will be procured before LRIP exit criteria—including satisfactory operational testing results—are fully satisfied, resulting in increased risk of costly fixes or retrofits.

Program and DOD officials stated that risks associated with purchasing a high percentage of total units during LRIP are mitigated by the CRH's reliance on legacy helicopter subsystems. OUSD (R&E) assessed manufacturing of the system as low risk, noting that there are active production lines for the legacy helicopter and subsystems common to the CRH and no new manufacturing technology is required. However, by buying a high percentage of units during low-rate initial production, the program may not have the benefit of incorporating complete information from an evaluation completed by the Director, Operational Test and Evaluation on the adequacy of testing and system effectiveness and suitability until after purchasing significant quantities.

Software and Cybersecurity

The program is using Waterfall, Agile, and Incremental software development, with deliveries every 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 two weeks—so that feedback can focus on efforts to deploy greater capability.

The Air Force reviewed and approved the program's cybersecurity strategy in September 2019. The 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 January 2021.

Other Program Issues

Since our last assessment, estimated unit costs increased from 5.2 percent below the development estimate to 1.9 percent above it. These increases in costs are related to new increases in system capability requirements, such as an infrared countermeasure and an anti-jamming capability, among others, which were added in the program's updated cost estimate for the September 2019 production decision. Program officials anticipate a 6-month delay since our last review in the start of operational testing, now planned to start in July 2021. Program officials stated that the basis of this delay was an independent schedule assessment using historical helicopter testing schedules.

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 advanced significantly and is performing 4 to 5 months ahead of the approved program schedule. The program office said that the contractor completed qualification testing of all required hardware and software. It also said it has the first two production lots under contract, anticipates completion of developmental testing before the end of 2020; and continues to monitor aircraft weight, but is less concerned about weight due to delivery of production-representative aircraft and initial flight test results. According to the program, nearly half of its planned flight testing has been completed. It said that hardware performance is stable, and that it identified no deficiencies that would delay the availability of systems to users. According to the program office, in lieu of testing a system-level integrated prototype, it tested what it termed a fully-qualified radar warning receiver and air vehicle.

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's 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 meet the challenges of today's EW threat environment. The Air Force developed EPAWSS Increment 1 to replace the F-15's 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.

CONCEPT — 08/15 Program start

SYSTEM DEVELOPMENT — 11/16 Development start; 02/17 Critical design review; 01/20 GAO review

PRODUCTION — 10/20 Low-rate decision; 04/23 Start operational test; 09/23 End operational test; 01/24 Full-rate decision; 04/25 Initial capability

Program Essentials

Milestone decision authority: Air Force

Program office: Wright-Patterson Air Force Base, OH

Prime contractor: Boeing

Contract type: CPIF/CPFF (technology maturation and risk reduction); CPIF/CPFF/FFP (development)

Next major milestone: Low-rate initial production (October 2020)

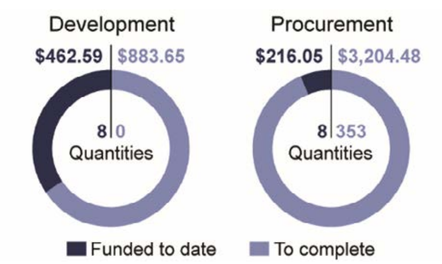
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (11/2016)	Latest (01/2020)	Percentage change
Development	$947.77	$1,346.24	+42.0%
Procurement	$3,649.44	$3,420.52	-6.3%
Unit cost	$11.13	$13.13	+18.0%
Acquisition cycle time (months)	83	116	+39.8%
Total quantities	413	363	-12.1%

Total quantity includes 2 F-15C development units, and 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.

Funding and Quantities

(fiscal year 2020 dollars in millions)

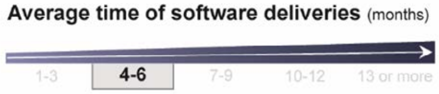


Software Development

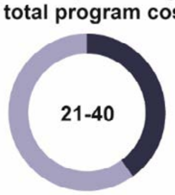
(as of January 2020)

Approach: Agile and Waterfall

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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 manufacturing maturity because the program has yet to reach production.

F-15 EPAWSS Program

Technology Maturity and Design Stability

The EPAWSS program began system development more than 3 years ago with four immature critical technologies and two of them are still not mature. This immaturity is inconsistent with best acquisition practices and has contributed to much of the development cost growth and schedule delay realized by the program to date. The program planned to demonstrate full technology maturity at the start of flight testing in April 2019, but was unable to because issues with the two critical technologies required additional time to resolve. Specifically, both technologies rely on a component that needed to be redesigned to address performance shortfalls discovered in the past year by component level testing, according to program officials. The redesigned component will not enter flight testing to demonstrate full maturity until June 2020.

Program officials report that nearly all EPAWSS design drawings are released, although the additional technology maturation work created design instability after critical design review in February 2017. We previously reported on concerns related to the program's planned concurrency between testing and production. As a result of the design instability after critical design review, the program schedule includes additional concurrency between product development and initial production, which officials believe is required to minimize further fielding delays. According to officials, the high-priority component level testing and other ground-based testing they conducted during the past year gives them confidence that the risk of continued design instability is low.

Production Readiness

In 2018 the Air Force attempted to accelerate the program by granting a two-decision approach for EPAWSS production and fielding in lieu of a single milestone decision point. However, the low-rate production decision was subsequently delayed by 15 months until October 2020 due to continued technology issues and design instability, with the follow-on decision to begin fielding EPAWSS on F-15 aircraft expected in May 2022. Additionally, delays during the system development phase led the program to delay operational testing (now planned to begin in April 2023) and full-rate production (now planned for January 2024) by approximately 2 years.

The program will proceed with production a few months after the redesigned EPAWSS hardware demonstrates full technology maturity, but according to officials, about 20 percent of the component level testing will still need to be completed after the start of production. While no retrofits are currently planned, our past work has shown that the risk of uncovering design issues from the testing completed while in production could result in added costs to retrofit already fielded EPAWSS units to achieve the promised operational capability.

Software and Cybersecurity

The software delivered at the start of system integration in 2018 and flight testing in 2019 provided less capability than planned due to the additional technology maturation work and design instability. Program officials stated that delays to the software development effort could adversely impact the flight testing needed to inform the future EPAWSS fielding decision. Given the concurrency between testing and production, a delay of the fielding decision may result in the stockpiling of EPAWSS hardware that is subject to possible retrofit.

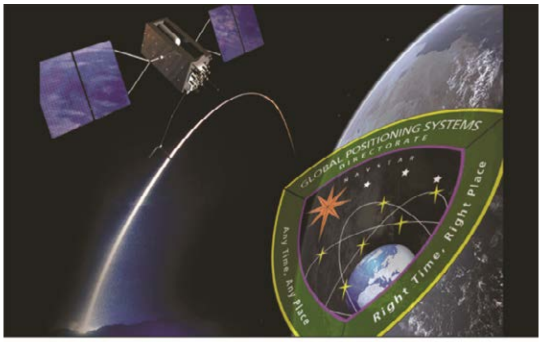
The program has a cybersecurity strategy but has yet to complete its cybersecurity assessments. Cybersecurity testing of the EPAWSS design is planned for July through December 2020 and will be completed just as low-rate production begins. Our past work has shown that not focusing on cybersecurity until late in the development cycle or after a system has been deployed is more difficult and costly than designing it in from the beginning.

Other Program Issues

Due to the additional technology maturation work and an F-15 force structure change made by the Air Force, the program updated its acquisition baseline in January 2020 to reflect a quantity change, cost growth, and schedule delay from initial estimates at development start. The Air Force no longer plans to procure EPAWSS for the F-15C as originally planned but will instead procure it for the new F-15EX—an EPAWSS-equipped replacement for some F-15s that are beyond their service life. Procurement of EPAWSS for the F-15EX is less than the amount planned for the F-15C, resulting in a quantity decrease of 12 percent and some loss in buying power, but the negative cost impact is much less that what was estimated by the Air Force for an F-15E-only procurement.

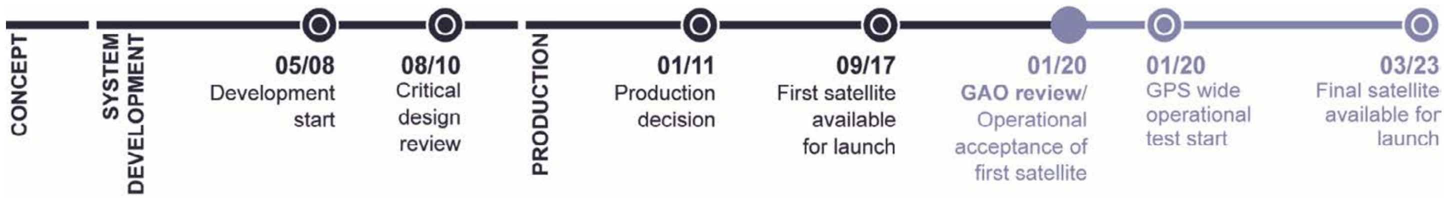
Program Office Comments

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.

Global Positioning System III (GPS III)

The Air 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: CPAF (development) CPAF/FPI (production)

Next major milestone: Final satellite available for launch (March 2023)

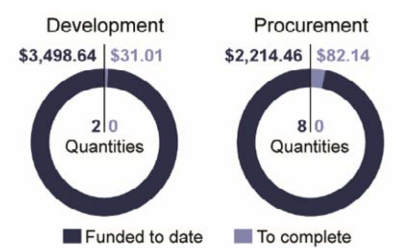
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (05/2008)	Latest (09/2019)	Percentage change
Development	$2,908.45	$3,529.65	+21.4%
Procurement	$1,632.96	$2,296.60	+40.6%
Unit cost	$567.68	$582.63	+2.6%
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 2 development quantities and 8 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

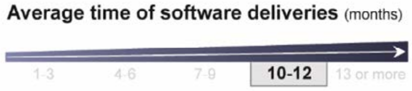


Software Development

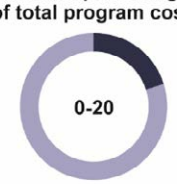
(as of January 2020)

Approach: Waterfall and Incremental

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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	○	○

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

We did not assess GPS III critical technologies in a realistic environment because satellite technologies demonstrated in a relevant environment are assessed as fully mature.

GPS III Program

Technology Maturity, Design Stability, and Production Readiness

The GPS III program office reported that its eight critical technologies are mature and the design is stable. Lockheed Martin has delivered four of the 10 GPS III satellites to the Air Force, with six in various production stages.

The first and second GPS III satellites launched in December 2018 and August 2019, respectively, and the Air Force declared the third GPS III satellite available for launch in May 2019. However, the Air Force has postponed the third satellite's launch twice; first due to delays to the second GPS III satellite's launch and subsequently due to concerns about the adequacy of the shielding of the satellite's on-board computer in the military space environment. According to the contractor, it identified a shielding deficiency when a similar on-board computer from a different satellite program was returned to the computer subcontractor for rework on a matter unrelated to shielding. To address the deficiency, the subcontractor retrofitted lead sheeting onto the exterior of the computer chassis of the third GPS III satellite. The Air Force plans for a March 2020 launch of the third satellite.

The program is implementing the shielding modification across subsequent satellites in the GPS III series, with some schedule impact. Due to the shielding rework launch of the third GPS III satellite shifted from January 2020 to March 2020, and launch of the fourth from May 2020 to July 2020. Resulting delays to subsequent satellites are less severe, according to the Defense Contract Management Agency projections, averaging 38 days.

Software and Cybersecurity

The GPS III program has pursued software development efforts specific to various satellite components, such as the satellite's mission data unit and the on-board computer. In 2019, the Air Force assessed the software as part of its successful testing of the on-orbit GPS III satellites.

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 has 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 fall 2019 integrated GPS test event that led to the operational acceptance of the first GPS III satellite included the testing of cybersecurity objectives.

Other Program Issues

In July 2019, the Air Force successfully completed on-orbit checkout testing of the first GPS III satellite with the GPS Next Generation Operational Control System (OCX) Block 0 Launch and Checkout System. Subsequently, from October to November 2019, the Air Force conducted an integrated GPS test in which the GPS III satellite was successfully operationally controlled by the Contingency Operations (COps) modification to the GPS Operational Control Segment (OCS). This modification was developed under a separate acquisition program initiated due to OCX schedule delays. The COps modification allows OCS to control the GPS III satellites for all currently available GPS signals. The Air Force transferred control of the satellite to the GPS ground operators in late December 2019, and operationally accepted the satellite in early January 2020.

The Air Force also successfully completed on-orbit checkout testing of the second GPS III satellite with OCX Block 0, following the satellite's August 2019 launch. The Air Force expects to operationally accept the second GPS III satellite into the GPS satellite constellation following a planned 45-day GPS-wide operational test event from January to February 2020 and planned April 2020 operational acceptance of the COps-modified OCS.

Because of delays to OCX needed to enable the full range of GPS III capabilities, the GPS III program expects to accept delivery of at least the first nine satellites before beginning developmental and operational testing with OCX Block 1. The Air Force anticipates that these tests, planned to begin in 2022, will confirm GPS III's modernized signal capabilities. This sequencing introduces the possibility that testers will discover deficiencies to already-produced or launched satellites—thereby constraining the Air 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 its main focus continues to be satellite production, launch, and mission operations. It said that the U.S. Space Force operationally accepted the first GPS III satellite in January 2020 after completion of the GPS integrated systems test, and the second GPS III satellite launched from Cape Canaveral Air Force Station in August 2019. The program office said the satellite successfully completed on-orbit checkout testing in September 2019, and the satellite's operational acceptance was on track for March 2020. Additionally, the office stated that the third GPS III satellite arrived in in Florida in preparation for a no-earlier-than June 2020 launch; the fourth GPS III satellite is on track for a late 2020 launch; and satellites five through 10 are in various stages of production.

Source: Lockheed Martin Corporation.

Global Positioning System III Follow-On (GPS IIIF)

The Air 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.

Program Essentials

Milestone decision authority: Air Force

Program office: El Segundo, CA

Prime contractor: Lockheed Martin

Contract type: FPI (production)

Next major milestone: Critical design review (March 2020)

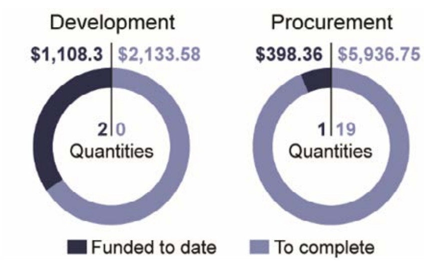
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (09/2018)	Latest (09/2019)	Percentage change
Development	$3,288.39	$3,241.89	-1.4%
Procurement	$6,359.76	$6,335.10	-0.4%
Unit cost	$438.55	$435.32	-0.7%
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 2 development quantities and 20 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



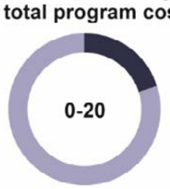
Software Development

(as of January 2020)

Approach: Waterfall

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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	NA	NA
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		
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 some resources and requirements knowledge points because they are not applicable to the program. We did not assess design stability and manufacturing process maturity because the program had not yet reached, respectively, critical design review or production start.

GPS IIIF Program

Technology Maturity and Design Stability

The GPS IIIF program considers its two critical technologies to be mature and is currently preparing for its critical design review, planned for March 2020. Specifically, the GPS IIIF program office continues to report that its two critical technologies—an L-band traveling wave tube amplifier and a digital waveform generator—are mature to the level generally required for the program to begin development. The program is reviewing the designs for these technologies as part of the critical design review activities. According to program officials, the GPS IIIF satellite will heavily leverage mature technologies from GPS III, primarily in the satellite bus design. The GPS IIIF contractor indicated that this is in line with the company's broader effort to pursue cross-programmatic efficiency through greater parts commonality among programs using the company's A2100 satellite bus.

Since completion of the program's integrated baseline review in March 2019, the program has been focused on critical design review activities. These activities are planned to culminate in a March 2020 critical design review—the review that assesses design maturity and established the initial design and build specifications. The program has identified the risk that design changes to certain components, such as the propulsion subsystem and the lithium ion batteries, could drive schedule delays. However, program officials reported that as of October 2019, the design activities had not caused any schedule delays. The Air Force waived the requirement for a preliminary design review prior to development start, in part to expedite contract award given DOD's critical national security need for GPS IIIF capabilities.

Production Readiness

After completion of the critical design review, expected in March 2020, the program plans to make a production start decision in mid-2020. Subsequently, it plans to award a contract for the third GPS IIIF satellite. The program expects the majority of the technical risk to have been mitigated in the building of the first two satellites. Therefore, the third GPS IIIF satellite, as well as subsequent GPS IIIF satellites, will be production, rather than developmental, satellites and will be funded with procurement funding. Program officials stated that the program plans to adopt efficiencies to the GPS IIIF assembly, integration, and testing flow based on knowledge acquired from the GPS III program. Such efficiencies include test schedule streamlining and planning to ensure the timely availability of test equipment.

Software and Cybersecurity

The GPS IIIF program is utilizing a waterfall approach to develop custom software for satellite control, payload, command and control, and other domains. The program reported that the first flight software delivery is planned for April 2020. The program stated that its average time between software deliveries to end users is 13 months or more. Software deliveries using waterfall development are often broadly scoped and multi-year. However, multiple DOD reports have recommended delivering capability using faster development practices than waterfall development in order to identify challenges earlier and take faster corrective action, which reduces cost, time, and risk.

The GPS IIIF program has an approved cybersecurity strategy, and has begun a cybersecurity review of its supply chain and subcontracts. However, the program has yet to complete a cybersecurity assessment. Not addressing cybersecurity issues sooner may increase risk to the program. Our past 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.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that since the Air Force's 2018 award of the fixed-price-type contract for 22 GPS III Follow-On satellites, the program has been working closely with the contractor to validate contractor delivery milestones with the aim of ensuring that no schedule growth occurs. The program office also stated that the program completed its integrated baseline review in March 2019 and has been preparing for a critical design review to validate a production-ready satellite design.

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

CONCEPT | SYSTEM DEVELOPMENT | PRODUCTION

- 02/11 Development start
- 07/13 Critical design review
- 09/15 KC-46 first flight
- 08/16 Low-rate decision
- 10/19 Start operational test
- 01/20 GAO review
- 03/20 End operational test
- 09/20 Full-rate decision
- 12/20 Initial capability/required assets available

Program Essentials

Milestone decision authority: Air Force

Program office: Wright-Patterson Air Force Base, OH

Prime contractor: Boeing

Contract type: FPI (development) FFP (production)

Next major milestone: End of operational testing (March 2020)

Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (02/2011)	Latest (07/2019)	Percentage change
Development	$7,895.34	$6,491.03	-17.8%
Procurement	$38,338.71	$32,165.44	-16.1%
Unit cost	$282.11	$230.18	-18.4%
Acquisition cycle time (months)	78	113	+44.9%
Total quantities	179	179	+0.0%

Total quantities comprise 4 development quantities and 175 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

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 Commercial

0 percent Modified commercial

100 percent Custom software

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

Attainment of Product Knowledge

As of January 2020

	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 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—two software modules related to situational awareness and a display that allows the crew to monitor aerial refueling—are fully mature. At its 2013 critical design review (CDR), the program released over 90 percent of design drawings. However, since CDR the program stopped using drawings to assess the design and instead, according to program officials, began using the Federal Aviation Administration's (FAA) certification process. As a result, we cannot assess design stability using this metric.

As of December 2019, the aircraft has four critical deficiencies discovered during developmental testing that require design changes, the last one of which was discovered over the past year. The most recently identified deficiency relates to auxiliary power unit duct clamps detaching, which could pose personnel safety risks. Program officials report that Boeing is fixing this deficiency without cost to the government. Two of the other three deficiencies relate to shortcomings with the remote vision system used by refueling operators that can cause the operators to scratch stealth aircraft during refueling, which can make these aircraft visible to radar or hamper future refueling. Program officials stated Boeing will also address these two deficiencies without cost to the government. A final 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. Officials report the Air Force will be responsible for the cost to redesign the boom to a lower stiffness standard than the international standard the Air Force previously approved. Program officials estimate that it will take up to 4 years to correct all of these deficiencies.

As of December 2019, Boeing has completed over 98 percent of the developmental test program, including testing the refueling booms that are used for Air Force aircraft. All remaining tests relate to the wing aerial refueling pods, which will be used for Navy and some allied aircraft. Until this testing is complete, Boeing may find additional deficiencies that could require further design changes.

Program officials said they are using a combination of manufacturing readiness assessments and the FAA certification process to assess KC-46A production readiness. The FAA certified Boeing's production process for the 767 aircraft before the program began and has certified the production process for almost all military unique parts since then. The Air Force has also conducted manufacturing readiness assessments for key production processes related to military unique parts. Officials said that Boeing is behind schedule in demonstrating manufacturing readiness for production and installation of the wing aerial refueling pods—the remaining processes for the FAA to certify. Officials expect the FAA to certify these processes in 2020.

The Air Force started accepting aircraft with the refueling booms in January 2019. Officials told us that while they formally entered operational testing in October 2019, they had previously started operational ground and flight testing in April and June 2019 respectively. Program officials told us that, as of December 2019, Boeing has manufactured four development aircraft, delivered 27 low-rate production aircraft, and is in the process of producing 29 additional low-rate initial production aircraft. Program officials said the program has delivered 33 aircraft since January 2019 and that each of these aircraft will be retrofitted with a redesigned boom when it becomes available. The program expects Boeing to deliver the first nine sets of wing aerial refueling pods by December 2020.

Software and Cybersecurity

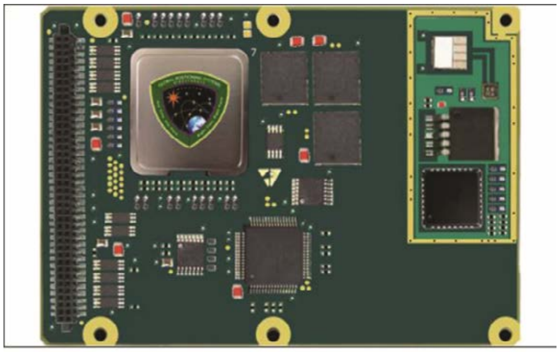
While the initial software development effort is completed, current software activities are directed at fixing critical deficiencies and delivering capability for the refueling pod, which program officials estimate could take up to 4 years to complete. According to these officials, the program plans to move toward an agile approach that delivers capability on a regular schedule, but there is currently no set delivery schedule. The program's cybersecurity strategy was updated in 2016 to reflect DOD guidance, and the program has since conducted vulnerability and penetration assessments.

Other Program Issues

The original development contract required Boeing to deliver the first 18 aircraft with nine sets of wing aerial refueling pods by August 2017. However, because of wiring problems, test delays, and other setbacks, Boeing now plans to deliver the required aircraft and refueling pods in December 2020, 40 months later than initially planned. According to program officials, the Air Force is withholding 20 percent of its payment to Boeing for each aircraft until Boeing demonstrates that it meets contract specifications and corrects critical 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. According to the program office, the Air Force continues to work with Boeing to resolve major deficiencies associated with the KC-46's Remote Vision System and stiff boom. The program office said that the Air Force also continues to require Boeing to deliver performance specification-compliant aircraft and that Boeing must resolve any deficiencies discovered during operational testing.



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 receiver cards for testing. The military services will make procurement decisions. Increment 1 cards are being developed for aviation/maritime and ground platforms. Increment 2 is developing smaller receiver cards for space, munitions, and handheld receivers.

Program Essentials

Milestone decision authority: Air Force

Program office: El Segundo, CA

Prime contractor: L3Harris, Raytheon, Collins Aerospace

Contract type: CPIF/CPFF/FFP (development)

Next major milestone: Start of operational test (October 2020)

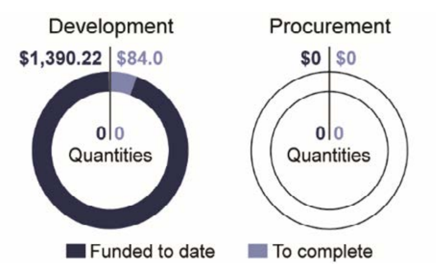
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (01/2017)	Latest (09/2019)	Percentage change
Development	$1,600.96	$1,474.22	-7.9%
Procurement	$0.00	$0.00	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. Total quantities comprise 0 development quantities and 0 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Software Development

(as of November 2019)

Approach: Agile and Incremental

Average time of software deliveries (months)

Software percentage of total program cost

Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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 and manufacturing maturity metrics because the program is only developing production-representative test items. Production decisions will be made by the military services.

MGUE Increment 1 Program

Technology Maturity

The program assessed four of its five critical technologies as fully mature. The program's remaining critical technology—anti-spoof software designed to prevent MGUE from acquiring and tracking false GPS signals—is nearing maturity. The program office forecasts this software will be mature once operational testing is complete on the first lead platform for the ground and aviation/maritime receiver cards, respectively. Additionally, in May 2019, the third MGUE contractor completed the security certification process for its receiver cards—a key step for making the receiver test cards available for continued development and eventual procurement. All three contractors have now received at least initial security certification.

Design Stability

Program officials stated that the design is stable. The number of design drawings has not changed since the development decision, but past developmental testing uncovered limited hardware deficiencies requiring changes. As of January 2020, card-level integration and testing was ongoing for ground and aviation cards, and the program expects to begin formal platform-level testing on the first of four lead platforms in February 2020. If this integration and testing reveals unexpected issues, they could disrupt the design stability the program says it has achieved.

Production Readiness

Since our last assessment, the program delayed completion of operational testing from April 2021 to March 2022. According to a program official, the change is due to the program receiving a more accurate integration and test schedule from the Navy for the DDG 51—the last of four lead platforms to undertake operational testing. While there are no acquisition program baseline milestones associated with operational testing (the final milestones comprise certification of readiness to undertake operational testing on each of the lead platforms), delays in operational testing could delay MGUE procurement decisions across the military departments.

Software and Cybersecurity

MGUE Increment 1 uses a mix of incremental and Agile software development. According to program officials, completing the originally planned software effort has proven to be more difficult than expected, including developing the software needed to successfully conduct both developmental and operational testing. Program officials said MGUE contractors have experienced challenges in finding and hiring staff with required expertise to complete planned software development work.

Officials reported that the MGUE Increment 1 program included cybersecurity requirements in contracts since initial award in 2012, and cybersecurity assessments are conducted during contractor security certifications and for each MGUE software build. However, according to program officials, addressing deficiencies in cybersecurity implementation and cybersecurity vulnerabilities, such as security improvements relating to crypto keys, has contributed to changes in the program's security architecture and technical baseline. These changes resulted in cost and schedule growth, although, as of February 2020, that growth remains within the program baseline. The program expected to complete an evaluation for potential cybersecurity vulnerabilities in January 2020.

Other Program Issues

The MGUE program has had mixed success completing key schedule milestones. For example, the program completed government verification and qualification testing on schedule for the ground card in March 2019. However, the program will not reach this milestone—or subsequent milestones—on schedule for the first aviation/maritime card, which failed to satisfy requirements for card-level testing. According to program officials, delays resulting from a lapse in information system accreditation at one subcontractor's facility led to software maturity issues that could not be resolved prior to testing. The program is currently rebaselining, with a decision expected by mid-2020.

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 office stated that MGUE made significant progress demonstrating card-level functionality, and that the first ground card completed verification of technical requirements in March 2019. It also said that, as of March 2020, the government had verified 75 percent of requirements for the first aviation card, but software deficiencies are delaying completion. In October 2019, the office provided formal notification of schedule and cost deviations against three of five remaining milestones, including verification of technical requirements for the first aviation/maritime card and certification of readiness to begin operational testing on the DDG ship and B-2 aircraft. It stated that a February 2020 independent program assessment would inform program re-baselining by mid-2020.

Source: U.S. Air Force.

Next Generation Operational Control System (OCX)

Through its OCX program, the Air Force is developing software to replace the existing Global Positioning System (GPS) ground control system. The Air Force intends for OCX software to help ensure reliable, secure delivery of position, navigation, and timing information to military and civilian users. The Air 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
- 02/10 Development contract award

SYSTEM DEVELOPMENT
- 11/12 Development start
- 10/17 Initial capability –Block 0
- 09/18 Development restart
- 01/20 GAO review

PRODUCTION
- 06/21 Block 1/2 delivery
- 04/22 Start operational test
- 04/22-04/23 Initial capability –Block 1/2

Program Essentials

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

Program office: El Segundo, CA

Prime contractor: Raytheon

Contract type: CPIF (development)

Next major milestone: Blocks 1 and 2 delivery (June 2021)

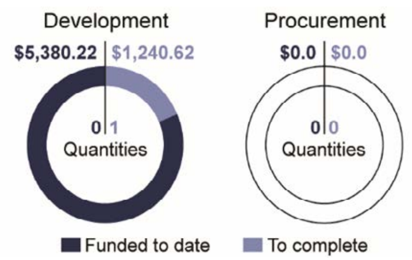
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (11/2012)	Latest (09/2019)	Percentage change
Development	$3,815.34	$6,620.84	+73.5%
Procurement	$0.00	$0.00	N/A
Unit cost	$3,815.34	$6,620.84	+73.5%
Acquisition cycle time (months)	55	113	+105.4%
Total quantities	1	1	+0.0%

We calculated acquisition cycle time using the program's initial capability date for Block 2. Total quantities comprise 1 development quantity and 0 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Software Development

(as of January 2020)

Approach: Waterfall, Agile, and Incremental

Average time of software deliveries (months)

Software percentage of total program cost

Software type

37 percent Commercial

21 percent Modified commercial

42 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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 OCX design stability metrics because the program does not track the metrics we use to measure design stability or manufacturing maturity metrics because the system has not yet reached production.

OCX Program

Technology Maturity and Design Stability

The OCX program has not fully matured all critical technologies. It delivered nine of the 14 technologies when it delivered Block 0 in September 2017, but the remaining five were not mature at the completion of Block 1 software development in August 2019. The program does not track the metrics we used for this assessment to measure design stability, such as the number of releasable design drawings, as OCX is primarily a software development effort.

In September 2017, the OCX prime contractor, Raytheon, delivered Block 0. Block 0 successfully supported the Air Force launch of the first two GPS III satellites, launched in December 2018 and August 2019, respectively. According to the Air Force, OCX Block 0 is currently exceeding its requirements for operational availability, and Raytheon expects OCX Block 0 to support the third GPS III satellite launch in early 2020.

Software and Cybersecurity

OCX uses Agile, Incremental, and Waterfall software development methods and has adopted portions of DevOps. Raytheon began employing this mixed software approach in late 2016 with a goal to identify software defects earlier, as well as to reduce their number, the time required to resolve them, and the overall time to code, integrate, and test. In October 2019, Raytheon reported that employing this mixed approach helped identify defects 12 months faster than the previous approach and reduced overall software development cycle times by 40 percent compared to the prior software segment. However, problems with system configuration control and high defect discovery rates during OCX integration have delayed planned activities. These delays are increasing the number of tasks that must be done at the same time and add cost and schedule risks to the program.

A DOD advisory report recommended the use of commercial software without customization whenever possible, and OCX employs a large amount of commercial software. However, according to the Air Force, the use of this software increases the overall complexity of the software architecture and requires significant effort by the OCX program to address commercial software obsolescence. Further, aging IBM server hardware in use by the OCX program poses risks to performance and reliability, placing the scheduled completion of the OCX acquisition program at risk. Additionally, the Air Force reported that, with the sale of the IBM x86 server product line to Lenovo, this hardware will no longer be supportable after August 2022 and must be replaced due to cybersecurity risks. According to program officials, funding to replace this hardware is needed by fiscal year 2021. As of January 2020, contract negotiations for this effort are in progress. The Defense Contract Management Agency estimates software and hardware obsolescence, to include IBM server replacement, will potentially add $100 million in program cost and up to 2 months to schedule. Raytheon estimates the cost to address obsolescence of system software and hardware at approximately $350 million.

Other Program Issues

Program officials reported that, under the terms of the development contract, Raytheon has approximately 18 months to complete development of the OCX system, including system integration and test of Block 1 software. Integrated system testing will begin in September 2021, demonstrating constellation management. Starting in April 2022, the program will begin further operational test and evaluation in operations-like conditions by operators, to include all on-orbit, legacy, and new GPS satellite vehicles.

Since development start, OCX has incurred persistent cost and schedule growth, which the Air Force attributes to poor systems engineering and Raytheon's lack of understanding of cybersecurity requirements. In June 2016, the Secretary of the Air Force notified Congress of a critical statutory unit cost breach in the program.

Air Force officials said the historical causes of cost and schedule growth have been addressed. However, the OCX program office estimates delivery in November 2021, 5 months after the reported contractual delivery date of June 2021. As we have previously reported, completion of the OCX program within the approved baseline requires timely delivery of the system by Raytheon, evaluation and acceptance by the Air Force, and efficient completion of the planned 7-month, government-run, post-acceptance developmental testing before beginning operations.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated that Raytheon continues to meet contractual commitments, and is on-track to meet cost and schedule estimates. It also said that OCX Block 0 launched, initialized, checked-out, and transferred the first two GPS III satellites to operations. In addition, the program noted that Raytheon executed the final design review, completed all software development, and directed focus to system integration and testing of OCX Blocks 1 and 2. According to the program office, metrics indicate significant improvement over the previous two software iterations, and the program is addressing known software obsolescence via contract. The program also stated that it is reviewing Raytheon's proposal to replace obsolete IBM hardware, with contract award targeted for March 2020. It said this effort fits within current funding profile and is projected to save about $150 million in rework and achieve initial capability 5 months prior to the planned April 2023 date.

Source: © 2009 Raytheon Company.

Small Diameter Bomb Increment II (SDB II)

The Air Force's Small Diameter Bomb Increment II (SDB 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 Air Force and Navy aircraft, including the F-15E, F/A-18E/F, and F-35.

Program Essentials

Milestone decision authority: Air Force

Program office: Eglin Air Force Base, FL

Prime contractor: Raytheon

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

Next major milestone: Initial capability (August 2020)

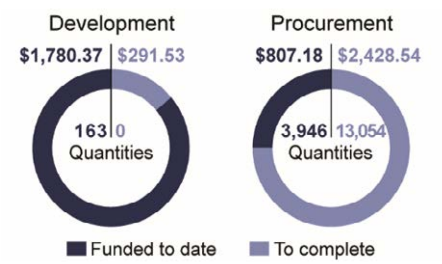
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (10/2010)	Latest (01/2020)	Percentage change
Development	$1,895.14	$2,071.90	+9.3%
Procurement	$3,522.67	$3,235.72	-8.2%
Unit cost	$0.32	$0.31	-2.0%
Acquisition cycle time (months)	72	121	+68.1%
Total quantities	17,163	17,163	+0.0%

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

Funding and Quantities

(fiscal year 2020 dollars in millions)

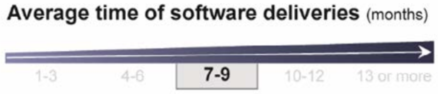


Software Development

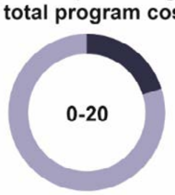
(as of January 2020)

Approach: Agile

Average time of software deliveries (months)



Software percentage of total program cost



Software type

0 percent Commercial

8 percent Modified commercial

92 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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 impacted the design stability previously reported at its design review.

SDB II Program

Technology Maturity, Design Stability, and Production Readiness

The SDB II program has matured its critical technologies and stabilized its system design, although redesigns after test failures could impact its design stability. We have previously reported that SDB II had four mature critical technologies—guidance and control, multi-mode seeker, net-ready data link, and payload. However, officials stated that guidance and control was misreported as a critical technology. Instead, the program has now identified its fourth mature critical technology as classification, which allows the weapon to classify the type of target being selected.

The program reported that it has released 100 percent of SDB II's design drawings. However, after production started, qualification and flight test failures revealed design deficiencies that required hardware and software changes. Because the contractor does not track revisions to previously released design drawings, we do not have visibility into how these redesigns are affecting the program's design stability.

The program completed operational testing in May 2019 and reported that it met its 80 percent reliability requirement. During operational testing in 2018-2019, the program completed 56 mission scenarios and reported 11 failures. According to program officials, eight were software related and are being addressed through new software releases, two were hardware related and corrective actions have been implemented, and one was the result of an anomaly with the guidance component. As of December 2019, the program was conducting a review board on the guidance component. Depending on the outcome of the review board, the program may have to redesign the component and conduct retrofits on all bombs delivered to date.

SDB II's estimate for initial operational capability has been delayed about 1 year to August 2020 and the program is planning to retrofit all 598 delivered weapons with a redesigned component. SDB II is currently producing the third lot of bombs, and, while the program has delivered 204 of 312 units, production was partially halted in 2019 after several safety deficiencies were discovered. The most notable problem occurred with the bomb's fins, which guide the bomb in flight and could inadvertently deploy before launch. The problem is related to fatigue of the clips holding the fins in place until the bomb is released from the aircraft. While this problem could affect all aircraft carrying the bomb, officials said the greatest impact is to the F-35, because the bomb is carried in the aircraft's internal weapons bay and could cause serious damage if the fins deploy while the bomb is in the bay. This problem prompted the contractor to partially halt production of the third lot.

The program plans to retrofit all 598 delivered bombs with a redesigned clip to reduce the amount of vibration on the fins. Program officials stated that the contractor would be responsible for any costs associated with this corrective action. The program estimates that production will not resume until April 2020. As a result of these safety concerns, and because the final operational test report will not be completed until February 2020, the estimate for initial operational capability slipped from September 2019 to August 2020.

Software and Cybersecurity

According to program officials, the program is utilizing Agile software development and delivering working software to the squadrons approximately every 7 to 9 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 2 weeks. Program officials noted that they experienced difficulties finding and hiring government and contractor staff with required expertise in a timely manner. The program completed its first cybersecurity testing in October 2019, and results will be included in the operational test report planned for February 2020.

Other Program Issues

The program is experiencing obsolescence problems with circuit cards, which are critical components in the guidance system. The manufacturer notified the program that it will end production 4 years sooner than expected. As a result, the program needs to order all circuit cards necessary to complete production by December 2020. The program is working with the Office of the Secretary of Defense on a mitigation strategy.

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 in January 2020 it achieved F-15 Required Assets Available—the ability to fully arm 12 F-15 aircraft and a pre-cursor to initial operational capability. It also stated that, as of February 2020, it projects contract award for Lot 6/7 production in March 2020.

The program office said it declared a breach of a statutory significant unit cost growth threshold in September 2019. It stated it reported a revised unit cost 24 percent over the current baseline established at the low rate production decision, which it said is 8 percent below the original baseline established at development start. According to the program, the breach occurred after it incorporated Lot 2 production actual cost data and additional performance requirements into the updated cost estimate. The program said it finalized an updated Acquisition Program Baseline in January 2020.

The program office reported that it anticipates a fielding decision by Air Combat Command in spring 2020, which it said will allow initial operational capability to be declared.

Source: Leonardo Helicopters Division.

Utility Helicopter (UH-1N) Replacement

The UH-1N Replacement program will replace the Air Force's fleet of 63 utility helicopters. The program office reports the current fleet, initially manufactured in the 1960s, does not comply with DOD's nuclear weapons security guidance and cannot meet all mission requirements. The helicopter's missions include securing intercontinental ballistic missile sites and convoys, and transporting senior government officials in the National Capital Region. The program plans to acquire 84 helicopters, an integration laboratory, a training system, support and test equipment, and software.

CONCEPT
- 04/16 Program start

SYSTEM DEVELOPMENT
- 09/18 Development start
- 06/19 Critical design review
- 01/20 GAO review

PRODUCTION
- 09/21 Low-rate decision
- TBD End operational test
- 03/23 Full-rate decision
- 09/23 Initial capability

Program Essentials

Milestone decision authority: Air Force

Program office: Wright-Patterson Air Force Base, Ohio

Prime contractor: Boeing

Contract type: FFP (integration)

Next major milestone: Low-rate initial production (September 2021)

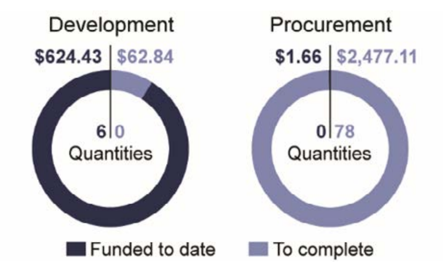
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (09/2018)	Latest (07/2019)	Percentage change
Development	$592.38	$687.27	+16.0%
Procurement	$2,520.29	$2,478.78	-1.6%
Unit cost	$40.98	$40.62	-0.9%
Acquisition cycle time (months)	60	60	+0.0%
Total quantities	84	84	+0.0%

Total quantities comprise 6 development quantities and 78 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



Software Development

(as of January 2020)

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 Commercial

100 percent Modified commercial

0 percent Custom software

Officials said they plan to deliver software to users every 2 to 3 months once the aircraft is fielded. They do not know software cost because they do not track software work separately.

Attainment of Product Knowledge

As of January 2020

	Status at Development Start	Current Status
Resources and requirements match		
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 critical technologies because the program said it does not have any; preliminary design review or some design stability knowledge metrics because the program office said these were not applicable; or manufacturing maturity because the system has not reached production.

UH-1N Replacement Program

Technology Maturity and Design Stability

The UH-1N Replacement program plans to procure a militarized version of a commercial helicopter that will be integrated with previously developed—or non-developmental—items. Accordingly, the program is not developing technologies for the helicopter. Through this acquisition approach, the program office intends to facilitate an expedited delivery schedule.

In September 2018, the Air Force approved an acquisition program baseline and the program entered system development. Although the program is considered non-developmental, the Air Force determined that it needed this phase to facilitate contractor modifications to the existing helicopter design. During this phase, the contractor is integrating technologies and conducting developmental testing.

The program completed its critical design review in June 2019, 5 months ahead of schedule. However, the helicopter, as it is currently designed, may not be able to meet all performance requirements if the final weight of the aircraft exceeds design parameters. If an appropriate weight is not achieved, the aircraft may not be able to meet requirements for speed or range. Air Force officials stated that they expect to determine the final weight of the aircraft in December 2019.

Additionally, Boeing identified that the Federal Aviation Administration (FAA) may require additional testing to demonstrate the engine's power before certifying the helicopter's airworthiness, which could result in schedule delays or cost increases. However, program officials told us that based on discussions between Boeing and the FAA in December 2019, the FAA will allow Boeing to use existing data instead of requiring an additional test of engine power as part of the certification process. According to these officials, this will be reflected in an update to Boeing's certification plan.

Production Readiness

In 2019, the program took steps to reduce risk in advance of production, which contributed to development cost increases. For example, the Air Force modified the program schedule to include additional time for the non-developmental item integration effort, and the program delayed the purchase of initial helicopters by 1 year to align purchasing with the low-rate production decision. Further, the program received approval in March 2019 to purchase two additional helicopters during the engineering and manufacturing development phase, which shifted some costs earlier in the program. Officials told us this would allow them to better understand the helicopters' capabilities, reduce concurrency during testing, and allow personnel to be trained on the helicopters earlier.

Software and Cybersecurity

The program is modifying commercial software for its systems, communications, and training domains that it plans to have certified by the FAA. According to program officials, the program has been challenged to find contractor and government staff with required software expertise. The program does not track software work elements or total software cost, so we cannot assess the extent to which software may impact program's overall cost estimate or schedule.

The program office has yet to determine whether the helicopter can meet DOD's cybersecurity requirements. Opportunities to change the design to implement cybersecurity controls are limited under the program's non-developmental item acquisition strategy. Program documentation indicates that the Air Force may not implement some cybersecurity controls, and as a result may accept operational risk. Program officials said they are implementing a risk management framework and a cybersecurity working group to understand the risks. Further, program officials stated that they plan to complete cyber resilience testing by 2020.

Other Program Issues

The Air Force Cost Analysis Agency estimated that Boeing may lose money on the contract starting in fiscal year 2023 and noted that strict adherence to program requirements could help the government avoid cost increases.

Program officials previously identified the hiring of testing staff and availability of test facilities as schedule risks. Program officials stated that they have hired sufficient testing staff and constructed needed facilities for use in testing.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that while final aircraft weight is a risk, the aircraft had an adequate weight margin at critical design review that the program has since maintained. It stated that in March 2019, the Milestone Decision Authority approved purchase of two additional helicopters during system development. The program office stated this increase allows the program to expedite training, mitigate schedule risk, field operational capability, and maintain assets for follow-on testing, if required. The office also stated that the program's cyber test strategy facilitates testing on all but four systems on a non-production-representative aircraft, lowering the risk for production. The program office reported that the program is developing mitigation strategies to ensure it addresses remaining cybersecurity requirements.

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 President of the United States, 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, design, and integration)

Next major milestone: Modification start (February 2020)

Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (12/2018)	Latest (08/2019)	Percentage change
Development	$4,741.47	$4,661.46	-1.7%
Procurement	$53.06	$52.95	-0.2%
Unit cost	$2,608.20	$2,564.03	-1.7%
Acquisition cycle time (months)	136	142	+4.4%
Total quantities	2	2	+0.0%

Total quantities comprise 2 development quantities and 0 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)

Software Development

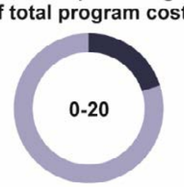
(as of January 2020)

Approach: Information not available

Average time of software deliveries (months)

Information not available

Software percentage of total program cost



Software type

0 percent Commercial

50 percent Modified commercial

50 percent Custom software

The program was unable to provide information on its software development approach and software delivery timing.

Attainment of Product Knowledge

As of January 2020

	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	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 VC-25B critical technologies because the program said it does not have any. We did not assess design stability and 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 technology used on other platforms into existing commercial aircraft. According to VC-25B program officials, in March 2018, an independent review team completed its technology readiness assessment of 12 candidate VC-25B critical technologies and determined none are critical technologies and all technologies have been demonstrated in a relevant environment. In April 2019, the Air Force, in coordination with the Office of the Secretary of Defense, Acquisition and Sustainment determined that all 12 technologies are mature.

The program is finalizing the detailed design to support aircraft modification. Boeing has completed 16 of 20 major subsystem design reviews with suppliers—including the electrical power generation system, the mission communications system, engines, and auxiliary power units, among others. According to program officials, the system-level design review conducted in January 2020, was delayed nearly 5 months due to the complexity of system integration and late subcontract awards. For example, VC-25B program officials stated Boeing discovered that the number of interfaces between subsystems and the aircraft were more than double the amount originally anticipated. They also noted that Boeing experienced delays awarding subcontracts to several key suppliers. VC-25B officials also said the program is implementing a phased modification approach that allows Boeing to start low risk modification work in parallel with system-level design review closure expected in March 2020.

Program officials also stated that the Air Force is incorporating lessons learned from the KC-46 program, another commercial derivative aircraft. For example, in October 2019, the VC-25B program conducted a comprehensive wiring review with Boeing to verify the logical design of over 250 miles of wiring before installation. Boeing previously experienced wiring issues on the KC-46 program that resulted in a 7-month delay in the start of developmental testing.

Production Readiness

The VC-25B program does not involve the production of aircraft, but rather the modification of 2 existing commercial aircraft. In December 2019, the program office and Boeing conducted a modification readiness review to determine if the two aircraft were ready for modification, adequate planning has taken place, and modification design and activities are well-documented and understood. Program officials stated they developed criteria for this review jointly with Boeing, to include review of manufacturing, modification, facilities, supply chain, and personnel readiness activities. Program officials also stated the majority of the VC-25B aircraft will be Federal Aviation Administration (FAA)-certified. As part of the certification process, the FAA will be reviewing manufacturing specifications in addition to other safety-related aspects of the aircraft such as airworthiness, operations, and maintenance.

In March and April 2019, the two Boeing 747-8 aircraft were transported to a facility in San Antonio, Texas, to prepare for modification expected to begin in February 2020. Preparations include removal of the engines, the auxiliary power unit, seats, and 90 percent of the aircraft wiring, among other things. Program officials stated that as another lessons learned from the KC-46 program, Boeing has been proactively inspecting the aircraft to ensure the aircraft remains free of foreign object debris.

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 and when completed will comply with the FAA design assurance levels.

The VC-25B program is implementing National Institute for Standards and Technology cybersecurity controls and program officials reported that contractors are responsible for documenting their compliance with the controls. Program officials stated that once the system-level design has been finalized, the VC-25B will undergo cybersecurity testing as part of the overall test program.

Other Program Issues

VC-25B officials stated that in December 2019, the program definitized the engineering, manufacturing and development contract modification with Boeing in December 2019. The program reported that In January 2016, the Air Force awarded a sole-source contract to Boeing for VC-25B risk reduction activities. The program has since modified the contract based on different phases of development work with a not-to-exceed value of $3.9 billion dollars to include aircraft purchase and preliminary design.

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.

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.

CONCEPT

10/12 Program start

SYSTEM DEVELOPMENT /PRODUCTION

11/18 Preliminary design review

10/19 Development start

01/20 GAO review

04/20 Critical design review

11/23 First satellite initial launch capability

09/24 Initial capability

Program Essentials

Milestone Decision Authority: Air Force

Program office: El Segundo, CA

Prime contractor: Ball Aerospace and Technologies Corporation

Contract type: FFP/CPIF (design, risk reduction, development, fabrication integration, test, and operations)

Next major milestone: Critical design review (April 2020)

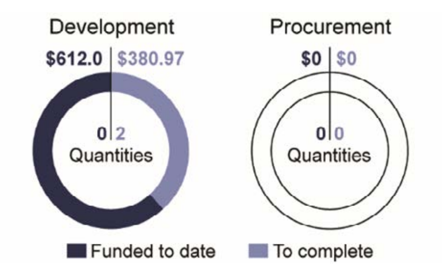
Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (10/2019)	Latest (10/2019)	Percentage change
Development	$992.96	$992.96	+0.0%
Procurement	$0.0	$0.0	0.0%
Unit cost	$496.48	$496.48	0.0%
Acquisition cycle time (months)	143	143	0.0%
Total quantities	2	2	0.0%

Total quantities comprise 2 development quantities and 0 procurement quantities.

Funding and Quantities

(fiscal year 2020 dollars in millions)



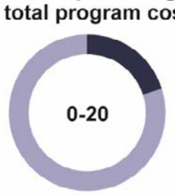
Software Development

(as of January 2020)

Approach: Waterfall and Incremental

Average time of software deliveries (months)

Software percentage of total program cost



Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Attainment of Product Knowledge

As of January 2020

	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 critical technologies in a realistic environment because satellite technologies demonstrated in a relevant environment are assessed as fully mature; design stability because the program has not reached design review; or manufacturing metrics because the program does not have a production milestone.

WSF Program

Technology Maturity

The WSF program entered system development in October 2019 with all eight critical technologies mature, as of the program's March 2016 technology readiness assessment. These critical technologies include capabilities for radio frequency interference mitigation and weather mission data processing software, among others.

Design Stability

The program is not tracking the release of design drawings as a metric to monitor design progress. Instead, the program is tracking design stability using metrics including interface specification requirements completed and interface control documents completed. The program reported that these metrics are currently showing expected progress. In addition, the program is monitoring progress by using prototypes and testbeds to assess the effectiveness of system components' designs. The WSF program does not have a production start milestone, and thus our production metrics do not apply to this program.

Software and Cybersecurity

The WSF program's software will be used for satellite vehicle control, other command and control, and simulation. The software is being developed as custom software using a combination of waterfall and incremental software development approaches. The program reported that as the software is onboard operational software, it is to be delivered in a single delivery with the completion of the first satellite, currently planned for November 2023.

The WSF program has an approved cybersecurity strategy and completed an evaluation for potential cybersecurity vulnerabilities in October 2019. This evaluation identified potential cybersecurity vulnerabilities to the space and ground segments. The program reported that data on these vulnerabilities was analyzed to quantify risks to the program and to guide risk mitigation efforts.

Other Program Issues

The program is working on a technology demonstration project to help inform decision making for weather satellite acquisition efforts subsequent to WSF. This project intends to launch a sensor to measure ocean surface vector winds—the Compact Ocean Wind Vector Radiometer (COWVR)—to the International Space Station by March 2021. Program officials noted that the WSF satellite is not dependent on the COWVR effort.

According to the program's acquisition strategy, maintaining the WSF schedule is important to mitigate potential capability gaps. Currently, WindSat, a payload operating over 14 years beyond its design life, is the only capability that fully meets the Air Force's needs for ocean surface vector wind data—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.

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

The Air Force's B-52 RMP is expected to support nuclear and conventional operations by replacing the current APQ-166 radar on all 76 B-52H aircraft in the Air Force inventory and modifying or upgrading the associated training systems. This modernization will allow the Air Force to fully utilize the capabilities of the B-52H aircraft to employ an array of nuclear and conventional weapons and to perform mission-essential navigation and weather avoidance functions.

Program Essentials

Milestone Decision Authority: Air Force

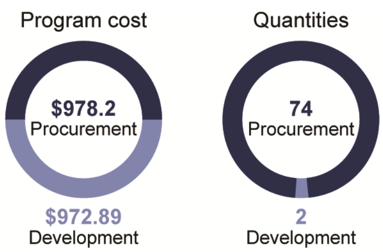
Program office: Wright-Patterson Air Force Base, Ohio

Prime contractor: Boeing

Contract type: CPFF (risk reduction and requirements development**)**

Next major milestone: Development start (March 2021)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)

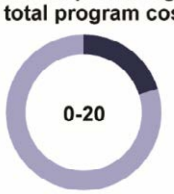


Software Development

(as of January 2020)

Approach: Agile, Waterfall, and Incremental

Software percentage of total program cost



Software type

29 percent Commercial

14 percent Modified commercial

57 percent Custom software

Current Status

During fiscal year 2019, the B-52 RMP program identified performance requirements, and provided input into the prime contractor's process for soliciting suppliers for the radar, radome, and crew stations subsystems. In September, the program released a request for proposal for the development effort to the prime contractor. The program plans to start development in March 2021, a delay of 6 months from our previous assessment. According to program officials, providing input into the prime contractor's solicitation process took longer than expected and involved establishing a framework to vet program requirements. Officials noted that the prime contractor was solely responsible for final supplier selection and will be responsible for ensuring supplier performance going forward.

Although the program has yet to identify critical technologies, program officials stated they plan to integrate technologies currently used on other aircraft. We have reported in the past that reusing existing technologies can reduce technical risk, but if the form, fit, or functionality of those technologies changes from one program to another, technology maturity may also change and should be reassessed. Program officials noted that the Air Force will perform an independent technology readiness assessment of potential critical technologies in preparation for the start of development. Program officials also plan to conduct a system-level preliminary design review in July 2020, prior to development start in March 2021.

Attainment of Technology Maturation Knowledge

As of January 2020

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 stated that B-52 RMP is executing its March 2018 approved acquisition strategy, as planned.

Source: U.S. Air Force.

Long Range Standoff (LRSO)

The Air Force's Long Range Standoff (LRSO) weapon system is being designed as a long-range, survivable, nuclear cruise missile to penetrate advanced threat air defense systems. It is planned to replace the Air Launched Cruise Missile. The LRSO missile program plans to incorporate a nuclear warhead called the W80-4, which is undergoing a life extension program. Coupled with both a legacy and a potential future bomber, the LRSO is expected to modernize the bomber segment of the nuclear triad (air-, land-, and sea-based weapons).

Program Essentials

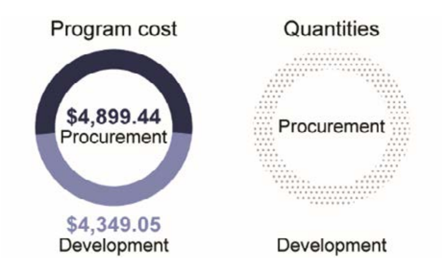
Program office: Eglin Air Force Base, FL

Prime contractor: TBD

Contract type: TBD

Next major event: Development start (February 2022)

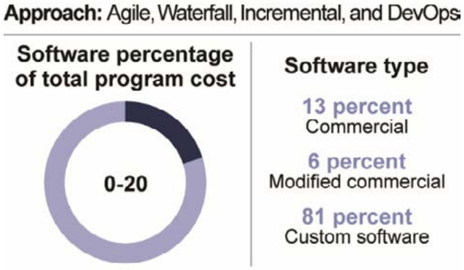
Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)



The Air Force has deemed quantity information as not suitable for public release.

Software Development
(as of January 2020)

Approach: Agile, Waterfall, Incremental, and DevOps



Current Status

The LRSO program was granted approval to begin technology development in July 2016. Officials report that the program awarded contracts to two competing contractors in August 2017 to develop and mature critical subsystems and system-level designs over a 54-month technology development phase. Missile reliability, manufacturing maturation, and design compatibility with a legacy and a potential future bomber aircraft are being emphasized during the technology development phase.

Both competing contractors recently held preliminary design reviews, and after an evaluation of the designs, the Air Force indicated they would move forward with just one contractor for the remainder of technology development. A final design review is planned later in the technology development phase prior to development starting in 2022 and continuing through 2025.

The program is coordinating with the Department of Energy (DOE), which is separately managing the related W80-4 nuclear warhead life extension program. Conducting parallel development, design, and test activities with the DOE to ensure the LRSO adequately integrates the DOE-designed warhead will likely be challenging for the program. Related schedule risks also exist as delays in either program would likely impact overall LRSO development and delivery.

Attainment of Technology Maturation Knowledge
As of January 2020

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 could not assess competitive prototyping because, while the program plans to conduct this activity, it has not yet scheduled a date.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office stated it is on track for development start in fiscal year 2022 and initial operational capability as planned. It said that it conducted preliminary design reviews.

Source: United Launch Alliance and SpaceX.

National Security Space Launch (NSSL)

The Air Force's NSSL (previously known as Evolved Expendable Launch Vehicle, or EELV) program provides space lift support for national security and other government missions. Currently, United Launch Alliance (ULA) and Space Exploration Technologies Corporation (SpaceX) are the only certified providers of launch services. We reviewed NSSL program investments in the development of new launch vehicles.

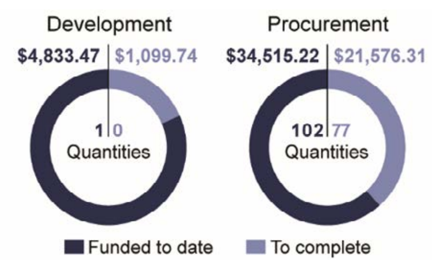
CONCEPT
- 12/96 Program start

SYSTEM DEVELOPMENT /PRODUCTION
- 06/98 Development/ production start
- 08/02 First launch
- 06/06 Initial capability
- 01/16 New engine development
- 10/18 New launch vehicle development
- 01/20 GAO review
- 04-06/20 Launch service procurement

Program Essentials

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

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)



Software Development
(as of January 2020)

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

According to the program, software used to provide commercial launch services is designed, owned, and managed by the launch service contractors.

Current Status

Currently, the NSSL program procures launch services from ULA and SpaceX which supports the U.S. policy, as stated in law, to ensure to the maximum extent practicable that the United States has the capabilities necessary to launch and insert national security payloads into space when needed. The NSSL program will cease use of ULA's two current launch vehicles—Atlas V and Delta IV—over the next several years. The National Defense Authorization Act for Fiscal Year (NDAA) 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-EELV) program if such contract carries out such activities using rocket engines designed or manufactured in the Russian Federation. The Atlas V uses Russian-designed and -manufactured engines. ULA's Delta IV uses U.S.-manufactured engines, but ULA has largely stopped producing them due to cost.

To ensure DOD's continued access to space, the NSSL program continues to invest in multiple engine and launch vehicle development efforts from U.S. launch providers. Program officials said that in early 2016, the Air Force awarded four other transaction agreements totaling $560 million for engine development. As of September 2019, the resulting engines were undergoing testing, with select systems planned for use in future launch vehicles. The officials also said that in October 2018 the Air Force awarded three more other transaction agreements totaling over $2.3 billion to develop launch vehicle prototypes able to meet national security requirements, and that the prototypes are on track to support initial launches in 2021. In the summer of 2020, under a full and open competition, the program plans to award launch service contracts to two providers. Using these contracts, the Air Force plans approximately 34 launches from 2022 to 2027.

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 NSSL continues 100 percent mission success with 79 consecutive successful launches.

Source: U.S. Air Force (Distribution A; Public Release Case Number: 96TW-2019-0267)

Air-launched Rapid Response Weapon (ARRW)

The Air Force's ARRW, a rapid prototyping middle-tier acquisition program, 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 leverages the Defense Advanced Research Projects Agency's (DARPA) ongoing tactical boost glide effort to develop the missile's high-speed glider component. The Air Force plans to achieve an early operational capability by September 2022.

- **05/18** MTA initiation
- **08/18** Contract award
- **08/18** MTA funds obligated
- **01/20** GAO review
- **02/20** Critical design review
- **10/21** First test flight
- **09/22** Early operational capability/expected MTA completion
- **08/23** 5 years since MTA funds obligated

Program Essentials

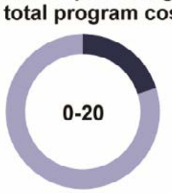
Decision authority: Air Force
Program office: Eglin Air Force Base, FL
Prime contractor: Lockheed Martin
MTA pathway: Rapid prototyping
Contract type: CPFF/CFIF (development)
Next major event: Critical design review (February 2020)

Estimated Program Cost and Quantities (fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

Approach: Agile



Software type
0 percent Commercial
0 percent Modified commercial
100 percent Custom software

Custom software includes contractor-developed code from existing weapon systems.

Program Background and Expected Results

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. Program officials stated that they plan to deliver eight hypersonic missiles: four to conduct flight tests and four spares. Specifically, ARRW plans to develop an operational prototype with solid-fuel booster, ordnance package, and specialized equipment to enable it to be carried on the B-52H. According to program officials, the program will build knowledge through the flight and operational testing of prototype units, as well as potentially provide an operational capability from the deployment of any remaining spare test units.

Air Force officials stated that they have yet to determine next steps after the completion of the middle-tier effort, but that the knowledge gained from prototyping will inform future decisions on whether to continue development or procure additional units.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	●	●
Approved middle-tier acquisition strategy	●	●
Technology, Cost, and Schedule Assessed		
Formal technology risk assessment	○	●
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	○	●

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

ARRW Program

Key Elements of a Program Business Case

The ARRW program had several key elements of its business case developed by the time of its initiation in May 2018 as a middle-tier acquisition program. Requirements were approved by the Air Force in March 2018 and the acquisition strategy was approved in May 2018, before program intiation. The program had also completed a cost assessment in March 2018 that was reviewed by the Air Force Cost Analysis Agency. However, ARRW did not have other key elements of its business case—including a formal schedule or technology risk assessment—approved at the time of program initiation. Our prior work has shown that this type of information is important to help decision makers make well-informed decisions about middle-tier program initiation, including whether the program is likely to meet a statute-based objective of fielding a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of an approved requirement.

Since program initiation, the Air Force has updated its cost estimate and completed the remaining business case elements. In March 2019, the program increased its cost assessment to reflect changing program circumstances and reported a 39 percent increase in total costs. Program officials attributed this increase in part to an almost 1-year delay to DARPA's tactical boost glide project. The tactical boost glide and ARRW schedules are concurrent, and as a result the ARRW schedule was similarly delayed. Additionally, the previous estimate was based on the program's assumption that ARRW could continue working through a modification to DARPA's tactical boost glide contract. However, ARRW officials reported that a new, program-specific prime contract was needed and that the award of this contract increased the estimated cost.

An Air Force independent review team also completed a formal schedule risk assessment for ARRW in August 2018, 3 months after program initiation. The Air Force has characterized ARRW's schedule as aggressive, and its current early operational capability date already reflects the above-mentioned delay due to schedule slips in DARPA's tactical boost glide project. Further, slips to key milestones have continued to occur. For example, the program currently plans to hold a critical design review in February 2020 and the first flight test in October 2021, representing schedule slips from the new baseline of 3 months and 5 months, respectively. A schedule analysis the program conducted in July 2019 shows that these and other schedule slips have cascaded through the program, such that the third and fourth flight tests are now both scheduled for the same month, May 2022, making lessons learned in the third test difficult to apply to the fourth.

Technology

The program has identified two critical technologies, both related to materials capable of withstanding the extreme temperatures experienced by objects moving through the atmosphere at hypersonic speeds.

The program stated that technology risk was assessed during its preliminary design review in March 2019, although there has not been an independent assessment completed for either technology. The program office estimates that both of these technologies were immature at program start but that one is currently approaching maturity. The program office plans for both technologies to be mature by the program's end.

Software Development and Cybersecurity

ARRW is not a software-intensive program, with 20 percent or less of its total cost attributable to software development. The program released a software development strategy in May 2018, calling for an agile development approach. Approximately 60 percent of the code will be new and the remaining 40 percent re-used, non-commercial off-the-shelf code.

The program has a cybersecurity strategy in place, and the strategy received final approval in March 2019, but the program has yet to complete any cybersecurity assessments.

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 Air Force utilized an accelerated approach for the ARRW prototype weapon to deliver an early hypersonic weapon operational capability. In addition, the office stated that prototype efforts enable the DOD acquisition community to reduce risks and improve a weapon system that will eventually be transitioned, procured, and fielded while leveraging the existing Air Force/DARPA Tactical Boost Glide effort. It also stated that prototyping efforts inform the warfighter in the development of formal requirements. The program office said that disciplined systems engineering processes have enabled it to manage technical and schedule risks. It stated that, as a result, the ARRW prototype is on track for an early operational capability in fiscal year 2022.

The program office also said that the planned fourth ARRW flight test is no longer scheduled for May 2022, but will now be conducted in September 2022.

The program office also noted that our estimated program cost graphic captures a snapshot in time before adjustments were made to shift funding from the cancelled Hypersonic Conventional Strike Weapon program to ARRW to fully fund the program and add the cost of new requirements.

Source: U.S. Air Force.

B-52 Commercial Engine Replacement Program (CERP)

The Air Force's B-52 CERP, a rapid prototyping middle-tier acquisition (MTA), 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 prototype. A second Spiral will deliver physical prototypes. The Air Force expects the physical prototypes to use modified off-the-shelf components that will improve aircraft performance and extend the life of the B-52H fleet beyond 2030.

Program Essentials

Decision authority: Air Force

Program office: Tinker Air Force Base, OK

MTA pathway: Rapid prototyping

Prime contractor: Boeing

Contract type: CPIF

Next major event: Virtual prototype contract award (February 2020)

Program Background and Expected Results

The Air Force initiated B-52 CERP as a middle-tier acquisition in September 2018 with an objective of completing the virtual rapid prototyping effort by April 2021. In December 2018, the program placed an order for risk reduction requirement studies for the virtual prototype to define engine requirements as well as other efforts. The program placed another order for virtual prototype rapid prototyping development efforts in February 2020.

At the completion of the Spiral 1 virtual rapid prototyping effort, the Air Force plans to transition to a follow-on rapid prototyping program for Spiral 2, to deliver a physical prototype. Once installed, the physical prototypes will complete ground, flight safety, and flight testing. The Air Force considers the completion of initial flight testing of the engine pods to be the end of the two rapid prototyping spirals. If prototyping is successful, the Air Force expects to procure 592 new engines within 296 new engine pods to modify the 74 remaining B-52H aircraft.

Estimated Middle-Tier Program Cost and Quantities

(fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

Approach: Information not available

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

Officials said it is too early in the design phase to determine software approach or type of software used.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	●	●
Approved middle-tier acquisition strategy	●	●
Technology, Cost, and Schedule Assessed		
Formal technology risk assessment	●	●
Cost estimate based on independent assessment	●	●
Formal schedule risk assessment	●	●

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

B-52 CERP Program

Key Elements of Program Business Case

The B-52 CERP Spiral 1 program had all the elements of its business case approved at the time of program initiation in September 2018. In May 2018, Air Force Global Strike Command established high-level requirements. Program officials stated the program is conducting early system design work while developing the virtual system prototype that will later inform the development of the physical engine pod prototypes. The Air Force Acquisistion Center of Excellence, along with the program office, completed technology and schedule risk assessments in August 2018. The Assistant Secretary of the Air Force (Acquisition, Technology, and Logistics) approved the acquisition strategy in September 2018 for both the virtual prototyping spiral and follow-on physical prototyping spiral.

In April 2018, the Air Force Cost Analysis Agency assessed the combined Spiral 1 and Spiral 2 development cost estimate for approximately $947 million through fiscal year 2024. In March 2019, the Air Force Cost Analysis Agency completed an independent cost assessment that estimated a combined $1.3 billion for Spirals 1 and 2 through fiscal year 2024. According to the Air Force, the 2019 cost assessment incorporated updated schedule, capabilities, and requirements information.The program office said, the development estimates increased due to updated fidelity, but life cycle costs changed little due to reduced estimates for production and operations and support cost.

Technology

The program stated it had performed a formal technology risk assessment, and it would define critical technologies or technology readiness levels in the future. The program did not provide specific technology information relating to the virtual prototype, as it had not yet identified the specific technology to be used.

Software Development and Cybersecurity

Officials stated it is too early in design to determine the final amount of software development required or the software development approach. They stated that they are considering using Agile software development and open system architecture to support the prototyping effort. The program approved a cybersecurity strategy in January 2020.

Other Program Issues

The Air Force plans to conduct the preliminary design review and award the contract for the Spiral 2 physical prototype middle-tier acquisition before the virtual prototype is complete. As a result, the Spiral 2 program may not have all the information it needs to set requirements for the physical prototype contract. Officials stated that the program plans to have defined all key system requirements by critical design review in fiscal year 2023.

The Spiral 2 program plans to use off-the-shelf components in prototype pods for the physical prototype, such as a commercial generator and hydraulic pumps that will be modified to form, fit, and function on the aircraft. The program office stated that its strategy rests on proven commercial engines, but some components necessary for integrating the new engines will require development. It said it plans for the development efforts to be mature by the time Spiral 2 is complete. However, if development does 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 currently expected.

Due to long production lead times, the program plans to order items for the first production lot after testing verifies the prototype aircraft performs as predicted; maintenance and training are in place; ground support equipment is mature; and cybersecurity is effective. The program stated that it will complete remaining testing concurrently with long lead procurements, and early engine production is critical to aircraft modification start.

The National Defense Authorization Act for Fiscal Year 2020 requires the Air Force to submit a report to the congressional defense committees that includes, among other information, the acquisition strategy, requirements information, as well as its test and evaluation strategy, before the Air Force may obligate or expend the last 25 percent of the program's fiscal year 2020 funding.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. According to the program office, the B-52 CERP prototyping phase reduces design, development, and integration risks associated with replacing the current B-52 engines with commercially available engines. It stated that it understands the technology risk; the acquisition strategy rests on proven commercial engines; and it is focused on integrating commercial technology rather than developing new technology. Further, the program said it has made significant progress since our review; is maturing requirements with a disciplined systems engineering process; and plans for preliminary design review and first virtual system prototype delivery to occur prior to physical prototype contract award. It also said that it plans to define key requirements by critical design review, 3 years before the start of engine production for the fleet.

After the cut-off date for our review, the program said it had identified critical technologies and their maturity levels and validated software scope and lines of code. It said it has identified virtual system prototype technologies, leveraging lessons from virtual prototypes delivered in November 2019.

Source: Defense Video Imagery and Distribution System.

F-22 Capability Pipeline

The Air Force's F-22 Capability Pipeline, a middle-tier acquisition program, is intended to continuously develop, integrate, and deliver hardware and software capabilities to F-22 aircraft. The program plans to deliver prototypes of capabilities—such as enhanced tactical information transmission, improved combat identification, modernized navigation, and sensor enhancements—that will be delivered iteratively as increments of capability.

- **02/18** Contract award
- **09/18** MTA initiation
- **10/18** MTA funds obligated
- **01/20** GAO review
- **02/20** Prototype 1 first flight demonstration
- **09/21** Prototype 2 operational demonstration/expected MTA completion
- **10/23** 5 years since MTA funds obligated

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 (development)

Next major event: Prototype 2 operational demonstration/expected MTA completion (September 2021)

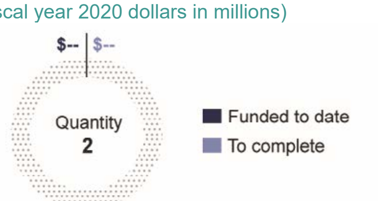
Program Background and Expected Results

The Air Force designated the F-22 Capability Pipeline in September 2018 as a rapid prototyping and rapid fielding effort. In February 2018, the program entered into an undefinitized contract action with Lockheed Martin, followed by definitization in July 2018. The program will deliver two prototype releases, both to be demonstrated in an operational environment by the end of fiscal year 2021. According to program officials, these prototypes are expected to enhance tactical information transmission and improve combat identification. A concurrent development effort is authorized to modernize navigation and add sensor enhancements on F-22 aircraft, to be delivered in subsequent releases. Prototype 1 is intended to serve as a pilot for this acquisition approach and provide a foundation for future F-22 aircraft modifications. Prototype 2 hardware and software improvements remain undefined as of January 2020.

Program officials stated that the F-22 Capability Pipeline will most likely transition to a rapid fielding program, although the program has already initiated rapid fielding activities—in July 2019, the Air Force approved a production decision for developmental hardware to accelerate initial fielding.

Estimated Middle-Tier Program Cost and Quantities

(fiscal year 2020 dollars in millions)

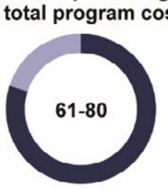


Our analysis of Air Force budget documents shows RDT&E costs of about $976.3 million. The Air Force deemed amounts funded and to complete not suitable for public release.

Software Development

(as of January 2020)

Approach: Agile, Continuous Delivery, and DevSecOps

Software percentage of total program cost	Software type
	Information not available

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	●	●
Approved middle-tier acquisition strategy	●	●
Technology, Cost, and Schedule Assessed		
Formal technology risk assessment	○	●
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

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

F-22 Capability Pipeline Program

Key Elements of Program Business Case

The F-22 Capability Pipeline program had several key elements of its business case completed by the time of its initiation in September 2018. The Air Force Chief of Staff approved requirements in 2011 and the Assistant Secretary of the Air Force (Acquisition, Technology, and Logistics) approved the program's acquisition strategy in September 2018, before program initiation.

However, the program did not have other key elements of its business case—a cost estimate informed by independent analysis, or formal schedule and technology risk assessments—at the time of program initiation. Our prior work has shown that this type of information is important to help decision makers make well-informed decisions about middle-tier program initiation, including whether the program is likely to meet the statute-based objective of fielding a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of an approved requirement.

Since program initiation, the Air Force has completed all of these business case elements. The Air Force Cost Analysis Agency completed a formal, independent cost estimate in August 2019. Prior to that, the program office had established its own cost estimate. Our analysis of the Air Force's February 2020 publicly releasable budget information determined that the Air Force expects the F-22 Capability Pipeline to cost approximately $976.3 million for the middle-tier prototyping phase. Program officials noted there is a potential funding shortfall for the F-22 Capability Pipeline. The officials said budget constraints will drive scoping of pipeline development activities.

The Air Force also conducted a formal technology and schedule risk assessment of the program in September 2019. This assessment found the program is exposed to schedule risk and late capability changes could lead to lenghty delays. According to program officials, there have not been any late capability changes to date, though they acknowledge ongoing schedule challenges.

Technology

The program identified one critical technology, Open System Architecture (OSA), which provides an interface for legacy systems and enables future capabilities on F-22 aircraft. The program noted OSA has been demonstrated in an operational environment, in an aircraft, and the technology is considered to be mature.

Software Development and Cybersecurity

Program officials stated the F-22 Capability Pipeline program is utilizing Agile, Continuous Delivery, and DevSecOps for its software development approach. Working software is deployed to a system test environment approximately every month. Program officials said, however, that the program's software development effort is hindered by deficiencies in testing infrastructure, including limitations in automated code testing. Program officials acknowledged the testing and delivery cadence of the software development effort is demanding, so the program has established working groups between users and the contractor to support test and release requirements, as well as implemented software tools for integration testing.

Program officials indicated the F-22 Capability Pipeline's cybersecurity requirements align with multiple guidelines for cybersecurity. The program approved a cybersecurity strategy in August 2018 and plans to update the strategy by the end of calendar year 2020.

Other Program Issues

Program officials emphasized the F-22 Capability Pipeline serves as a pilot program for the Air Force to use the middle-tier acquisition pathway to develop and rapidly deploy multiple capabilities under one effort. Program officials stated that unconventional business models like continuous integration and continuous delivery can benefit from the use of unconventional authorities, and that the middle-tier acquisition pathway is ideal for this type of acquisition.

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 F-22 Capability Pipeline was initiated as a prototype construct to inform rapid acquisition techniques for a hardware system. The program office said that it will continue to implement a strategy that allows for continuous integration and delivery of lethal capabilities.

According to the program office, it completed internal cost, schedule, and risk reviews prior to program initiation, and the approach to begin the program while pursuing independent reviews in parallel was a conscious measure to not delay the program and to further reduce schedule risk. The office stated that internal and external assessments have acknowledged schedule risk, and that the risk was fully understood at program initiation, accepted, and continues to be monitored.

The program office further stated that lessons learned prompted changes to the contract structure that are intended to increase contractor accountability and overall performance standards. Additionally, the office said the F-22 Capability Pipeline program was designated as an Agile pilot under section 873 of the National Defense Authorization Act for Fiscal Year 2018. According to the program office, the program continues to provide valuable lessons to the Office of the Secretary of Defense for reforming acquisition policy.

Source: Lockheed Martin.

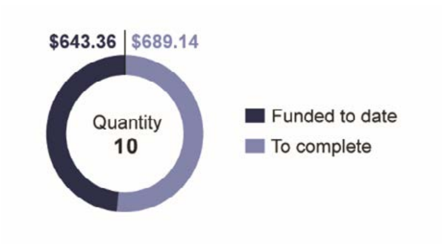
Hypersonic Conventional Strike Weapon (HCSW)

The Air Force's HCSW, a middle-tier acquisition program, is developing a conventional air-launched hypersonic missile that can be carried on the wing of a B-52H bomber and move at least five times the speed of sound. HCSW is intended to provide capability to strike time-critical, fixed soft surface targets in a contested environment. To speed up prototyping and fielding, the program is leveraging existing technology developed from previous hypersonic prototypes—including a hypersonic glide body and payload—and seeks to mature it. The Air Force indicated plans to cancel HCSW as of March 2020 after the critical design review.

Program Essentials

Decision authority: Air Force
Program office: Eglin Air Force Base, FL
Prime contractor: Lockheed Martin Corporation
MTA pathway: Rapid prototyping
Contract type: CPFF (development)
Next major event: Critical design review (March 2020)

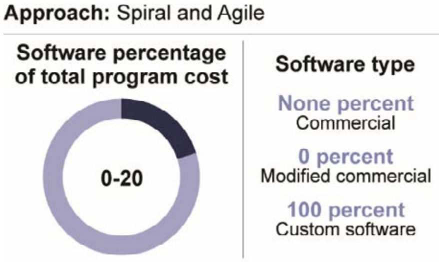
Estimated Middle-Tier Program Cost and Quantities (fiscal year 2020 dollars in millions)



Software Development

(as of January 2020)

Approach: Spiral and Agile



Custom software includes contractor-developed code from existing weapon systems.

Program Background and Expected Results

The Air Force initiated HCSW in May 2017 and designated HCSW as a middle-tier rapid prototyping acquisition in May 2018 with an objective to complete prototyping by January 2022. To accelerate the completion of HCSW's development, the Air Force directed the program to use DOD's Conventional Prompt Strike glide body—already in development—to produce an early operational hypersonic capability to counter hypersonic adversarial threats. Officials report that in May 2018, the Air Force awarded a development contract to Lockheed Martin Corporation to design, develop, integrate, test, and operationally qualify the HCSW missile. The Air Force intended for HCSW's first increment prototype to demonstrate an initial operational hypersonic capability with the potential for successive efforts to increase capability in later increments.

At the completion of the rapid prototyping effort, the Air Force planned to begin initial production using the middle-tier rapid fielding pathway. In February 2020, the Air Force indicated its plans to cancel HCSW and keep a second hypersonic weapon prototyping effort due to budget pressures. We included this assessment in our review because the program's funding and initiation decisions were made during our review period.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	○	●
Approved middle-tier acquisition strategy	○	●
Technology, Cost, and Schedule Assessed		
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

HCSW Program

Key Elements of a Program Business Case

The HCSW program did not have key elements of its business case—including approved requirements, an acquisition strategy, a cost estimate informed by independent analysis, or a formal schedule or technology risk assessment—approved at the time of program initiation. Our prior work has shown that this type of information is important to help decision makers make well-informed decisions about middle-tier program initiation, including whether the program is likely to meet the statute-based objective of fielding a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of an approved requirement.

Since program initiation, the Air Force has completed these business case elements. In the third quarter of fiscal year 2019, the Air Force Cost Analysis Agency independently assessed the program's cost estimate. In December 2019, program office officials said the program's latest cost estimate was nearly $1.2 billion.

The Air Force approved the program's systems requirements document in August 2019, approximately 15 months after the program was initiated as a middle-tier acquisition in May 2018. Program officials said that prior to approval of the systems requirements document, the program worked from higher-level requirements from the Air Force to guide the program. In May 2019, the Program Executive Officer approved the program's acquisition strategy.

According to program officials, the Air Force asked HCSW in May 2018 to deliver a hypersonic capability in fiscal year 2022.The Air Force assessed the HCSW schedule as aggressive. Specifically, program officials said that they removed all schedule reserve and planned to run several key development efforts concurrently, an approach that could put the schedule at risk for delays if every milestone did not go as planned.

The program completed its preliminary design review in July 2019. The Air Force also identified the availability of B-52H aircraft for testing and a number of dependencies from other DOD organizations for the glide body, the thermal protection system, and testing facilities, as elements of schedule risk.

Technology

The HCSW program identified the need to mature two key program technologies during integration and flight testing, which was scheduled to start in June 2020. These technologies were derived from other efforts in DOD and the Air Force. The HCSW program reported the first technology is a hypersonic payload delivery vehicle—the warhead—that will reach maturity once it is launched from a B-52H. The second technology for a variant of a solid rocket propellant is also immature, but the program office plans for it to reach maturity after a ground static fire test and launch from a B-52H.

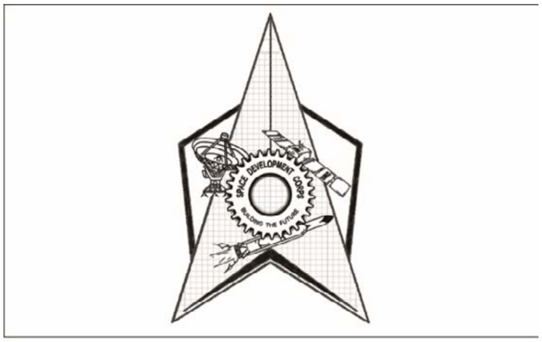
Software Development and Cybersecurity

HCSW's software development plan was approved in March 2019 and is a mixed development approach using some Agile development with software planned to be deployed to users every 2 weeks. This approach is consistent with industry practices, 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 software includes a combination of new and reused contractor code. None of the code is commercial off–the-shelf.

HCSW's cybersecurity strategy was approved in June 2019. Increment 1 software testing started in early fiscal year 2019 and was expected to run until 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. The program office said that the critical design review was held in March 2020 and that at the time the program was cancelled, the program was on schedule to deliver a limited capability in fiscal year 2022. The program office also noted that our estimated program cost and quantities graphic captures a snapshot in time before program cancellation and that costs and quantities have since changed as a result of the cancellation.



Source: U.S. Air Force.

Next Generation Overhead Persistent Infrared (Next Gen OPIR) Block 0

The Air Force's Next Gen OPIR Block 0, a follow-on to the current Space Based Infrared System, consists of three geosynchronous earth orbit (GEO) satellites and two polar coverage highly elliptical orbit satellites. The Block 0 rapid prototyping effort will deliver the main mission payload—an infrared sensor—for these satellites. The Air Force authorized another rapid prototyping effort in December 2019 to develop the future ground system, which is expected to award a contract in July 2020.

Program Essentials

Decision authority: Air Force

Program office: El Segundo, CA

Prime contractor: Lockheed Martin Space (GEO); Northrop Grumman Corporation Aerospace Systems (polar)

MTA pathway: Rapid prototyping

Contract type: CPIF (development)

Next major event: Critical design review (November 2021)

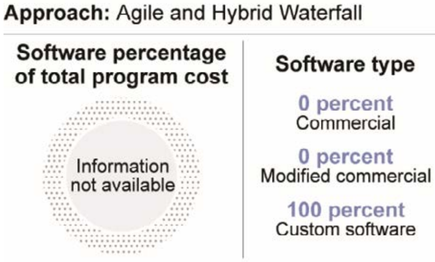
Estimated Middle-Tier Program Cost and Quantities (fiscal year 2020 dollars in millions)

Cost and quantities reflect Block 0 only.

Software Development

(as of January 2020)

Approach: Agile and Hybrid Waterfall



Program officials are still forecasting the full software effort. Custom software includes contractor-developed code from existing weapon systems.

Program Background and Expected Results

The Air Force initiated Next Generation OPIR Block 0 as a rapid prototyping middle-tier acquisition in June 2018, with an objective to complete prototyping by October 2023. Officials report that in August 2018, the Air Force awarded two sole-source contracts for Block 0 satellites–the first to Lockheed Martin Space for three GEO satellites; and the second to Northrop Grumman Corporation Aerospace Systems for two polar satellites. According to program officials, the Block 0 rapid prototyping effort will end once the main mission payload—an infrared sensor—has completed two steps to demonstrate operational capability: 1) a successful thermal vacuum test, and 2) delivery to the spacecraft for integration. However, the payload will still need to be attached—or integrated—onto the spacecraft.

At the completion of the Block 0 rapid prototyping effort, the Air Force plans to transition to a major capability acquisition pathway for the remaining Block 0 satellites. The Air Force expects its first Next Gen OPIR satellite to achieve initial launch capability by late 2025, and plans to launch all 5 satellites in Block 0 by 2029. A Block 1 effort is planned to add two additional GEO satellites. Block 1 is anticipated to be a full and open competition, but the Air Force has yet to determine the acquisition pathway for the block.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	●	●
Approved middle-tier acquisition strategy	●	●
Technology, Cost, and Schedule Assessed		
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

Next Gen OPIR Block 0 Program

Key Elements of Program Business Case

The Next Gen OPIR Block 0 program had most business case elements approved by program initiation in June 2018. In December 2017, the Joint Requirements Oversight Council validated the program's requirements, and in June 2018, the Air Force Service Acquisition Executive approved the program's acquisition strategy. The acquisition strategy calls for two satellite contractors to develop the GEO and polar satellites, respectively. According to the program, each satellite contractor is to compete the mission payload development and award up to two subcontracts. Air Force officials say this competition reduces schedule risk by spreading potential development issues across two teams, and provides the highest likelihood of an on-time payload delivery.

The program did not have a cost estimate based on an independent assessment or formal schedule risk assessment at the time of program initiation, but these have since been approved. In May 2019, nearly a year after program initiation, the Air Force Cost Analysis Agency completed an independent cost assessment of Block 0 GEO and polar satellites that spanned fiscal years 2021 through 2025 and estimated a cost of over $800 million more than the program for the same period. According to program officials, the cost difference reflects programmatic changes that occurred between program initiation and the independent cost estimate. In June 2019, the program office completed an integrated baseline review, which included a schedule assessment. The first GEO satellite is required to achieve initial launch capability by late 2025, with all five Block 0 satellites on orbit by 2029. However, our ongoing work assessed the schedule as highly aggressive and high risk, given concurrent development efforts within Block 0, and complex integration that includes first-time integration of a new payload and spacecraft, among other significant technical risks.

Technology

The Secretary of the Air Force's Office of Science, Technology, and Engineering and the Air Force's Space and Missile Systems Center Engineering Directorate conducted a formal technical risk assessment of the program in April 2018. Eight of 18 critical technologies are currently immature, with most of those related to the main mission payload. The Air Force has yet to finalize the payload design, which remains one of the highest risks to the launch schedule.

According to program officials, all but two critical technologies will be tested in an operational environment prior to the first satellite launch in 2025. The exceptions, satellite maneuvering thrusters and a sensor protection mechanism, present testing challenges with existing infrastructure. Program officials say these will be "sufficiently scrutinized" to avoid becoming single points of failure after launch.

Software Development and Cybersecurity

Program officials said they are still forecasting the software effort, but they plan to generally reuse software from the Space Based Infrared System (SBIRS) GEO programs, ground system, and other programs. The program has an approved cybersecurity plan which, according to the Air Force, will be assessed and authorized in accordance with DOD's Risk Management Framework for Information Technology.

Other Program Issues

The program faces multiple challenges. For example, the future ground system may not be ready when the first GEO satellite is delivered. To mitigate this risk in the interim and ensure a ground system is available for the first launch, the program is designing GEO satellites to integrate into existing SBIRS ground architecture with some modifications. This risk mitigation measure is intended provide a continuation of existing missile warning capabilities.

Also, while the program considers the spacecraft a mature legacy technology, the spacecraft will be modified to meet new mission requirements. DOD officials acknowledged the added risk presented by the first-time integration of a new sensor design with a modified spacecraft.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical corrections, which we incorporated where appropriate. According to the program office, the shift of the nation's missile warning architecture to an initial warning constellation resulted in designation of Next Generation OPIR as a MTA rapid prototyping program. The office further stated that the MTA decision accelerated the planned delivery date of the first vehicle by 42 months to meet the 2025 need date. It said the program is on track, completed systems requirements and preliminary design reviews within 13 months of contract award, and has established a technical design baseline and integration strategies. The program also said it is leveraging existing technology to mitigate multiple risks.

Source: LinQuest.

Protected Tactical Enterprise Service (PTES)

The Air Force's PTES, a middle-tier acquisition (MTA), plans to develop and field the ground system for enabling adaptive anti-jam wideband satellite communications capabilities through two sequential rapid prototyping releases. We evaluated the planning and execution of the first rapid prototyping release, which the Air Force expects will demonstrate operational readiness for anti-jam tactical communications in the Pacific.

06/18	11/18	12/18	01/20	04/20	11/21	12/23
MTA initiation	Contract award	MTA funds obligated	GAO review	Initial production	Operational demonstration/ Expected MTA completion	5 years since MTA funds obligated

Program Essentials

Decision authority: Air Force
Program office: El Segundo, CA
Prime contractor: The Boeing Company
MTA pathway: Rapid prototyping
Contract type: CPIF (development)
Next major event: Initial production (April 2020)

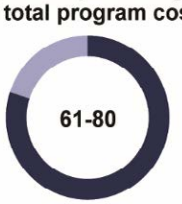
Estimated Middle-Tier Program Cost and Quantities (fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

Approach: DevOps and DevSecOps

Software percentage of total program cost



Software type

0 percent Commercial
0 percent Modified commercial
100 percent Custom software

Program Background and Expected Results

The Air Force initiated PTES as a middle-tier acquisition program in June 2018 with an objective of completing prototyping for the first of two planned rapid prototyping releases by the third quarter of fiscal year 2023. In November 2018, the program awarded Boeing a cost-plus-incentive-fee contract for PTES design and development. The Air Force originally intended the program to be conducted under the traditional DOD acquisition system but determined that using the rapid prototyping pathway and an Agile software development approach would accelerate the program's schedule. The program expects to demonstrate operational capabilities in November 2021, 1.5 years prior to initial operational capability, which completes its current rapid prototyping release.

After the completion of the first rapid prototyping release, the program plans another release with the goal of providing full operational capability for Navy, Army, and Air Force operations by fiscal year 2026.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	●	●
Approved middle-tier acquisition strategy	●	●
Technology, Cost, and Schedule Assessed		
Formal technology risk assessment	○	○
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	●

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

PTES Program

Key Elements of Program Business Case

The PTES program had approved requirements and a middle-tier acquisition strategy at the time of MTA initiation. In 2017, the Joint Requirements Oversight Council approved PTES requirements and the Principal Deputy Assistant Secretary of the Air Force (Acquisition and Logistics) approved the program's aquisition strategy to competitively award a single contract for both development and production phases. The acquisition strategy includes planning specific to the rapid prototyping pathway prior to MTA initiation.

The program did not have several other key elements of its business case—including a cost estimate informed by independent analysis, or a formal schedule or technology risk assessment—approved at the time of middle-tier program initiation in June 2018. Our prior work has shown that this type of information is important to help decision makers make well-informed decisions about middle-tier program initiation, including whether the program is likely to meet statute-based objectives of fielding a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of an approved requirement.

Since program initiation, the program has gained Air Force approval of a cost estimate based on independent analysis in November 2018. The program plans to complete an integrated Technical Risk Assessment in April 2020 and perform an independent technical risk assessment in July 2020 as well as a technical readiness assessment in September 2020.

Technology

The program has identified three technology areas critical for development, all of which the program has assessed as either approaching maturity or mature based on an initial assessment in May 2017. These technology areas are Joint Hub and Network, Dynamic Resource Allocation, and Crypto and Cross Domain Solution. After the completion of field demonstration test reports in March 2020, the program plans to update the technologies' maturity levels.

PTES subsystems are either based on commercial off-the-shelf communications hardware or are integrations of such hardware and software components.

Software Development and Cybersecurity

The PTES program is using an Agile software development process to develop mission management system and key management system software. According to the program office, the program's development cycle consists of 2-week sprints with working software tested at the end of each sprint, quarterly build demonstrations, and 9-month builds with working software delivered as capabilities are completed. Program officials stated that the program obtains user feedback during development through periodic sessions with system operators and planners, cybersecurity operators, and tactical warfighters. The program plans to use functioning software, product backlogs, and smaller software report updates as reporting metrics.

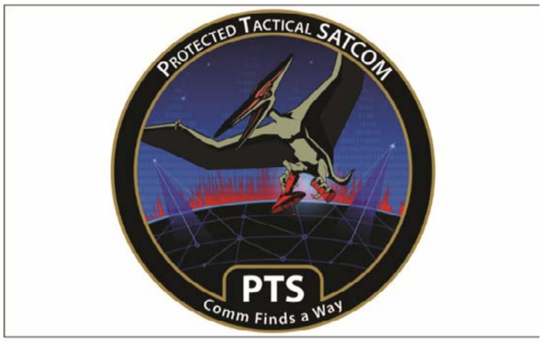
PTES has a cybersecurity strategy, which was approved in November 2018. According to the program office, the main cybersecurity challenges are planning related, with multiple external cybersecurity-related entities having limited resources and lengthy cybersecurity certification coordination schedules required to support the evaluation or assessment of the program.

Other Program Issues

Contract negotiations for implementing End Cryptographic Unit technical baseline changes concluded in November 2019, and execution of changes is expected to begin at the start of 2020. The program office stated that the delays were absorbed within existing schedule margin and are not expected to impact initial operational capability, currently planned for June 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. The PTES program office stated that it has made significant progress since June 2018 initiation as a middle-tier program, including meeting technology development milestones and making significant strides developing and implementing Agile best practices. These achievements, it said, include implementation of continuous feedback mechanisms and a strategy to capture and forecast Agile software development metrics, among other things. The program office stated that it completed an independent cost estimate in October 2018, which updated the estimate that informed the middle-tier program initiation decision. According to the program office, the middle-tier acquisition structure allowed it to rapidly adjust to a fiscal year 2021 budget reduction by restructuring program deliverables instead of delaying prototype delivery as well as maintain its course to deliver and learn from early prototypes planned for November 2021.



Source: LinQuest.

Protected Tactical SATCOM (PTS)

The Air Force's PTS, a rapid prototyping middle-tier acquisition program, is a space-based system that will transmit a protected, anti-jamming waveform—the Protected Tactical Waveform—to users in contested environments. The PTS program will prototype several components, including hosted payloads, satellites, and an end cryptographic unit to operate with the protected waveform. PTS is part of the Air Force's broader Protected Anti-Jam Tactical SATCOM (satellite communications) effort, which also includes the Protected Tactical Enterprise Service, another middle-tier acquisition program.

Program Essentials

Decision authority: Air Force

Program office: El Segundo, CAL

Prime contractors: Boeing, Lockheed Martin, and Northrop Grumman (all prototype design)

MTA pathway: Rapid prototyping

Contract type: FFP (development)

Next major event: Critical design review (June 2020)

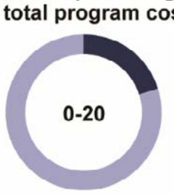
Estimated Middle-Tier Program Cost and Quantities (fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

Approach: Agile and DevSecOps

Software percentage of total program cost



Software type

0 percent
Commercial

75 percent
Modified commercial

25 percent
Custom software

Program Background and Expected Results

The Air Force initiated PTS as a middle-tier acquisition in November 2018 with an objective of completing prototyping by June 2024. The program originally began under the traditional DOD acquisition system in 2017 but the Air Force determined that rapid prototyping would accelerate the program's development schedule. Officials reported that in February and March 2020, the program awarded three contracts for different vendors to develop hosted payload prototypes. Officials stated that each contractor will be responsible for designing a modular, scalable, hosted payload design that demonstrates key PTS requirements. Following this phase, the program plans to down-select to two contractors to build the prototype payloads and integrate them with space vehicles in fiscal year 2022. The program expects to deliver the two prototype payloads for launch by June 2024, which it anticipates will provide a limited capability on orbit to serve users. The program plans to incorporate feedback from users on system performance before advancing to production, subsequent to the rapid prototyping effort.

Following delivery of its prototypes, the program plans to enter production for nine additional units that can be placed on commercial or DOD satellites, though the program has yet to choose a follow-on acquisition approach.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	○	●
Approved middle-tier acquisition strategy	○	●
Technology, Cost, and Schedule Assessed		
Formal technology risk assessment	●	●
Cost estimate based on independent assessment	○	●
Formal schedule risk assessment	○	○

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

PTS Program

Key Elements of Program Business Case

The PTS program had completed a formal technology risk assessment at the time of program initiation. However, the program did not have several other key elements of its business case—including an approved requirements document, acquisition strategy, cost estimate based on an independent assessment, and formal schedule risk assessment—completed prior to its initiation in November 2018. Our prior work has shown that this type of information is important to help decision makers make well-informed decisions about middle-tier program initiation, including whether the program is likely to meet the statute-based objective of fielding a prototype that can be demonstrated in an operational environment and provide residual operational capability within 5 years of an approved requirement.

Since program initiation, the program has completed its program requirements document, which the Air Force Requirements Oversight Council approved in December 2018. The program's acquisition strategy was approved in April 2019.

The PTS program obtained approval of its service cost position in January 2020, over a year after program initiation. The PTS program office estimates the MTA portion of the program will cost $906.7 million. According to program officials, the program is currently on schedule, however officials told us they do not plan to conduct a formal schedule risk assessment but may reconsider such an assessment later in the program's development. Without this type of information, decision makers lack assurance that they have accurate schedule expectations for the program to use as a starting point to monitor program performance.

Technology

PTS relies on technology operating in space and on Earth, including ground-based terminals and network access management systems. The program has identified five critical technologies, all of which are currently immature based on the program's technology risk assessment and market research. The program plans for these technologies to contribute to more direct connectivity, thereby reducing latency and operational risk for forward-deployed users. According to the acquisition strategy, the program plans for all of the critical technologies to be fully mature through testing in in an operational environment at the end of the rapid prototyping effort. The program initiated prototype development for its cryptographic unit that secures satellite transmissions late in fiscal year 2019.

Software Development and Cybersecurity

PTS program contractors are developing about 25 percent of the software to support the program's space and ground segments, while the remaining 75 percent of software will be a combination of reused custom, open source, and modified commercial off-the-shelf software. For its satellites, PTS is developing onboard Protected Tactical Waveform processing to facilitate secure, anti-jam communications. Terminals operating with the protected waveform can be deployed to forward locations. The PTS ground segment will rely on software development to support mission planning and satellite operations, as well as command and control for the satellite elements. The program plans to make minor modifications to the software systems of its sister program—Protected Tactical Enterprise Service, or PTES—to support PTS. We assessed the PTES program separately in this report.

The PTS program plans to have a cybersecurity strategy approved in January 2020.

Other Program Issues

PTS depends on software development conducted by the PTES program to support its initial ground segment functions. According to program officials, PTES remains on schedule and they are not concerned about possible PTES delays affecting PTS. However, if PTES systems are not functionally available in time for PTS prototypes, the PTS program plans to leverage other working prototypes for mission planning and satellite operations, which are being developed to support the broader Protected Anti-Jam Tactical SATCOM enterprise.

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 office said it awarded three Other Transaction Prototype Payload Agreements in February 2020 to support technical maturation and risk reduction activities. According to the program office, acquisition of an End Cryptographic Unit continues to define the PTS schedule overall, and that acquisition is progressing as planned. It also stated that it successfully completed a preliminary design review of the unit in March 2020.

Further, the office stated it continuously evaluates PTS schedule performance. According to the program office, several factors, including market research, historical data from similar weapons systems, and competitive proposed schedules submitted in a competitive environment, informed its current assessment of PTS schedule risk. It also said that its firm fixed-price prototype payload development efforts are designed to maximize capability delivery within a defined schedule. Additionally, the program office stated that its January 2020 service cost position updated estimates that informed the middle-tier program initiation decision.

UNIFIED PLATFORM

Source: U.S. Air Force.

Unified Platform (UP)

The Air Force's UP, a rapid prototyping middle-tier acquisition (MTA), is developing a federated software platform to consolidate service-specific cyber capabilities and data processing, storage, and sharing as part of DOD's Joint Cyber Warfighting Architecture. UP will enable advanced analysis and mission planning to support cyber operations. Previously, the military services, U.S. Cyber Command, and other agencies developed systems and applications with little to no interoperability, creating challenges for joint operations, information sharing, and overall mission effectiveness.

- **08/18** MTA initiation
- **10/18** MTA funds obligated/ contract award
- **03/19** Operational demonstration
- **01/20** GAO review
- **04/20** Annual authority to proceed review
- **10/23** Expected MTA completion/ 5 years since MTA funds obligated

Program Essentials

Decision authority: Air Force
Program office: San Antonio, TX

Contractor: multiple (government is managing the integration)

MTA pathway: Rapid prototyping

Contract type: multiple (see above)

Next major event: Annual authority to proceed review (April 2020)

Estimated Middle-Tier Program Cost and Quantities (fiscal year 2020 dollars in millions)

Software Development

(as of January 2020)

Approach: Agile and DevSecOps

Software percentage of total program cost

Software type

90 percent Commercial

0 percent Modified commercial

10 percent Custom software

Program Background and Expected Results

The Air Force initiated the UP program as a middle-tier acquisition in August 2018. Officials reported that in October 2018, the program awarded a contract to Northrop Grumman to act as the system coordinator, and that in March 2019, the program awarded contracts to five different companies for software development. The program is delivering software in 3-month increments, which allows for successive rapid prototyping. Program officials said U.S. Cyber Command accepted the program's first prototype, increment 1, in April 2019. Under DOD guidance, the objective of a middle-tier acquisition rapid prototyping program is to field a prototype meeting defined requirements that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of the program start date. The program has delivered three additional increments. UP developers integrated services' data platforms, improving information sharing and data queries. However, the program plans to continue as a middle-tier rapid prototyping program until October 2023. Subsequent increments are expected to improve interoperability and to provide new analysis features.

The Air Force is evaluating what type of acquisition pathway to pursue at the end of its rapid prototyping effort.

Attainment of Middle-Tier Acquisition Knowledge

As of January 2020

	Status at Initiation	Current Status
Requirements and Acquisition Strategy Approved		
Approved requirements document	○	●
Approved middle-tier acquisition strategy	●	●
Technology, Cost, and Schedule Assessed		
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

UP Program

Key Elements of Program Business Case

UP did not have several key elements of its business case approved at the time of program initiation, such as approved requirements, a cost estimate informed by independent analysis, or a formal schedule risk assessment. Our prior work has shown that this type of information is important to help decision makers make well-informed decisions about middle-tier program initation.

Since program initiation in August 2018, U.S. Cyber Command approved the program's requirements and the Air Force Cost Analysis Agency independently assessed the program's cost estimate. The program's cost estimate was more than five times its initial estimate at program initiation, which had not been independently assessed. The new cost estimate includes costs beyond the completion of this middle-tier acquisition. Program officials attribute this cost increase to new U.S. Cyber Command requirements.

The program does not plan to complete a schedule risk assessment. Although the program organizes its development activities in 3-month increments, the program's schedule does not link the sequence of activities required to achieve a specific result—information necessary to conduct a schedule risk assessment. Instead, the program collaborates with stakeholders to plan and prioritize the content for each increment. Any features completed within the 3-month increment are then demonstrated for users, who provide feedback to inform future increments.

The program also does not plan to complete a technology risk assessment. Unified Platform program officials said they do not have any critical technologies.

Software Development and Cybersecurity

According to program officials, the UP program is utilizing Agile and DevSecOps software development methodologies. However, the program's current approach allows for fielding new features at the end of each 3-month increment, an approach that differs from industry's Agile practices, which encourage the delivery of working software to actual users on a continuing basis—as frequently as every 1 to 6 weeks—so that feedback can focus on efforts to deploy greater capability.

Program officials expect to make significant use of open source software and applications and are initially focused on interoperability of existing capabilities. For example, integrating the services' existing big data platforms has increased users' access to data that was previously kept separate.

Program officials said that after completing and demonstrating each new feature—a distinguishing software characteristic—U.S. Cyber Command determines whether the software is ready for operational deployment and that this approach allows for successive rapid prototyping. The program reported that it delivered 32 features through the first four increments and that U.S. Cyber Command accepted all features for deployment. There is currently no set number of new features planned.

The program has yet to complete its cybersecurity strategy, but program officials estimate that they will complete the strategy in April 2020, a year after delivery of the first increment. Not addressing cybersecurity issues sooner may increase risk to the program. Our past 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.

Other Program Issues

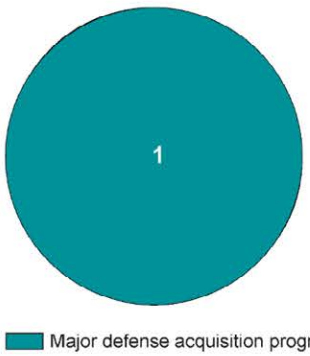
The Assistant Secretary of the Air Force (Acquisition, Technology, and Logistics) provides acquisition oversight for the UP program through annual authority to proceed reviews, most recently in April 2019. Based on that review, the program is required to notify and brief the Assistant Secretary if funding needs increase or decrease by 25 percent in a given year or if the number of development teams needed to accomplish requirements increases or decreases by 25 percent, among other things.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The office provided technical comments, which we incorporated where appropriate. The program office stated that it continues to mature processes for delivering operational software to U.S. Cyber Command customers. According to the program, current initiatives include increasing the pace of software delivery from every 3 months at the conclusion of each program increment, toward a goal of continuous delivery. The program office also stated that it anticipates formal approval of the UP program's cybersecurity strategy by August 2020.

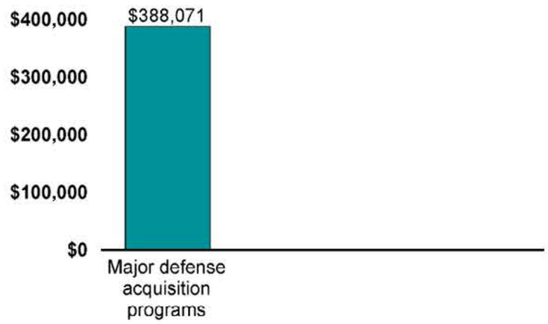
JOINT DOD PROGRAM ASSESSMENTS

GAO Assessed One Joint DOD Weapon Acquisition Program



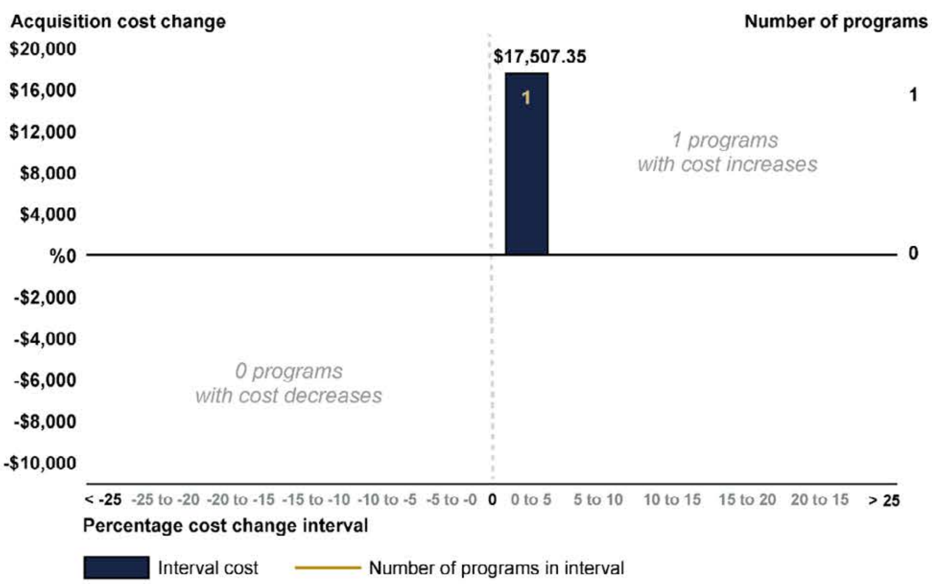
GAO Reviewed the F-35 Lightning II Program that Had an Estimated Total Acquisition Cost of $388 Billion

(Fiscal Year 2020 dollars in millions)

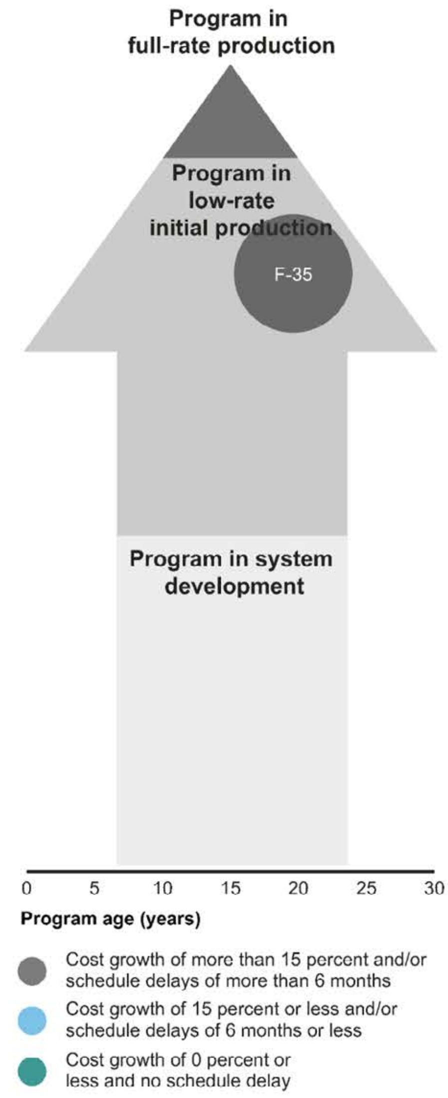


GAO Assessed the F-35 Lightning II Program that Increased in Cost Since Last Year

(Fiscal Year 2020 dollars in millions)



GAO Assessed the F-35 Lightning II Program that Has Had Cost Growth and Schedule Delays since First Full Estimate



Note: Bubble size is based on the program's currently estimated total acquisition cost.

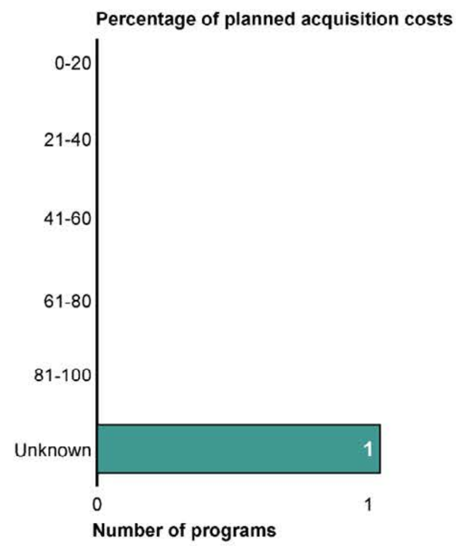
- Cost and schedule analyses are primarily based on estimates from December 2018 selected acquisition reports. This information may differ from information reported in the Program Performance table and Funding and Quantities figures in the F-35 Lightning II individual assessment, which is based on more recent program estimates. Please see appendix II for details.

JOINT DOD PROGRAM ASSESSMENTS

The F-35 Lightning II Program GAO Assessed Reported a Software Delivery Time 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 increments.

The F-35 Lightning II Program's Planned Acquisition Costs that are Specifically for Software are Unknown



The F-35 Lightning II Program GAO Assessed Did Not Attain Knowledge at Key Points, but Attained Some Knowledge Later

- Note: For each knowledge point, GAO assessed the F-35 Lightning II program if it reached that point as of January 2020.

At Occurrence of Knowledge Point

Knowledge Point 1

0 of 1

programs attained knowledge

Knowledge Point 2

0 of 1

programs attained knowledge

Knowledge Point 3

0 of 1

programs attained knowledge

As of January 2020

Knowledge Point 1

1 of 1

programs attained knowledge

Knowledge Point 2

1 of 1

programs attained knowledge

Knowledge Point 3

0 of 1

programs attained knowledge

Source: Department of Defense.

F-35 Lightning II (F-35)

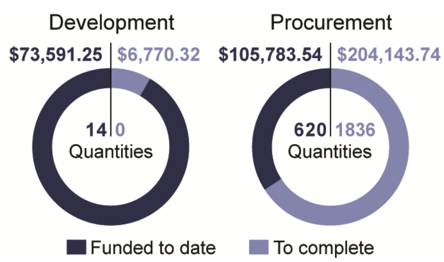
DOD is developing and fielding three strike fighter aircraft variants integrating stealth technologies, advanced sensors, and computer networking for the United States Air Force, Marine Corps, and Navy, international partners, and foreign military sales customers. The Air Force's F-35A variant will complement 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.

Program Essentials

Milestone decision authority: Under Secretary of Defense, Acquisition and Sustainment
Program office: Arlington, VA
Prime contractor: Lockheed Martin, Pratt & Whitney
Contract type: FPI/CPIF/CPFF (aircraft low-rate production)
Next major milestone: End operational test (July 2020)

Funding and Quantities

(fiscal year 2020 dollars in millions)

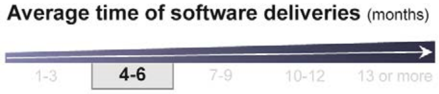


Software Development

(as of January 2020)

Approach: Agile and Waterfall

Average time of software deliveries (months)



Software percentage of total program cost

Software type

0 percent Commercial

0 percent Modified commercial

100 percent Custom software

Software costs are unknown because officials are currently updating documents that provide information on software costs.

Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (10/2001)	Latest (09/2019)	Percentage change
Development	$44,911.01	$80,361.56	+78.9%
Procurement	$199,249.17	$309,927.28	+55.6%
Unit cost	$85.92	$159.94	+86.1%
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 2020

	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

All of the F-35's critical technologies are mature, and the baseline engineering drawings are complete for all three variants. However, the F-35's development cost increased by $12.4 billion this year. While this cost increase was primarily due to the F-35 program adding modernization activities to the baseline development, it is also partially attributable to continuing design changes on the aircraft. In addition to increasing program cost, these changes could pose a risk to the contractor delivering the aircraft on time. For example, the contractor is adding wiring through the wings of the aircraft to accommodate an upgrade to the F-35's electronic warfare system. This wiring resulted in some structural changes for the Navy's F-35C variant.

Operational testing is ongoing to ensure the contractor has delivered all of the baseline aircraft capabilities. Since we reported last year, DOD delayed completion of this testing by 7 months, to July 2020. The program needed more time to move test equipment to a maritime environment to conduct the final F-35 open air flight tests. Additionally, the Naval Air Systems Command's development of the test simulator, needed for more complex testing that cannot be done in open air, will not be complete until July 2020. As a result of these delays, the program has also delayed the F-35 full-rate production about 11 months, from October 2019 to September 2020.

The program office is taking actions to prioritize the resolution of F-35 aircraft deficiencies identified in testing. Over the past year, the contractor worked to resolve 32 deficiencies. However, as of December 2019, there were over 850 unresolved deficiencies, of which over 300 were identified during the ongoing operational testing. Until operational testing is complete, there is potential risk that the testing will reveal additional deficiencies with the aircraft. Addressing the current deficiencies and any additional deficiencies found during testing will require retrofits to delivered aircraft, which will add to the program's costs.

As of December 2019, the prime contractor had delivered 491 production aircraft. The program reported that it has reached a high level of manufacturing readiness but that it has not achieved statistical control of critical processes. We have updated our attainment of product knowledge table to reflect this change from our previous assessment. Additionally, the program has tested a production representative prototype in its intended environment, but it has not met reliability and maintainability goals.

Future aircraft deliveries will likely be affected by Turkey's suspension and ultimate removal from the F-35 international partnership following Turkey's acquisition of military equipment from Russia. As part of this removal, Turkish suppliers will no longer be used and the prime contractor must find new suppliers for about 1,000 parts that Turkish suppliers provided, including key components such as the center fuselage. The prime contractor has identified new suppliers for most parts; it is still working to source about 15 additional parts. To date, production has not been affected, but by March 2020, 46 aircraft may be affected if the program no longer accepts parts from Turkey.

Since the start of production in 2007, the F-35 contractors have continued to refine their production processes and improve efficiency, often through process changes. While some of these changes have led to improvements, 30 percent of the program's critical manufacturing processes are not in control and since last year, the number of critical processes has increased by 71 percent. Critical processes should be repeatable, sustainable, and consistent in producing parts within the quality standards, which provides confidence that the product can be produced within cost, schedule, and quality targets.

Software and Cybersecurity

Software development is a risk area for the F-35 program. Completing the original and ongoing software development work continues to present challenges and has caused delays to testing over the past 5 years. For example, recent software updates led to problems with baseline functionality that were discovered after developmental testing was complete. This kind of issue requires the software developers to spend time fixing problems rather than developing new capabilities. According to test officials, some of the software issues are due to the program not conducting sufficient lab testing of the software to ensure other key functionality still works before releasing it to operational testing.

To date, the program performed 25 cybersecurity tests against supporting ground systems and 12 tests against air vehicle components. Four additional test events are required to complete formal operational testing, currently scheduled to occur between April and August 2020.

Program Office Comments

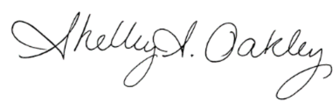
We provided a draft of this assessment to the program office for review and comment. The office provided technical comments, which we incorporated where appropriate. The program agreed with our assessment and stated that it continues to work with its industry, military service, and international partners to address the challenges outlined above by looking for cost and schedule efficiencies to deliver the required capability on time and within its budget.

Agency Comments

We provided a draft of this report to DOD for review and comment. In its comments, reproduced in appendix V, DOD generally concurred with our report. DOD also provided us with technical comments, which we incorporated where appropriate.

We are sending copies of this report to the appropriate congressional committees and offices; the Secretary of Defense; the Secretaries of the Army, Navy, and Air Force; and the 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 are your staff have any questions concerning this report, please contact me at (202) 512-4841. 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 James M. Inhofe
Chairman
The Honorable Jack Reed
Ranking Member
Committee on Armed Services
United States Senate

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

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

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

Appendix I: Fifteen Business and Non-Business Major Information Technology (IT) Systems in Our Review

Table 21: Fifteen Business and Non-Business Major IT Programs

Service	Program
Air Force	Deliberate and Crisis Action Planning and Execution Segments Increment 2B (DCAPES Inc 2B)
Office of the Secretary of Defense	Public Key Infrastructure Increment 2 (PKI Inc 2)
Air Force	Integrated Strategic Planning and Analysis Network Increment 4 (ISPAN Inc 4)
Office of the Secretary of Defense	Teleport Generation 3 (Teleport Gen 3)
Navy	Common Aviation Command and Control System Increment 1 (CAC2S Inc 1)
Navy	Consolidated Afloat Networks and Enterprise Services (CANES)
Navy	Distributed Common Ground System-Navy Increment 2 (DCGS-N Inc 2)
Air Force	Air Force Integrated Personnel and Pay System Increment 1 (AFIPPS Inc 1)
Air Force	Defense Enterprise Accounting and Management System-Increment 1 (DEAMS Inc 1)
Air Force	Maintenance Repair and Overhaul Initiative (MROI)
Army	Integrated Personnel and Pay System-Army Increment 2 (IPPS-A Inc 2)
Office of the Secretary of Defense	Department of Defense Healthcare Management System Modernization (DHMSM)
Office of the Secretary of Defense	Defense Agencies Initiative Increment 3 (DAI Inc 3)
Army	Army Contract Writing System (ACWS)
Navy	Navy Electronic Procurement System (Navy EPS)

Source: GAO analysis of Department of Defense data. | GAO-20-439

Appendix II: Objectives, Scope and Methodology

This report (1) summarizes the characteristics of the 121 programs we reviewed; (2) assesses the four sets of programs we reviewed on selected cost and schedule measures and other topics uniquely applicable to each of them, such as implementation of knowledge-based acquisition practices and software development approaches and cybersecurity practices; and (3) summarizes recent organizational and legislative changes that have potential implications for execution and oversight of the programs we reviewed. This report also presents individual knowledge-based assessments of 63 Major Defense Acquisition Programs (MDAP) and Middle Tier Acquisition (MTA) programs.

Summary of Program Characteristics and Selected Organizational and Legislative Changes

To report on the characteristics of the Department of Defense's (DOD) most expensive weapon and Information Technology (IT) programs, we selected 121 programs—100 of which have baselined cost information, meaning they have formal cost estimates included in a selected acquisition report or acquisition program baseline, and 21 that do not. The 100 baselined programs include 85 MDAPs and 15 major IT programs. We also selected 21 unbaselined programs, which means they do not have a formal cost estimate included in a selected acquisition report or acquisition program baseline. These 21 programs included eight future MDAPs and 13 MTA programs. Our selection methodology and data sources for each type of program are described in more detail below.

To illustrate the total number of programs and projected costs for baselined programs, we combined the total projected costs for baselined MDAPs and major IT systems into a single graphic. To report on the unbaselined programs' planned spending, we collected cost projections for future MDPAs through our web-based questionnaire and, for MTA programs, through program identification data forms submitted by the programs to the Office of the Secretary of Defense (OSD) and a separate follow-on questionnaire. We then totaled the eight unbaselined future MDAP cost estimates and the 13 unbaselined MTA cost estimates. For all programs we reviewed, we converted all cost information to fiscal year 2020 dollars using conversion factors from DOD Comptroller's National Defense Budget Estimates for Fiscal Year 2020 (table 5-9).[1]

[1]Department of Defense, Undersecretary of Defense, *National Defense Budget Estimates for Fiscal Year 2020*, Green Book Table 5-9 (Washington, D.C: May 2019), 66.

MDAPs

To identify the MDAPs in DOD's 2019 portfolio, we retrieved DOD's list of MDAPs from the Defense Acquisition Management Information Retrieval (DAMIR) system.[2] We selected the programs that issued an unclassified December 2018 Selected Acquisition Report (SAR) and determined these to be the number of MDAPs in the 2019 portfolio. 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 assess the reliability of the DAMIR system and SAR data, we sent to DOD officials three questionnaires with numerous questions related to their management information systems, the data in those systems, and the custodians of the data. Based on DOD officials' responses to those questions, we determined that the SAR data and the information retrieved from DAMIR were sufficiently reliable for the purposes of this report.

To determine the total acquisition cost for MDAPs in the 2019 portfolio, we obtained and analyzed cost data from each program's December 2018 SAR. We compared the 2019 portfolio with the programs that issued SARs in December 2017 (i.e., the 2018 portfolio) to identify the programs that exited and entered the 2019 portfolio, and the total cost and number of programs in the 2019 portfolio compared to DOD's MDAP portfolios for previous years. Specifically, where we had historical information on prior portfolios, we compared total cost estimates for the most recent portfolio against the last 10 portfolio years. We also used the SAR's annual funding information to calculate the amount of funds that programs had spent to date, as well as how much money programs project to spend in the future.

Future MDAPs

To identify the future MDAPs in DOD's 2019 portfolio, we obtained the list of future MDAP systems from DOD's DAMIR. We then reviewed budget materials and DOD documentation to identify planned milestone dates for these future MDAPs. We selected systems that planned to conduct a major milestone event within the next 2 years.

To collect data about costs and schedule events from future MDAPs—including projected cost estimates—we distributed an electronic questionnaire to the future MDAP programs. This questionnaire was web-based so respondents could respond and submit their answers online. We received responses from all of the programs we assessed from

[2]The Defense Acquisition Management Information Retrieval (DAMIR) is a DOD repository for program data.

September 2019 to January 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 three pretests of the future MDAP questionnaire prior to distribution to ensure our questions were clear, unbiased, and consistently interpreted. Our pretests covered each branch of the military to better ensure the questionnaire could be understood by officials within each branch.

MTA Programs

We selected MTA programs to review that were identified by the military departments as at or above the equivalent threshold cost for designation as an MDAP—$523.6 million for Research, Development, Test, and Evaluation (RDT&E) or $3.1 billion in procurement (fiscal year 2020 dollars)—and that already had funds obligated or were expected to have funds obligated within 30 days of July 2019.[3] We obtained and analyzed data from program identification data forms that the military departments submitted to the OSD in the third and fourth quarter of fiscal year 2020, including program start and planned end dates, program budget estimates, and technology maturity. To obtain additional verification of MTA program budget and cost data, we collected MTA programs' service cost positions or independent cost estimates, when available. We also sent a supplemental questionnaire to each program to confirm cost and quantities. To collect additional data from MTA programs—such as key schedule milestones, information on business case documentation developed by the program, and software approaches and cybersecurity practices—we distributed a web-based questionnaire. We received responses from all 13 programs from September 2019 through December 2019.

Major IT Programs

To select the major IT programs in our review, we selected programs based on DOD's official list of 29 major business and nonbusiness IT programs, as of April 10, 2019. Programs on the DOD list included those that have historically been designated as Major Automated Information System (MAIS) programs and were listed in the Defense Acquisition Management Information Retrieval System. Of the 29 programs, we selected the 15 business and nonbusiness major IT programs that had established an initial acquisition program baseline (APB) that could be

[3]Three of these programs—the Air Force's B-52 Commercial Engine Replacement Program and Practical Tactical Enterprise Service; and the Army's Extended Range Cannon Artillery—were identified by the military departments as meeting the criteria for inclusion in our review because the multiple rapid prototyping increments that make up the program have combined ACAT I equivalent costs.

used as a reference point for evaluating cost, schedule, and technical performance characteristics.[4] These 15 programs also were not fully deployed on or before December 31, 2019.

Assessment of DOD's MDAP Portfolio on Selected Cost and Schedule Performance Measures and Other Relevant Topics

Cost and Schedule Performance

Our analysis of the 2019 portfolio includes comparisons of cost and schedule changes over the past year and from baseline estimates that utilize SAR data from December 2018, December 2017, and from the programs' initial SAR submissions. We compared the procurement, research and development, military construction and operations and maintenance, and total acquisition costs of the 2019 portfolio with the corresponding costs of the programs that issued SARs in December 2017 (2018 portfolio). We calculated the cost changes of the 2019 portfolio compared with the 2018 portfolio.

We calculated the total acquisition cost change of the 2019 portfolio from the 2018 portfolio and determined the total dollar and percentage increase or decrease of each program in the 2019 portfolio. We calculated the total costs of each program in the 2019 portfolio that are both attributable and not attributable to quantity changes. We separately reported acquisition costs attributable to quantity changes—generally procurement costs affected by quantity changes—and acquisition costs not attributable to quantity changes—research and development, military construction and operations and maintenance, and procurement costs not affected by quantity changes. We compared the 2019 portfolio costs to

[4]The 15 programs that were assessed are: Army Contract Writing System, Integrated Personnel and Pay System-Army Increment 2, Air Force Integrated Personnel and Pay System Increment 1, Defense Enterprise Accounting and Management System-Increment 1, Maintenance Repair and Overhaul Initiative, Navy Electronic Procurement System, Department of Defense Healthcare Management System Modernization, Defense Agencies Initiative Increment 3, Deliberate and Crisis Action Planning and Execution Segments Increment 2B, Integrated Strategic Planning and Analysis Network Increment 4, Common Aviation Command and Control System Increment 1, Consolidated Afloat Networks and Enterprise Services, Distributed Common Ground System-Navy Increment 2, Teleport Generation 3, Key Management Infrastructure Increment 2, and Public Key Infrastructure Increment 2.

the corresponding costs that are attributable and not attributable to quantity changes for each program in the 2018 portfolio.

We aggregated DAMIR funding stream data for the total planned investment of each portfolio for each year since 2008 to determine any trends. We also calculated yearly totals for research and development, procurement, and total acquisition cost. To distinguish between the funding already invested and the funding needed to complete the programs in each portfolio since 2008, we used funding stream data obtained from DAMIR for each December SAR submission for the years 2007 (2008 portfolio) through 2018 (2019 portfolio). We define funding invested as all funding that has been provided to the programs in the fiscal year of the annual SAR submission (this includes fiscal year 2019 for the December 2018 submission) and earlier, while funding remaining is what will be provided in the fiscal years following the annual SAR submission (fiscal year 2020 and later for the December 2018 submission). Invested and remaining research and development and procurement funding totals for the 2019 portfolio were organized by the military departments overseeing portfolio programs.

We compared the procurement, research and development, military construction and operations and maintenance, and total acquisition costs of the 2019 portfolio to the corresponding costs of the programs' initial SAR submissions. We calculated the cost changes of the 2019 portfolio to the initial program estimates. We calculated the total costs of each program in the 2019 portfolio that are both attributable and not attributable to quantity changes. We separately reported acquisition costs attributable to quantity changes—generally procurement costs affected by quantity changes—and acquisition costs not attributable to quantity changes—research and development, military construction and operations and maintenance, and procurement costs not affected by quantity changes. We compared the 2019 portfolio costs to the corresponding costs that are attributable and not attributable to quantity changes for each program's initial program estimates.

We calculated the average procurement unit costs (APUC) for each program in the 2019 portfolio by dividing procurement costs by procurement quantities. We calculated the APUC for each program at the initial program estimate and compared program APUC in the 2019 portfolio to program APUC at initial program estimate.

We calculated the change in procurement quantities from the programs' initial program estimates to the 2019 portfolio. We also calculated the change in APUC from the programs' initial program estimates to the 2019 portfolio. We identified the change in procurement quantities for each program, grouped together programs that had similar quantity increases or decreases, and used the calculated APUC change of each program to calculate the average APUC change of each group of programs.

We compared the cycle time of the 2019 portfolio to the cycle time of the programs that issued SARs in December 2017 (2018 portfolio). We calculated the cycle time changes of the 2019 portfolio compared to the 2018 portfolio. To analyze the possible link between cycle time delays and program knowledge attainment at key decision points in the acquisition process, we identified 16 programs in the 2019 portfolio that had cycle time delays. We aggregated their questionnaire responses to knowledge attainment questions to determine the extent each program attained knowledge and the length of their cycle time delay.

We also compared the cycle time of the 2019 portfolio to the cycle time of the programs' initial SAR submissions. We calculated the cycle time changes of the 2019 portfolio to the initial program estimates. We compared the cycle time changes of the 2019 portfolio since the programs' initial program estimates to the APUC changes of the 2019 portfolio since the programs' initial program estimates. We identified each program's cycle time change, as well as its APUC change since initial program estimate. We aggregated all changes to calculate the average increase for all programs that had increases and the average decrease for all programs that had decreases, for both cycle time and APUC changes.

Software and Cybersecurity

To examine programs' software development approaches and cybersecurity practices, and the extent to which they are consistent with leading software practices and cybersecurity guidance, we included a number of software- and cybersecurity-related questions in our questionnaire. We reviewed several reports, including a May 2019 Defense Innovation Board report, that recommend 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. We also reviewed DOD guidance, including Department of Defense Instruction 5000.02T, *Operation of the Defense Acquisition System*, which generally requires that acquisition programs have a cybersecurity strategy, and Department of Defense Instruction 5000.02, *Operation of the Adaptive Acquisition Framework*, which outlines the software acquisition pathway. We identified programs that reported their software as a risk item and then aggregated the reasons they provided for identifying software as a risk. We also tallied responses from programs that identified challenges associated with government and contractor software development staff and whether software-related challenges affected total costs.

To report on the extent to which programs are using custom software, we asked programs to identify application domains for the software under development, and then to categorize that software as either commercial or custom. We then followed up with program offices to verify answers and aggregated the responses into a single figure.

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 cross-compared 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 National Defense Industrial Association, International Standards Organization, and other industry studies.

To determine the extent to which programs were adhering to established cybersecurity policies, we identified specific DOD guidance and legislation pertaining to cybersecurity in weapon acquisition programs.[5] In our questionnaire, we asked programs whether they had approved strategies or had conducted various assessments. We tallied programs' responses. We also asked programs to characterize the nature of certain cybersecurity events and tallied those responses. We also asked programs to identify the number of requirements that specifically address cybersecurity, tallied those responses and arranged them by service.

Analysis of Program 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 point include those that we have previously identified as

[5]Department of Defense Instruction 5000.02T generally requires that programs develop a cybersecurity strategy by milestone A and update the strategy at subsequent milestones. Section 1647 of the Fiscal Year 2016 National Defense Authorization Act generally required the Secretary of Defense to complete a cybersecurity vulnerability evaluation for each major weapon system by December 31, 2019.

underpinning a knowledge-based acquisition approach, including holding early systems engineering reviews, testing an integrated prototype prior to the design review, using a reliability growth curve, 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 42 MDAPs—most of which are in development or the early stages of production—about their knowledge at each point. We also include observations on the knowledge that the eight future MDAPs expect to obtain before starting development. We did not validate 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.

For programs that have passed a key decision point and have since been restructured, we assessed them against their original cost and schedule estimates at that milestone or decision point, such as development start. We did not reassess programs at milestones they had previously reached, as in cases where a program is repeating a key decision point or milestone, such as milestone B. We keep our original assessment of the program's knowledge attained at the original milestone. However, we did change future milestone dates if those milestone had yet to be reached, and we assessed those programs for their implementation of our best practices at that point in time.

For the third consecutive year, we performed an exploratory statistical analysis that examined our identified knowledge-based acquisition practices and selected programs' cost and schedule changes. We focused the analysis on the 21 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 best practices at each knowledge point. To ensure a minimally 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 practice, and at least three programs had not engaged in the practice. Although we sought to assess the statistical significance of demonstrating technologies to form, fit, and function within a realistic environment, we observed that only two programs in the sample demonstrated this level of technology maturity before they started development. These two programs provided an insufficient basis to determine whether this best practice corresponded with lower cost and schedule growth. We assessed the statistical significance of the observed differences between the groups at the 90 percent confidence level.[6] With such a small sample of MDAPs, our estimates are fairly imprecise and do not meet normality assumptions.

Description of Selected MTA Programs on Cost and Schedule Measures and Assessment of These Programs' Progress in Developing Business Case Documentation

To determine the projected costs and schedules of MTA programs, we obtained and analyzed data from program identification data forms that the military departments submitted to the OSD in the third and fourth quarter of fiscal year 2020, including program start and planned end dates, program budget estimates, and technology maturity. To obtain additional verification of MTA program budget and cost data, we collected MTA programs' service cost positions or independent cost estimates, when available.

To assess the maturity of MTAs' critical technologies, we asked MTA programs to identify their critical technology elements in our web-based questionnaire. We also asked the programs to identify the technology readiness levels for each critical technology, including projections for the technologies' maturity levels at completion of the MTA effort. We then compared the maturity levels against our best practices standards for critical technology maturity levels.

To report on planned deliverables and transition plans, we asked programs to characterize their planned deliverables at the conclusion of the MTA effort. We also asked programs to elaborate on the rationale for choosing a middle-tier pathway for their programs and what the next steps are for the program after conclusion of the current MTA effort.

To examine cost and schedule reporting for MTA programs, we compared cost information reported in the program identification data forms submitted to OSD against budget material and other documentation. We

[6]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.

looked at whether cost information was being consistently reported in those sources. We also examined the latest DOD and service-level guidance for MTA programs and compared those against recommendations from an earlier GAO report.[7] We also interviewed DOD and military department officials to understand how they plan to report program performance information to decision makers. We reviewed the specific schedule events that MTA programs reported in the web-based questionnaire and compared those to the type of schedule events required by more traditional acquisition programs. We also compared the MTA programs' schedule events against each other to identify similarities and differences among the different programs' approaches.

To determine whether DOD has taken steps to ensure MTA programs are establishing a business case, we reviewed a prior GAO report that identified elements that would provide a sound business case for MTA programs.[8] In our web-based questionnaire, we asked program officials whether they had approved documentation for those elements, which includes cost estimates, requirements, acquisition strategies, and risk assessments. We used responses to determine the number of programs that had all business-case documentation, partial documentation, or no documentation when the MTA was initiated.

Assessment of Selected Major IT Programs on Cost and Schedule Performance and Approaches to Software Development and Cybersecurity

To assess cost and schedule performance of the 15 DOD major IT programs we selected for review, we collected and analyzed key documents, reports, and artifacts for each program on estimated cost, schedule, and technical performance targets, including each program's latest status in meeting those estimated targets. This included information such as acquisition program baselines, DOD's MAIS annual and quarterly

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

[8]GAO, *Acquisition Reform: DOD Should Streamline Its Decision-Making Process for Weapon Systems to Reduce Inefficiencies,* GAO-15-192 (Washington, D.C.: Feb. 24, 2015).

reports, and information reported in prior GAO reports.[9] For each program, we analyzed and compared the initial APB cost estimate (in fiscal year 2020 dollars) to the most recent estimate available to us as of December 2019 (in fiscal year 2020 dollars) to determine the extent to which planned program costs had changed.[10] We calculated the dollar amount for the estimated change in cost in millions by subtracting the current planned total life-cycle cost from the original planned total life-cycle cost. We calculated the percentage cost change by dividing the difference in most recent total life-cycle cost by the original total life-cycle cost.

Similarly, to determine the extent to which these programs experienced schedule delays, we compared each program's first APB schedule to the most recent approved schedule. Specifically, we used the first, or initial, baseline estimates for each milestone (e.g., milestone B, milestone C, full deployment decision, and full deployment) and compared those estimates to the latest estimates. If there were changes to these baseline estimates, we identified the most notable delay.[11] To determine whether system performance targets were tested and met, we identified that ten of 14 major IT programs that had conducted performance tests. We then analyzed each program's self-identified system performance targets and compared them against actual system performance metrics.

[9]GAO, *DOD Major Automated Information Systems: Adherence to Best Practices is Needed to Better Manage and Oversee Business programs*, GAO-18-326 (Washington, D.C.: May 24, 2018); *DOD Major Automated Information Systems: Improvements Can Be Made in Applying Leading Practices for Managing Risk and Testing*, GAO-17-322 (Washington, D.C.: Mar. 30, 2017); *DOD Major Automated Information Systems: Improvements Can Be Made in Reporting Critical Changes and Clarifying Leadership Responsibility*, GAO-16-336 (Washington, D.C.: Mar. 30, 2016); *Defense Major Automated Information Systems: Cost and Schedule Commitments Need to Be Established Earlier*, GAO-15-282 (Washington, D.C.: Feb. 26, 2015); *Major Automated Information Systems: Selected Defense Programs Need to Implement Key Acquisition Practices*, GAO-14-309 (Washington, D.C.: Mar. 27, 2014); and *Major Automated Information Systems: Selected Defense Programs Need to Implement Key Acquisition Practices*, GAO-13-311 (Washington, D.C.: Mar. 28, 2013).

[10]A program's first APB contains the original life-cycle cost estimate, schedule estimate, and performance parameters that were approved for that program by the milestone decision authority. The first APB is established after the program has assessed the viability of various technologies and refined user requirements to identify the most appropriate technology solution that demonstrates that it can meet users' needs.

[11]The most notable delay is the most significant delay in any single milestone date. For example, if Milestone C is delayed by 1 month and full deployment decision is delayed by 3 months, the most notable delay is 3 months.

We used the information we collected to complete a summary of each program's cost, schedule, and technical performance, and requested that program officials review and validate each summary. In addition, for programs we identified as having a year or more delay in schedule baselines, or a 20 percent increase or decrease in cost baselines, we conducted interviews with program officials to obtain the reasons for the changes and performance shortcomings. We then aggregated and summarized the results of our analyses across programs.

To evaluate major IT program approaches to software and cybersecurity, we aggregated DOD program office responses to a questionnaire we developed seeking information about the software approaches and cybersecurity practices used by each of the IT programs. The questionnaire allowed respondents to submit their answers electronically. We received responses from all of the programs we assessed during October 2019. To ensure the reliability of the data collected through our questionnaire, we took steps to reduce measurement error and non-response error. Specifically, we conducted two pretests of the questionnaire to ensure that the questions were clear, unbiased, and consistently interpreted. The pretests allowed us to obtain initial program feedback and helped to better ensure that officials within each program understood each question. Our pretests were conducted with two programs—one business program and one nonbusiness major IT program.

This report refers to major business IT programs and major nonbusiness IT programs. The programs referred to as major business IT programs are governed by DOD Instruction 5000.75 and include programs that support key areas such as personnel, financial management, health care, and logistics. This report refers to the remaining major IT programs as nonbusiness programs. These programs support key areas such as communications and information security.

Summary of Recent Organizational and Legislative Changes

To summarize recent organizational and legislative changes that have potential implications for execution and oversight of the portfolio, we reviewed acquisition-related provisions contained in the National Defense Authorization Act for Fiscal Year 2019. We selected provisions that, in our view, may affect the execution and oversight of DOD's most expensive weapon and IT acquisitions. We met with DOD officials from OSD, the Air Force, and the Navy to discuss the specific acquisition provisions and the potential impact they may have on defense acquisitions. The Army did not meet with us to discuss these provisions, but an Army official did send updated policy that is guiding Army efforts. We also discussed other provisions and other issues DOD officials considered to be relevant to defense acquisition execution and oversight.

Additionally, we reviewed provisions in the National Defense Authorization Act for Fiscal Year 2020 related to our June 2019 report on acquisition reform and obtained information from DOD on actions taken to address these provisions through March 1, 2020. We also reviewed recently issued DOD policy and guidance that addressed organizational and legislative changes, including those that clarify acquisition roles and decision authority, and establish alternative acquisition pathways for the DOD acquisition community.

Individual Assessments of Weapon Programs

This report presents individual knowledge-based assessments of 63 current and future weapon programs. Appendix VI contains a list of these assessments. Of the 63 assessments:

- Thirty-eight assess MDAPs—most 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.[12]
- Twelve assess future or current MDAPs in a one-page format that describes the program's current status. Those one-page assessments include (1) seven future MDAPs not yet in development, and (2) five MDAPs that are well into production, but introducing new increments of capability or significant changes.
- Thirteen assess MTA programs in a two-page format discussing each program's knowledge when compared to key elements of a program business case as well as technology maturation, software development and cybersecurity, and other program issues.

For presentation purposes we grouped the individual assessments by lead service—Army, Navy and Marine Corps, Air Force, and DOD-wide—and inserted a lead service separator page at the start of each grouping. These four summary analysis pages present aggregated information about selected programs' acquisition phases, knowledge attainment, cost and schedule performance, software characteristics and business case activities. We obtained this data primarily from the December 2018 SARs

[12]One of the 38 two-page assessments is for a future MDAP—the Navy's FFG(X) Guided Missile Frigate—because the Navy scheduled it to begin development in advance of our planned issuance date. We reported cost and quantity amounts that align with the program's Future Years Defense Program estimates because the current cost estimate provided by the program does not include a full funding profile beyond fiscal year 2024.

and supplemented them with program office responses to our questionnaires. We report cost and schedule growth in the separator pages in a manner that is consistent with how it is reported and described elsewhere in the report.

For all assessments, we obtained the information presented in the Program Essentials section from program office responses to a questionnaire and program office documents and communication with program officials. As a result, DOD is the source of the information regarding the identity of the contractors and the contract types. We did not review individual contract documents to verify information in the Program Essentials Section.

For each program we assessed, all cost information is presented in fiscal year 2020 dollars. We converted cost information to fiscal year 2020 dollars using conversion factors from the DOD Comptroller's National Defense Budget Estimates for Fiscal Year 2020 (table 5-9). We have depicted only the program's main elements of acquisition cost—research and development and procurement. However, for MDAPs, 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, and we annotate this by using the term "not applicable (NA)." The quantities listed refer to total quantities, including both procurement and development quantities. We obtained the information in the "Software and Cybersecurity" section of the MDAP and MTA individual assessments from program office responses to a questionnaire, program office documents, and communications with program officials. As a result, DOD is the source of the information regarding software development approach, software percentage of total program cost, and software type. In their questionnaire responses, program offices self-identified the type of software used based on definitions from DOD's Cost Assessment Data Enterprise and the Defense Innovation Board, and the software development approach based on definitions from the Defense Acquisition University.

Selection and Analysis of MDAP and Future MDAP Programs

We selected MDAPs and future MDAPs to review based on a DAMIR list of programs in the 2019 portfolio. From this list, we selected MDAPs that were generally between system development and a full-rate production decision. We also included MDAPs that were well into full-rate production, but planning to introduce new increments of capability, should the costs of the new increment exceed the threshold needed to qualify as a MDAP. We selected future MDAP programs that expected to conduct a milestone decision event during the next 2 fiscal years (fiscal year 2021 or earlier), and those that expected to begin development before we published this report.

To make DOD's acquisition terminology consistent across our individual MDAP and future MDAP assessments, we standardized the terminology for key program events. For most individual programs 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 generally coincides with DOD's milestone B. A few programs in our assessment have a separate "program start" date, which begins a pre–system development phase for program definition and risk-reduction activities. This "program start" date generally coincides with DOD's milestone A, 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. 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 best 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 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 either the most recent Defense Acquisition Executive Summary (DAES) report reflecting 2019 data except in cases where the program did not submit a DAES report. In these cases, we used information collected through our questionnaire or program office interviews. In two instances, we used data from the December 2018 SAR. In some additional cases, we updated the DAES data based on new information provided in our questionnaire or program office interviews. 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 if those estimates were available. For systems for which a first full estimate was not available, we only present the latest available 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.

The schedule assessment for each MDAP 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” draws on funding stream information from DAES reports or on data from the program office. We define “funded to date” as all funding that has been provided to the program through fiscal year 2020. “To complete” funding is from fiscal year 2021 through completion of the program.

In our past work examining weapon acquisition issues and knowledge-based acquisition practices for product development, we have found that leading commercial firms pursue an acquisition approach that is anchored in knowledge, whereby high levels of product knowledge are demonstrated by critical points in the acquisition process. Although the knowledge points provide indicators of potential risks, by themselves they do not cover all elements of risk that a program encounters during development, such as funding instability. On the basis of this work, for MDAPs, we have identified three key knowledge points during the acquisition cycle—system development start, critical design review, and production start—at which programs need to demonstrate critical levels of knowledge to proceed. To assess the product development knowledge of each program at these key points, we reviewed questionnaires submitted by programs; however, not every program had responses to each element of the questionnaire. We also reviewed pertinent program documentation and discussed the information presented on the questionnaire with program officials as necessary.

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 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. We do not reassess a program at milestones that have already been reached if a program is repeating a key decision point or milestone, such as milestone B. We have kept our original assessment of the program's knowledge attained at the original milestone. However, we have changed future milestone dates in instances when the program had not yet reached the affected milestone. In these instances, we assessed the program for its implementation of our knowledge-based acquisition practices criteria at that point in time.

To assess a program's readiness to enter system development, we collected data through our questionnaire on critical technologies and early design reviews. To assess technology maturity, we asked program officials to apply a tool, referred to as technology readiness levels (TRL), for our analysis. The National Aeronautics and Space Administration originally developed TRLs, and the Army and Air Force science and technology research organizations use them to determine when technologies are ready to be handed off from science and technology managers to product developers. TRLs are measured on a scale from 1 to 9, beginning with paper studies of a technology's feasibility and culminating with a technology fully integrated into a completed product. 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.[13] For shipbuilding programs, we have recommended that this level of maturity be achieved by the contract

[13]GAO, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, D.C.: July 30, 1999); GAO, *Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes*, GAO-01-288 (Washington, D.C.: Mar. 8, 2001). While GAO's best practices work has shown that a TRL 7 is the level of technology maturity that constitutes a low risk for starting development, DOD's policy permits development to start at TRL 6. DOD's policy 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).

award for detailed design.[14] In our assessment, the technologies that have reached TRL 7, a prototype demonstrated in a realistic environment, 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.

In most cases, we did not validate the program offices' selection of critical technologies or the determination of the demonstrated level of maturity. We sought to clarify the TRLs in those cases where information existed that raised questions. If we were to conduct a detailed review, we may or may not adjust the critical technologies assessed, their readiness levels demonstrated, or both. It was not always possible to reconstruct the technological maturity of a weapon system at key decision points after the passage of many years. Where practicable, we compared technology assessments provided by the program office to assessments by officials from the Office of the Under Secretary of Defense for Research and Engineering.

To assess design stability, we asked program officials to provide the percentage of design drawings completed or projected for completion by the design review, the production decision, and as of our current assessment in the data-collection instrument. In most cases, we did not verify or validate the percentage of engineering drawings provided by the program office. We clarified the percentage of drawings completed in those cases where information that raised questions existed. 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

[14] 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).

prototype. We compared this date to the date of the design review. We did not assess whether shipbuilding programs had completed integrated prototypes.

To assess production maturity, we asked program officials for their Manufacturing Readiness Level (MRL) for process capability and control or to identify the number of critical manufacturing processes and, where available, to quantify the extent of statistical control achieved for those processes as a part of our questionnaire. In most cases, we did not verify or validate the information provided by the program office. We clarified the number of critical manufacturing processes and the percentage of statistical process control where information existed that raised questions. We used a standard called the Process Capability Index, a process-performance measurement that quantifies how closely a process is running to its specification limits. The index can be translated into an expected product defect rate, and we have found it to be a best practice. We also used data provided by the program offices on their MRL for process capability and control, a sub-thread tracked as part of the manufacturing readiness assessment process recommended by DOD, to determine production maturity. 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 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.

For future MDAPs in this year’s assessment, we included a table, “Attainment of Technology Maturation Knowledge,” 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’s Instruction 5000.02T: conduct competitive prototyping, validate requirements, and complete a preliminary design review. We also included completion of an independent technology risk assessment, a key activity per section 807(a) of the National Defense Authorization Act for Fiscal Year 2017, that is to be conducted prior to a program's entry into system development.[15] These are not the only activities contemplated at this stage, but the table is intended to provide insight into the extent to which a program has gained critical knowledge before milestone B. 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.

Selection and Analysis of MTA Programs

We selected 13 MTA programs to review that were identified by the military departments as at or above the equivalent threshold cost for designation as an MDAP—$523.6 million for RDT&E or $3.1 billion in procurement (fiscal year 2020 dollars)—and that already had funds obligated or were expected to have funds obligated within 30 days of July 2019.[16] We assessed eight Air Force MTA programs and five Army MTA programs. The Navy did not report programs that met our selection criteria. To assess these programs, we obtained and analyzed data from program identification data forms that the military departments submitted to the OSD in the third and fourth quarter of fiscal year 2020, including program start and planned end dates, program budget estimates, and technology maturity. To obtain additional verification of MTA program budget and cost data, we collected MTA programs' service cost positions or independent cost estimates, when available. We also sent a supplemental questionnaire to each program to confirm cost and quantities. To collect additional data from MTA programs—such as key schedule milestones, information on business case documentation developed by the program, and software approaches and cybersecurity practices—we distributed a web-based questionnaire. We received responses from all 13 programs from September 2019 through November 2019. We also collected and analyzed additional information, such as acquisition decision memorandums, acquisition strategies, program cost and schedule estimates, risk assessments, and documents relating to technology maturity, software development, and cybersecurity, among others. We interviewed or received written responses from program officials to supplement this information. In some instances, MTA programs represent one of multiple MTA or major capability acquisition

[15] National Defense Authorization Act for Fiscal Year 2017, Pub. L. No. 114-328 § 807(a)(1) (2016) (codified as amended at 10 U.S.C. § 2448b).

[16] Three of these programs—the Air Force's B-52 Commercial Engine Replacement Program and Practical Tactical Enterprise Service; and the Army's Extended Range Cannon Artillery—were identified by the military departments as meeting the criteria for inclusion in our review because the multiple rapid prototyping increments that make up the program have combined ACAT I equivalent costs.

efforts that are planned as part of a program's overall acquisition strategy or connected rapid prototyping or rapid fielding efforts. Our assessment focused on the current MTA effort, not the program's planned future efforts.

For each MTA program we assessed, we present the cost and quantity data obtained from a service cost position or independent cost estimate, when available, or data provided by the program in program identification data forms and supplemental questionnaires. We verified this information with interviews with program officials as needed. We collected MTA program schedule information through our questionnaire or program office interviews.

To assess knowledge for MTA programs, we underpinned our analysis of program information with our past work on elements of a business case that should be completed at program initiation.[17] We focused on business case elements because the MTA programs in our review had generally been recently initiated. A business case provides demonstrated evidence that (1) the warfighter need exists and it can best be met with the chosen concept and (2) the concept can be developed and produced within existing resources—including proven technologies, design knowledge, adequate funding, and adequate time to deliver the product when needed. For each MTA program, we used the program identification data forms to identify program initiation (start) dates the programs provided based on the middle-tier designation document that was signed by the military department MTA decision authority. We corroborated the program initiation dates with program acquisition decision memorandums, when available.

We then assessed the program's status at initiation and currently with regard to completing five key aspects of a program business case: requirements approved, acquisition strategy approved, technical risk assessment completed, schedule risk assessment completed, and cost estimate based on independent assessment. We gathered this information using online questionnaires and clarified and corroborated information with the respective program office as needed. For assessment at initiation, we compared dates the program offices provided

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

for the five activities above against the program's initiation date to determine whether the program had completed the respective activity prior to initiation or afterwards. 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.[18] 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. For current status, we assessed whether or not the program had completed the above five activities as of January 2020, the end of our review period. We clarified the program's development of business case documentation where information existed that raised questions.

We conducted this performance audit from May 2019 to June 2020, 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.

[18] GAO-19-439.

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 that their technologies are mature, their designs stable, and their production processes 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 22 summarizes these knowledge points and associated practices.

Table 22: 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-20-439

[a]Department of Defense policy 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 24: Technology Readiness Levels and Descriptions

Technology readiness level	Description	Hardware/software	Demonstration environment
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.	None (paper studies and analysis)	None
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 is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.	None (paper studies and analysis)	None
3. Analytical and experimental critical 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.	Analytical studies and demonstration of non-scale individual components (pieces of subsystem)	Lab
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.	Low-fidelity breadboard. Integration of nonscale components to show pieces will work together. Not fully functional or form or fit but representative of technically feasible approach suitable for flight articles.	Lab
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 the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.	High-fidelity breadboard. Functionally equivalent but not necessarily form and/or fit (size weight, materials, etc.). Should be approaching appropriate scale. May include integration of several components with reasonably realistic support elements/subsystems to demonstrate functionality.	Lab demonstrating functionality but not form and fit. May include flight demonstrating breadboard in surrogate aircraft. Technology ready for detailed design studies.

Technology readiness level		Description	Hardware/software	Demonstration environment
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.	Prototype. Should be very close to form, fit and function. Probably includes the integration of many new components and realistic supporting elements/subsystems if needed to demonstrate full functionality of the subsystem.	High-fidelity lab demonstration or limited/restricted flight demonstration for a relevant environment. Integration of technology is well defined.
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 a realistic environment, such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	Prototype. Should be form, fit and function integrated with other key supporting elements/subsystems to demonstrate full functionality of subsystem.	Flight demonstration in representative realistic environment such as flying test bed or demonstrator aircraft. Technology is well substantiated with test data.
8.	Actual system completed and "flight 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.	Flight-qualified hardware	Developmental Test and Evaluation in the actual system application.
9.	Actual system "flight 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. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.	Actual system in final form	Operational Test and Evaluation in operational mission conditions.

Source: GAO and its analysis of National Aeronautics and Space Administration data. | GAO-20-439

Appendix V: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION
AND
SUSTAINMENT

Ms. Shelby Oakley
U.S. Government Accountability Office
441 G St NW
Washington, DC 20548

Dear Ms. Oakley,

This is the Department of Defense response to the GAO Draft Report, GAO-20-439, "Drive to Deliver Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight" dated March 30, 2020.

The Department remains committed to acquisition reform and in January 2020 released guidance for the six pathways that make up the Adaptive Acquisition Framework. DoD continues to strive to implement knowledge-based acquisition practices in all of its pathways, including the three reviewed in this draft report: Major Capability Acquisition, Middle Tier Acquisition (MTA), and Defense Business Systems. We agree that the Major Defense Acquisition Program (MDAP) portfolio has generally stabilized non-quantity related cost and schedule growth. We continue to improve oversight of MTA programs and have deployed a GAO recommendation from June 2019 that would have the Department require business case documentation to assess whether candidate programs can field capabilities in a five-year timeline. In addition, DoD acknowledges the findings of inconsistent implementation of leading software practices and cybersecurity practices among MDAPs. Implementation and wider adoption of the Software Acquisition pathway will assist in improving this area, as will implementing the direction provided in Section 862 of the Fiscal Year 2020 National Defense Authorization Act to establish software development and software acquisition training and management programs.

The Department appreciates the opportunity to comment on the Draft Report. My point of contact for this effort is Ms. Kate Edgerton, 571-256-1528.

Sincerely,

CADMAN.DAVID.S.1229303615 Digitally signed by CADMAN.DAVID.S.1229303615 Date: 2020.04.27 09:46:13 -04'00'

David Cadman
Acting Principal Deputy Assistant Secretary of Defense (Acquisition Enablers)

Appendix VI: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

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Table 23 lists the staff responsible for individual program assessments.

Table 23: GAO Staff Responsible for Individual Program Assessments

Program name	Primary staff
Army programs	
Armored Multi-Purpose Vehicle (AMPV)	Charlie Shivers, R. Eli DeVan, April Yeaney
Common Infrared Countermeasure (CIRCM)	Tana M. Davis, Jacqueline W. Wade
Extended Range Cannon Artillery Increment IC (ERCA)	Robert Bullock, Leslie Ashton, Evan Nemoff
Future Long-Range Assault Aircraft (FLRAA)	Sean Merrill, Joe E. Hunter
Handheld, Manpack, and Small Form Fit Radios (HMS)	Jenny Shinn, Guisseli Reyes-Turnell, Ryan Lester
Improved Turbine Engine Program (ITEP)	Jasmina Clyburn, Wendy Smythe
Indirect Fire Protection Capability Increment 2 - Intercept, Block 1 (IFPC Inc 2-I Block 1)	Brian Smith, Brian Tittle
Integrated Air and Missile Defense (IAMD)	Ryan Stott, Julie Clark
Integrated Visual Augmentation System (IVAS)	Beth Reed Fritts, Betsy Gregory-Hosler
Joint Air-to-Ground Missile (JAGM)	Jessica Berkholtz, Meghan Perez
Lower Tier Air and Missile Defense Sensor (LTAMDS)	John Rastler-Cross, Molly Miller
Optionally Manned Fighting Vehicle – Increment 1	Scott Purdy, Hunter Stephan
Precision Strike Missile (PrSM)	TyAnn Lee, Cale Jones, Kari Terrio
Mobile Protected Firepower (MPF)	Hunter Stephan, Scott Purdy, Tamera Lockley

Program name	Primary staff
Navy and Marine Corps programs	
Advanced Anti-Radiation Guided Missile – Extended Range (AARGM-ER)	Ruben G. Gzirian, Marcus C. Ferguson, Shelby Gullion
Air and Missile Defense Radar (AMDR)	Nathan P. Foster, Sameena Ismailjee
Amphibious Assault Ship Bougainville (LHA 8)	Cale Jones, Jeff Hartnett
Amphibious Combat Vehicle (ACV)	Matthew M. Shaffer, Holly Williams, Monique Nasrallah
Amphibious Ship Program (LPD 17 Flight II)	Tonya Woodbury, Holly Williams
CH-53K King Stallion (CH-53K)	Lauren Wright, Victoria Klepacz
CVN 78 Gerald R. Ford Class Nuclear Aircraft Carrier / Advanced Arresting Gear (CVN 78/AAG)	Jessica Karnis, Burns C. Eckert
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)	Laura M. Durbin, Wendy Smythe
Guided Missile Frigate (FFG(X))	Chad Johnson, Sean Merrill
Infrared Search and Track (IRST)	Zachary J. Sivo, Nicole Warder
Joint Precision Approach and Landing System (JPALS)	Stephen V. Marchesani, TyAnn Lee, Josh Garties
Large Unmanned Surface Vehicles (LUSV)	Brendan K. Orino, Grace Haskin
Littoral Combat Ship Mission Modules (LCS Packages)	Brendan K. Orino, Brenda Mittelbuscher
MQ-25 Stingray (MQ-25)	Jillena Roberts, Meghan Kubit, Ethan Kennedy
MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)	Erin Stockdale, James Kim
Next Generation Jammer Low Band (NGJ Low-Band)	Daniel Glickstein, Anh Nguyen
Next Generation Jammer Mid-Band (NGJ Mid-Band)	Claire Li, Daniel Glickstein, Signe Janoska-Bedi
P-8A Poseidon, Increment 3 (P-8A Increment 3)	Heather Barker Miller, Andrew Powell, Sarah Cantatore
Ship to Shore Connector Amphibious Craft (SSC)	Teague Lyons, Tanya Waller
SSBN 826 Columbia Class Submarine (SSBN 826)	Nathaniel Vaught
SSN 774 Virginia Class Submarine Block V (SSN 774 Block V)	Laurier Fish, Jenny Shinn
T-AO 205 John Lewis Class Fleet Replenishment Oiler (T-AO 205 Class)	J. Andrew Walker, Jeffrey L. Hartnett
VH-92A Presidential Helicopter (VH-92A)	Bonita Oden, Marvin Bonner, Alexander Webb
Air Force programs	
Advanced Pilot Training (APT)	Marvin Bonner, Jean Lee
Air Launched Rapid Response Weapon (ARRW)	Patrick Breiding, Matthew J. Ambrose
B-2 Defensive Management System - Modernization (B-2 DMS-M)	Megan Setser, Don Springman, James McCully

Program name	Primary staff
B-52 Commercial Engine Replacement Program (B-52 CERP)	Andrea Evans, R. Eli DeVan
B-52 Radar Modernization Program (RMP) (B-52 RMP)	Jennifer Baker, Matthew C. Metz
Combat Rescue Helicopter (CRH)	Sean Seales, Matthew Drerup
F-15 Eagle Passive Active Warning Survivability System (F-15 EPAWSS)	Matthew Drerup, Adrianne Lewis, Jeffrey Carr
F-22 Capability Pipeline	Dennis A. Antonio, Sean Seales
Global Positioning System III (GPS III)	Jonathan Mulcare, Meredith Kimmett, Jaeyung Kim
Global Positioning System III Follow-On Production (GPS IIIF)	Jonathan Mulcare, Meredith Kimmett
Hypersonic Conventional Strike Weapon (HCSW)	Patrick Breiding, Lisa Fisher
KC-46A Tanker Modernization (KC-46A)	Katheryn Hubbell, Zachary J. Sivo
Long Range Stand Off (LRSO)	Don Springman, Charlie Shivers
Military Global Positioning System (GPS) User Equipment Increment 1 (MGUE Inc 1)	Andrew Redd, Erin Carson
National Security Space Launch (NSSL (Formerly EELV))	Erin R. Cohen, Jordan Kudrna
Next Generation Operational Control System (OCX)	Matthew Metz, Andrew Redd
Next Generation Overhead Persistent Infrared (Next Gen OPIR)	Claire Buck, Claire Li, Laura Hook
Protected Tactical Enterprise Service (PTES)	Jordan Kudrna, Matthew C. Metz
Protected Tactical SATCOM (PTS)	Burns C. Eckert, Claire Buck
Small Diameter Bomb Increment II (SDB II)	John Crawford, Steven Stern
Unified Platform (UP)	Andrew Berglund, Mary Diop
Utility Helicopter Replacement Program (UH-1N Replacement)	Lindsey Cross, Gina Flacco
VC-25B Presidential Aircraft Recapitalization (VC-25B PAR)	LeAnna Parkey, Sophia Payind
Weather System Follow-on (WSF)	Laura Hook, Tina Cota-Robles
Joint Department of Defense programs	
F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)	Desirée E. Cunningham, Jillena Roberts, Paulina Maqueda Escamilla

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