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Report to Congressional Committees

September 2021

DOD SOFTWARE ACQUISITION

Status of and Challenges Related to Reform Efforts

Accessible Version

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GAO-21-105298

GAO Highlight

Highlights of GAO-21-105298, a report to congressional committees

September 2021

DOD SOFTWARE ACQUISITION

Status of and Challenges Related to Reform Efforts

Why GAO Did This Study

GAO reported in June 2021 that DOD planned to invest over $1.8 trillion to acquire its costliest new weapon systems. DOD is also investing billions more in IT systems and capabilities.

The William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 included a provision for GAO to brief congressional defense committees on DOD's implementation of software acquisition reforms for certain systems and activities. This report summarizes past GAO findings about the extent to which DOD implemented required or recommended software acquisition reforms for weapon and business systems. Other elements of the provision will be addressed in future work.

For this report, GAO reviewed its June 2021 assessments of DOD weapon and major business IT systems, as well as other relevant prior work. GAO also identified software acquisition reforms initiated in response to recent statutory mandates. No new audit work was conducted for this report.

What GAO Recommends

In June 2021, GAO recommended that DOD automate data collection efforts for the software acquisition pathway. DOD concurred with the recommendation and reported that it is developing plans for automation of data collection.

View GAO-21-105298. For more information, contact Shelby S. Oakley at (202) 512-4841 or oakleys@gao.gov.

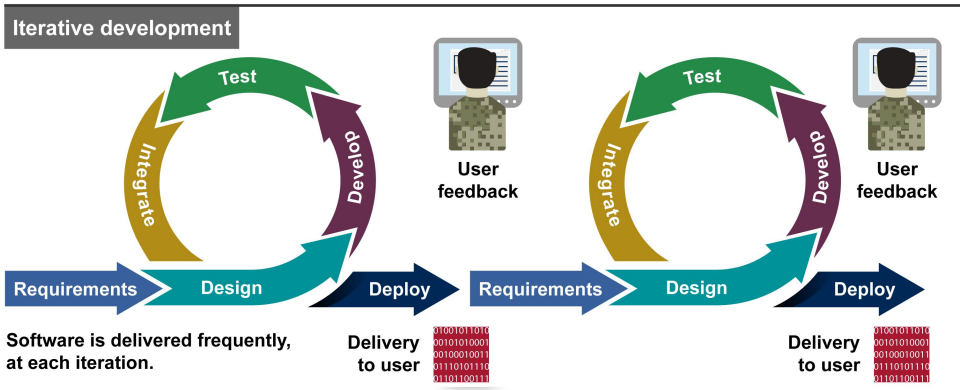
What GAO Found

The Department of Defense (DOD) increasingly relies on software to operate its weapon and business information technology (IT) systems. Yet, DOD has long faced challenges with software development. Over the past several years, DOD made efforts to modernize its software development approaches. For example:

New software acquisition pathway. As GAO reported in June 2021, DOD created a new acquisition framework in January 2020 with six acquisition pathways, including one for software. The pathway emphasized modern software development practices, such as encouraging more frequent user feedback, as GAO recommended in March 2019. In June 2021, GAO reported that, while DOD had recently started implementing this pathway, the department did not have a data collection strategy for it. As a result, we recommended that DOD automate data collection efforts for the pathway. DOD concurred with the recommendation.

Agile development. In February 2020, DOD issued an Agile Software Acquisition Guidebook that incorporates lessons learned from two pilot programs and emphasizes an iterative software development process. This process provides for rapid, frequent delivery of production-quality software. See figure.

The Department of Defense's Agile Development Process



Source: GAO analysis of Department of Defense (DOD) and industry documentation. | GAO-21-105298

However, GAO's recent work—including the June 2021 assessments of DOD's weapon and business IT systems—shows that many programs have yet to implement certain recommended practices associated with modern software development approaches. For example, GAO's *Agile Assessment Guide* emphasizes the early and continuous delivery of working software to users, and industry recommends delivery as frequently as every 2 weeks for Agile programs. Yet, as of June 2021, only six of 36 weapon programs that reported using Agile also reported delivering software to users in less than 3 months.

DOD programs also reported a number of other challenges that could affect their ability to implement reforms. For example, over half of the weapon systems and nearly all major business IT programs GAO reviewed reported staffing challenges related to software development, such as difficulty hiring government and contractor staff.

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Abbreviations

AAF	Adaptive Acquisition Framework
DOD	Department of Defense
IT	information technology
MDAP	major defense acquisition program
MTA	middle-tier acquisition
NDAA	National Defense Authorization Act
OMB	Office of Management and Budget

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441 G St. N.W.
Washington, DC 20548

September 30, 2021

Congressional Committees

We reported in June 2021 that the Department of Defense (DOD) planned to invest over $1.8 trillion to acquire its costliest new weapon systems such as aircraft, ships, and satellites. These systems increasingly rely on software to deliver needed capabilities to the warfighter. At the same time, the department is investing billions more in information technology (IT) systems and capabilities. The United States faces threats that are changing at an ever-increasing pace, and DOD's ability to adapt and respond is now determined by its ability to develop and deploy software to the field rapidly. DOD made efforts to modernize its software development approaches for its weapons and IT systems over the past several years, such as by implementing reforms required by law or recommended by recent studies from the Defense Science Board and Defense Innovation Board. However, our recent work found that DOD continues to face challenges in executing modern software development approaches and rapidly delivering software to users.[1]

The William M. (Mac) Thornberry National Defense Authorization Act (NDAA) for Fiscal Year 2021 included a provision for us to brief the congressional defense committees on DOD's implementation of software acquisition reforms for certain systems and activities.[2] This report summarizes our past work on the extent to which DOD implemented required or recommended software acquisition reforms for weapon and major business IT programs. Our future work will address other elements of the mandate, as agreed to with the congressional defense committees.

To conduct this work, we reviewed software-related provisions in the NDAAs for Fiscal Years 2018 through 2020 to identify relevant statutory

[1]GAO, *Software Development: DOD Faces Risks and Challenges in Implementing Modern Approaches and Addressing Cybersecurity Practices*, GAO-21-351 (Washington, D.C.: June 23, 2021); and *Weapon Systems Annual Assessment: Updated Program Oversight Approach Needed,* GAO-21-222 (Washington, D.C.: June 8, 2021).

[2]See William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Pub. L. No. 116-283, § 838 (2021). In addition, the law states that GAO is to submit one or more reports based on such briefing to the congressional defense committees, as jointly determined by such committees and the Comptroller General.

requirements.[3] We also reviewed relevant GAO reports to identify prior work on DOD's efforts to implement software acquisition reforms. We focused primarily on our two most recent assessments of weapons and business systems, both issued in June 2021.[4] We also identified relevant findings from other recent reports, including our work assessing DOD space acquisitions and other major weapon systems. See Related GAO Products at the end of the report. More detailed information on our objectives, scope, and methodology for our past work can be found in the issued reports. We confirmed the currency of the findings with knowledgeable DOD officials and updated the information as appropriate. No new audit work was conducted for this report.

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

Background

Software has become one of the most important components of DOD systems, but the department's software development practices have not kept up with leading industry practices. Our work and the findings of other recent studies show deficiencies in software acquisition and practices within DOD, such as slow software development practices and outdated acquisition processes. For example, the Defense Innovation Board released a report in May 2019 that emphasized the need for DOD to deploy software quickly and develop a workforce to follow modern software development practices.[5] The recommendations from this report include creating software development units in each service to develop

[3]See National Defense Authorization Act for Fiscal Year 2018, Pub. L. No. 115-91, 131 Stat. 1283 (2017); John S. McCain National Defense Authorization Act for Fiscal Year 2019, Pub. L. No. 115-232, 132 Stat. 1636 (2018); National Defense Authorization Act for Fiscal Year 2020, Pub. L. No. 116-92, 133 Stat 1198 (2019).

[4] GAO-21-222. GAO-21-351.

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

and deploy software, and expanding training programs for acquisition executives and program mangers on modern software development, among others. Further, according to a February 2018 report from the Defense Science Board, software development in the commercial world underwent significant change in the prior 15 years.[6] Our recent work shows the department still develops software using traditional and slower development approaches.

The February 2018 Defense Science Board report also identified a number of software development practices that it recommended DOD adopt, including those listed in table 1.

Table 1: Software Practices Recommended by the Defense Science Board in February 2018

Software practice	Description
Software factory	Cloud-based computing used to assemble a set of software tools enabling developers, users, and management to work together on a daily tempo.
Delivery of minimum viable product[a]	Development technique in which a new product or website is developed with sufficient features to satisfy early adopters, followed by a successive next viable product.
Continuous iterative development	Way of developing software in smaller blocks that can be incrementally evaluated by a user community. This incremental approach allows updates and improvements to be rapidly incorporated into the software.
Iterative development training for program managers and staff	Development of a training curriculum to create and train a cadre of software-informed program managers, sustainers, and software acquisition specialists.
Software documentation	Written text or illustration that accompanies computer software or is embedded in the source code.
Independent verification and validation for machine learning	Using machine learning in software systems coupled with independent testing to help monitor the systems.

Source: Defense Science Board. | GAO-21-105298

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

The NDAAs for Fiscal Years 2018 through 2020 included several provisions to address some of the challenges associated with software acquisition. These provisions directed DOD to

- implement recommendations of the February 2018 Defense Science Board report on the design and acquisition of software for defense systems, with certain exceptions;
- direct the Defense Innovation Board to undertake a study on streamlining software development and acquisition regulations;

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

- establish pilot programs on the use of Agile development methods—which emphasize the iterative development and delivery of products—and open source software; and
- establish pathways to provide for the efficient and effective acquisition, development, integration, and timely delivery of secure software.

Software Development Models

Our past work found that DOD acquisition programs employ a wide range of software development models, including Agile frameworks and various incremental models.[7] Table 2 describes software development models employed by DOD acquisition programs.

Table 2: Software Development Models Employed by Department of Defense Acquisition Programs

Software development 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 while also combining 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	An umbrella term for a variety of software practices, Agile calls for the delivery of software requirements in small and manageable predetermined increments. This model is based on an “inspect and adapt” approach where requirements change frequently and software is released in increments. Agile frameworks produce 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 can be delivered to the user. Agile emphasizes collaboration, as the customers, developers, and testers work together throughout the project.
DevOps	DevOps combines “development” and “operations,” emphasizing communication, collaboration, and continuous integration between 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.

[7]Throughout this report, we refer to steps DOD has taken to implement Agile software development. DOD has also developed resources for iterative development methodologies, such as DevSecOps, that are not mutually exclusive to Agile. However, in this report, we discuss these resources under the category of Agile development because they also support Agile software development.

Hybrid/Mixed	This approach is a combination of two or more different methodologies or systems to create a new model.

Source: GAO-20-590G and GAO analysis of Department of Defense and software industry documentation. | GAO-21-105298

Agile is the development of software in iterations that are continuously evaluated on their functionality, quality, and customer satisfaction. The Defense Innovation Board and industry's leading Agile practices encourage the delivery of working software to users on a continuing basis—as frequently as every 2 weeks.[8] In September 2020, we published our *Agile Assessment Guide: Best Practices for Agile Adoption and Implementation*.[9] Our guide notes that the most well-known feature of Agile software development is its emphasis on iterative product development and delivery. We reported that transitioning to Agile software development methods requires practitioners do more than implement new or modify existing tools, practices, and processes. The guide identifies best practices in adopting Agile values, including practices that address organizational environment, program operations, and team dynamics and activities. Agile software development, which hinges on rapid delivery of software to users, has been a priority of DOD to help ensure the department maintains its technological superiority and has the ability to respond to adversary advancements quickly by updating its systems accordingly. We reported that using Agile and engaging customers early in a program limits the chance of continuing to fund a failing program or outdated technology. In addition, according to the Defense Innovation Board, if program officials do not allow for more frequent software delivery, they may miss opportunities to obtain information from users and face challenges when adjusting requirements to meet and adjust to customer needs.

Adaptive Acquisition Framework

DOD established an Adaptive Acquisition Framework (AAF) in January 2020 that includes software acquisition. The AAF emphasizes several principles that include simplifying acquisition policy, tailoring acquisition approaches, and conducting data-driven analysis. The AAF is comprised of six acquisition pathways, each tailored for the characteristics and risk

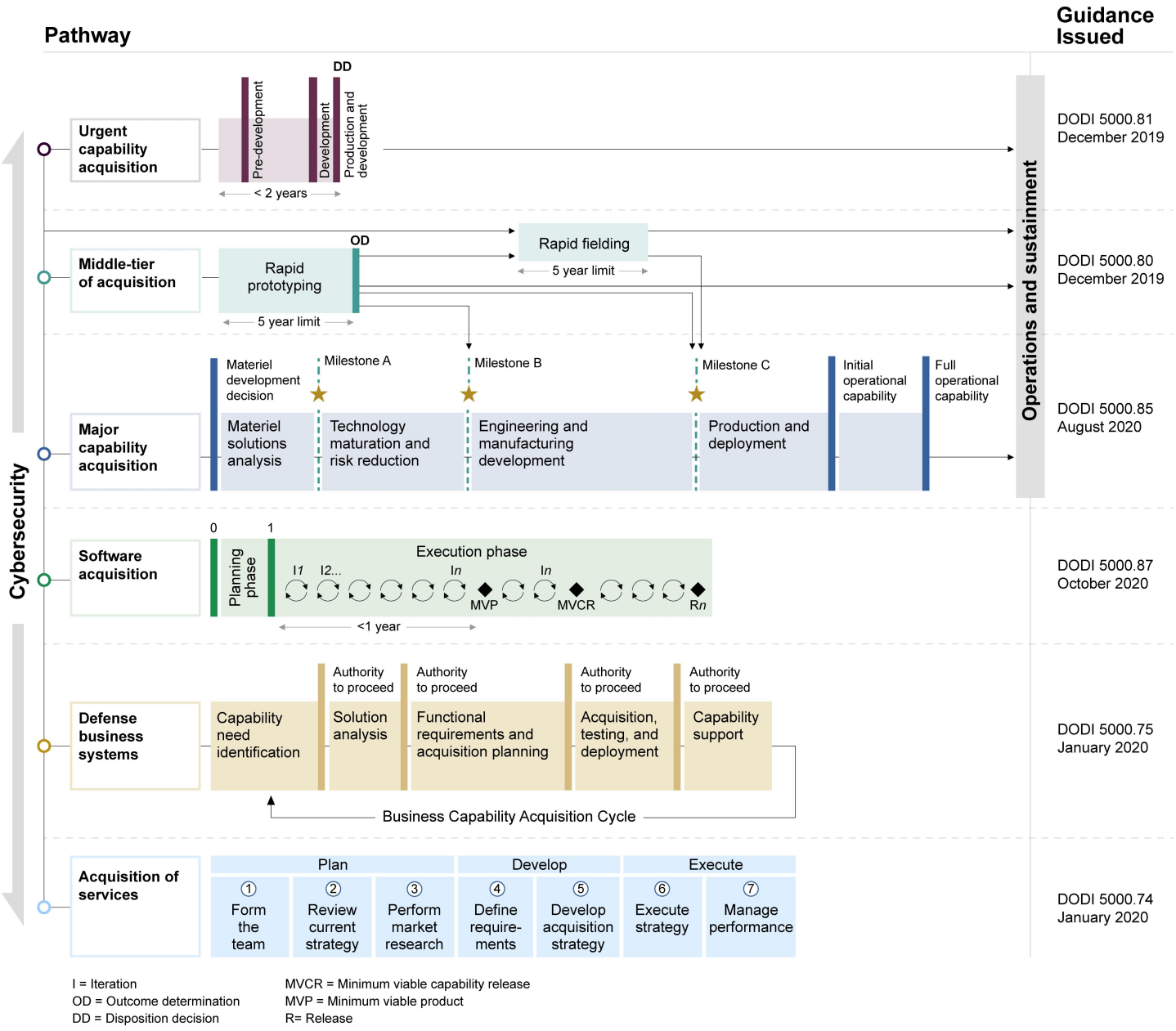
[8]The Defense Innovation Board recommends capability be delivered as frequently as every 2 weeks for many types of software. The National Defense Industrial Association, International Standards Organization, and other industry studies recommend deliveries of working software within a range of 1 to 6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

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

profile of the capability being acquired. DOD Instruction 5000.02 establishes the groundwork for the operation of the AAF. From December 2019 to October 2020, DOD issued specific guidance on the AAF and its six associated acquisition pathways, which are intended to, among other things, deliver solutions to the end user in a timely manner.[10] Figure 1 shows the AAF as depicted in the department's guidance and corresponding guidance specific to each pathway.

[10]DOD issued policy documents to address each of these six acquisition pathways from December 2019 to October 2020 and has issued or plans to issue additional functional policy documents in areas such as engineering and test and evaluation. Department of Defense Directive 5000.01, *The Defense Acquisition System* (Sept. 9, 2020); and DOD Instruction 5000.02, *Operation of the Adaptive Acquisition Framework* (Jan. 23, 2020).

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



Source: GAO analysis of DODI 5000.02 and related instructions. I GAO-21-105298

The AAF allows program managers flexibility in determining how to use the pathways for their acquisition efforts. The AAF includes one pathway—the software acquisition pathway—to facilitate rapid and

iterative delivery of software capability to the user. In addition to the software acquisition pathway, software development also occurs using other AAF pathways, such as the major capability acquisition or middle-tier acquisition (MTA) pathways. For example, a program using the major capability acquisition pathway may include significant software development efforts.

Further, a capability may be developed using multiple pathways. For example, a program manager may choose to concurrently use the major capability acquisition pathway to develop hardware and the software acquisition pathway to develop software. Once the software effort and major capability effort achieved required capabilities, the capability would be fully fielded and enter operations and sustainment.

In June 2021, we reported that DOD had trouble tracking programs transitioning between acquisition pathways or conducting multiple efforts using the same pathway and had yet to develop an overarching data collection and reporting strategy.[11] We made a recommendation that DOD, among other things, report overall cost and schedule information for capabilities developed using multiple pathways. DOD concurred with the recommendation and is still in the process of determining how it will address the recommendation.

DOD Updated Policy to Incorporate Reforms, but Implementation of Leading Practices Remains Inconsistent

DOD recently made efforts to improve its software acquisition processes by taking steps such as issuing an instruction that establishes policy and procedures for the software acquisition pathway. DOD has also focused on facilitating programs' ability to execute Agile software development by implementing new training and pilot programs. Our most recent assessments of weapon and major business IT programs show that an increasing number of programs report using modern software development practices such as Agile; however, many programs we

[11]GAO-21-222.

reviewed reported that they had yet to implement certain recommended practices.[12]

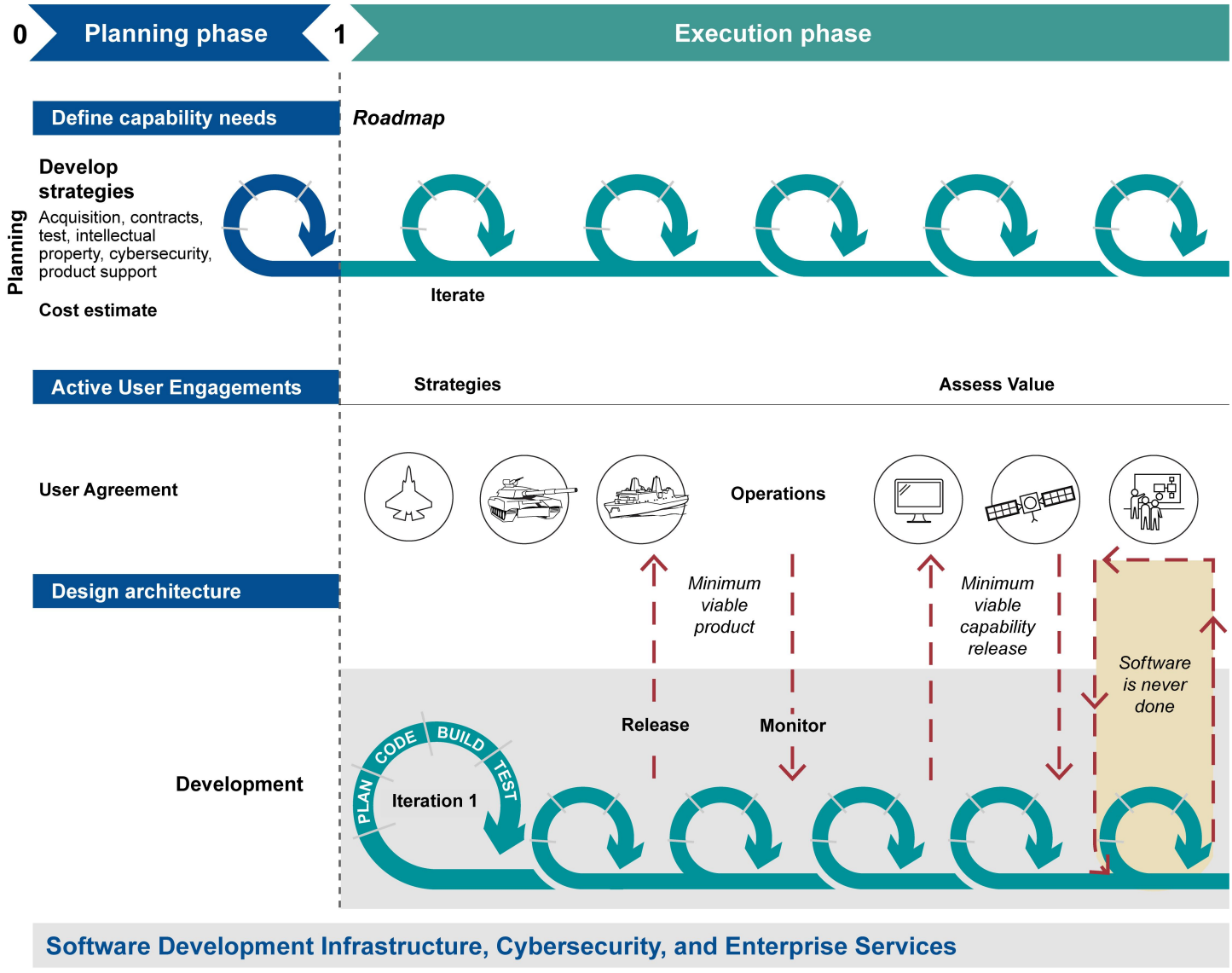
DOD Established a Software Acquisition Pathway Emphasizing Rapid Delivery and User Engagement

DOD established the software acquisition pathway in response to a provision in the NDAA for Fiscal Year 2020 and recommendations made in the 2018 Defense Science Board report. The report advised the department to adopt continuous iterative development and empower programs to immediately adopt a modern approach to software development.[13] The software acquisition pathway guidance, DOD Instruction 5000.87, was released in October 2020. The pathway contains a planning phase and an execution phase (see fig. 2).

[12]GAO-21-222. GAO-21-351.

[13]National Defense Authorization Act for Fiscal Year 2020, Pub. L. No 116-92, § 800, 133 Stat 1198, 1478 (2019). Defense Science Board, *Design and Acquisition of Software for Defense Systems* (Washington, D.C.: Feb. 14, 2018).

Figure 2: The Department of Defense's Software Acquisition Pathway



Source: Department of Defense Instruction 5000.87 (October 2020). | GAO-21-105298

This new pathway is intended to represent a major component of modernizing DOD's approach to software acquisition to provide for the efficient and effective acquisition, development, integration, and timely delivery of secure software. Using this pathway, small cross-functional teams that include users, testers, software developers, and cybersecurity experts can deliver software rapidly and iteratively to meet user needs.

The pathway guidance encourages program officials to frequently engage with users and deliver new capabilities to operations at least annually.

DOD's software acquisition pathway instruction also implemented recommendations we made in 2019 that DOD ensure its software development guidance provides specific, required direction on the timing, frequency, and documentation of user involvement and feedback.[14] Our 2019 report focused on software development in space acquisition programs and the programs' efforts to implement the 2018 Defense Science Board recommendations. At the time, two programs we reviewed—Joint Space Operations Center Mission System and Mobile User Objective System—were in the process of shifting to Agile development to improve software delivery times. However, we found that the programs lacked effective user engagement.

DOD has begun implementing the new software acquisition pathway. For example:

- In March 2021, we reported that the F-35 Lightning II's Operational Data Integrated Network program, which will facilitate operations and sustainment of the F-35, uses an Agile development process.[15] Officials told us they started following some aspects of the software acquisition pathway when interim guidance was released in January 2020.
- In June 2021, we reported that Unified Platform, which is developing software to consolidate cyber capabilities and data processing, transitioned from the MTA pathway to the software acquisition pathway in August 2020.[16]

However, we also reported in June 2021 that DOD had yet to collect the data and develop tools it needed to oversee the programs using the software acquisition and business systems pathways. Specifically, in our June 2021 assessment of its major business IT programs, we found that the department did not have data strategies or final metrics for the

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

[15]GAO, *F-35 Joint Strike Fighter: DOD Needs to Update Modernization Schedule and Improve Data on Software Development,* GAO-21-226 (Washington D.C.: Mar. 18, 2021).

[16]GAO-21-222.

pathways.[17] We recommended that, among other things, DOD automate data collection efforts for the software acquisition pathway to allow stakeholders to monitor and assess acquisition performance. DOD agreed with the recommendation and reported that it is developing plans for automation of data collection for AAF pathways.

It remains too early to assess whether the department's software acquisition has improved under this new instruction. We will continue to monitor DOD's use of the software acquisition pathway and report on these topics in future reports.

DOD Has Developed Guidance and Implemented Pilots That Further Address Software Development Leading Practices

DOD made other efforts beyond its software acquisition pathway instruction to adopt software development leading practices, including developing guidance and implementing pilot programs on Agile development. For example, we reported recently that DOD started to address other recommendations made by the Defense Science Board in 2018.[18] These recommendations included improving software acquisitions in defense systems by delivering minimum viable products, using software factories, and providing software acquisition training for program managers.[19] In August 2020, DOD reported to Congress that it is also addressing the numerous recommendations made by the 2019 Defense Innovation Board study that emphasized, among other things, speed and delivery time, hiring and retaining qualified staff, and focusing on continuous improvement throughout the software life cycle.[20]

[17]GAO-21-351.

[18]GAO-21-222. GAO-21-351.

[19]The Defense Science Board defines the software factory as low-cost, cloud-based computing used to assemble a set of tools enabling developers, users, and management to work together on a daily tempo. GAO-21-222. GAO-21-351.

[20]Defense Innovation Board, *Software Is Never Done: Refactoring the Acquisition Code for Competitive Advantage* (May 3, 2019). Office of the Under Secretary of Defense for Acquisition and Sustainment, *Report to Congress on Implementation of Defense Science Board Report Recommendations, "Design and Acquisition of Software for Defense Systems" Section 868 of the National Defense Authorization Act for Fiscal Year 2019 (P.L. 115-232)* (August 2020).

One of DOD's key focus areas has been to move towards Agile software development practices that are consistent with leading commercial practices for software development. The department made efforts to implement Agile as part of its software modernization efforts in several ways. For example, we reported in June 2021 that DOD

- updated the defense business system pathway and created the software acquisition pathway in part to help enable Agile software development, and both pathways include provisions that support Agile development—for example, a "limited deployment" in the business system pathway can be similar to a "minimum viable product" in Agile development methodology, and the program team is expected to iteratively release functionality;
- created training for the acquisition community, issued guidance, provided technical tools and resources to programs, and conducted public outreach to transition the department toward Agile; and
- established communities of practice and working groups to share information and address specific aspects of the department's Agile transition—for example, the Defense Acquisition University Agile Community of Practice has developed guidance and templates for programs transitioning to Agile practices.[21]

In addition, sections 873 and 874 of the NDAA for Fiscal Year 2018 mandated that DOD implement two pilot programs to enable selected acquisition programs to adopt Agile practices.[22] As we reported in June 2021, DOD provided participating programs with training and tailored Agile guidance. The section 874 pilot lasted 1 year, and involved seven participants, including the Air Force's Air and Space Operations Center. The section 873 pilot targeted large acquisition programs, including the Army's Integrated Air and Missile Defense program, and is planned to continue through Fiscal Year 2023. In February 2020, DOD issued an Agile Software Acquisition Guidebook that shared Agile lessons learned

[21]GAO-21-351.

[22]National Defense Authorization Act for Fiscal Year 2018, Pub. L. No. 115-91,§§ 873-874, 131 Stat. 1283, 1498-1503 (2017) (codified at 10 U.S.C. §§ 2223a note, 2302 note).

from these pilot programs.[23] The lessons learned from these pilot programs stated, among other things, that:

- Agile is built around frequent, small batch delivery of working functionality into the hands of end users to gain fast feedback.
- The biggest risk mitigator in an Agile framework is frequent delivery of a product or capability.

DOD Acquisition Programs Have Yet to Consistently Implement Software Development Leading Practices

Our recent work found that, while a substantial number of weapon systems and major business IT programs reported using modern software development approaches, many of these programs faced challenges implementing certain recommended leading practices associated with these approaches. Appendixes I and II provide detail from our recent work on weapon systems and major business IT programs. Key findings from this work included:

Employment of modern software development approaches. We found in our review of DOD's weapon programs that a total of 36 programs reported using Agile. This includes just over half of major defense acquisition programs (MDAP) (23 of 42 programs) and about three-quarters (13 of 17) of the programs using the MTA pathway, most of which initiated use of the pathway within the last 2 or 3 years.[24] Our

[23]Office of the Under Secretary of Defense for Acquisition and Sustainment, *Agile Software Acquisition Guidebook-Best Practices & Lessons Learned from the FY18 NDAA Section 873/874 Agile Pilot Program,* (Washington, D.C.: Feb. 27, 2020). See National Defense Authorization Act for Fiscal Year 2018, Pub. L. No. 115-91, § 873, 131 Stat. 1283, 1498-1500 (2017) (codified at 10 U.S.C. § 2223a note); John S. McCain National Defense Authorization Act of Fiscal Year 2019, Pub. L. No. 115-232, § 869, 132 Stat. 1636, 1902-04 (2018) (codified at 10 U.S.C. § 2223a note).

[24]MDAPs generally include those programs designated by DOD as such or that have a dollar value for all increments estimated to require eventual total expenditure for research, development, test, and evaluation of more than $525 million, or for procurement of more than $3.065 billion, in fiscal year 2020 constant dollars. Certain programs that meet these thresholds, including programs using the MTA pathway, are not considered MDAPs. In this report, we refer to programs currently using the MTA pathway as "MTA programs," although some of these programs may also plan to subsequently use one or more other pathways before fielding an eventual capability. We included MTA programs with costs greater than the MDAP threshold that met the scope of the engagement.

review of major business IT programs found just over half (14 of 22) reported using Agile.

Early and continuous delivery of working software. Fewer than one-third of the weapon programs we reviewed that reported using Agile (11 of 36 programs) also reported delivering software to users in less than 6 months. Further, only one-sixth of the programs (6 of 36) told us they deliver software in less than 3 months, which is closer to recommended industry standards.[25] However, major business IT programs that were developing software reported delivering functionality more frequently—over two-thirds (16 of 22) of major business IT programs we reviewed reported delivering software functionality every 6 months or less.[26]

Implementation of Defense Science Board recommendations. We found that the majority of MDAPs we reviewed have yet to implement certain practices that were recommended by the Defense Science Board in 2018. However, proportionally more MTA programs that we reviewed reported they have implemented these practices. For example, we found that less than one-sixth of MDAPs (6 of 42) and one-third of MTA programs (5 of 17) reported providing program managers training on modern software practices. We previously reported that program staff should have appropriate training in iterative methods since iterative techniques are different from those used for traditional software development. Otherwise, programs are at risk of falling back into the traditional practices they used prior to adopting more modern practices.[27]

Major business IT programs were more likely to use practices recommended by the Defense Science Board but still reported limited implementation of certain practices. For example, only approximately one-third of major business IT programs (8 of 22) reported assembling software tools through use of software factories. According to the Defense Science Board, the use of a software factory and continuous

[25]Industry recommends capability be delivered as frequently as every 2 weeks for many types of software.

[26]Office of Management and Budget (OMB) guidance calls for certain agency chief information officers and chief acquisition officers to take certain steps to ensure the application of adequate incremental development, which, for software development, OMB defines as planned and actual delivery of new or modified technical functionality to users at least every 6 months.

[27]GAO-20-590G.

iterative development could yield cost and schedule benefits for software-intensive DOD acquisition programs.

Challenges related to software development. The weapon systems and major business IT programs we reviewed reported a variety of challenges that could hinder their ability to implement recommended practices. For example, across all program types, programs reported difficulty in hiring government and contractor staff with sufficient software development expertise.

- Over half of all MDAPs and MTA programs reported challenges related to software development staffing. Challenges included hiring contractor and government staff in time to perform planned work and identifying contractor and government staff with expertise in software development. For example, the Air Force's Air Operations Center Weapon System Modifications program—which aims to modernize command and control for air operations—encountered difficulty finding and hiring government staff with required expertise to develop software, according to program officials. Specifically, the program cited challenges competing with the private sector for talent and long timelines to hire civilians, discouraging some highly qualified candidates. To address these issues, program officials told us they are filling positions with contractors and using expedited and direct hiring authorities.
- Officials from 18 of the 22 major business IT programs developing software reported that they faced software development workforce challenges, consistent with challenges reported for DOD software programs in May 2019 by the Defense Innovation Board.[28]

Programs also reported a variety of additional challenges, including requirements or design changes leading to additional software development efforts, availability of adequate software integration labs or facilities or developmental hardware, and difficulty transitioning to Agile development practices. Officials from the offices of the DOD Chief Information Officer and Under Secretary of Defense for Acquisition and Sustainment stated that the department is aware of the challenges

[28]In May 2019, the Defense Innovation Board reported that defense software programs are challenged in recruiting, retaining, managing, and developing a software development workforce. Defense Innovation Board, *Software Is Never Done: Refactoring the Acquisition Code for Competitive Advantage* (May 2019). For GAO's questionnaire, program officials provided responses to a list of six challenges. Program officials were also given the opportunity to identify challenges that were not already listed.

associated with the transition to Agile. The officials also stated that many of DOD's implementation efforts, also discussed in this report, have yet to be fully implemented or adopted across the department. DOD officials noted that the department continues work to address challenges and acknowledged that the transition to Agile will take years and require sustained engagement throughout DOD.

As agreed with congressional defense committee staff, we will conduct additional work to address Section 838 of the NDAA for Fiscal Year 2021, to include monitoring DOD's progress on implementing the recommended software acquisition reforms from the Defense Science Board and Defense Innovation Board reports, as well as the pilot programs. We will report on these topics and other elements of the mandate in future work.

Agency Comments

We requested comments from DOD on a draft of this report. The DOD Senior Lead for Software Acquisition provided us oral comments.

We are sending copies of this report to the appropriate congressional committees and the Secretary of Defense. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact me at 202-512-4841 or OakleyS@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix III.

Shelby S. Oakley
Director, Contracting and National Security Acquisitions

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Appendix I: Software Development Findings from GAO's 2021 Weapon Systems Annual Assessment

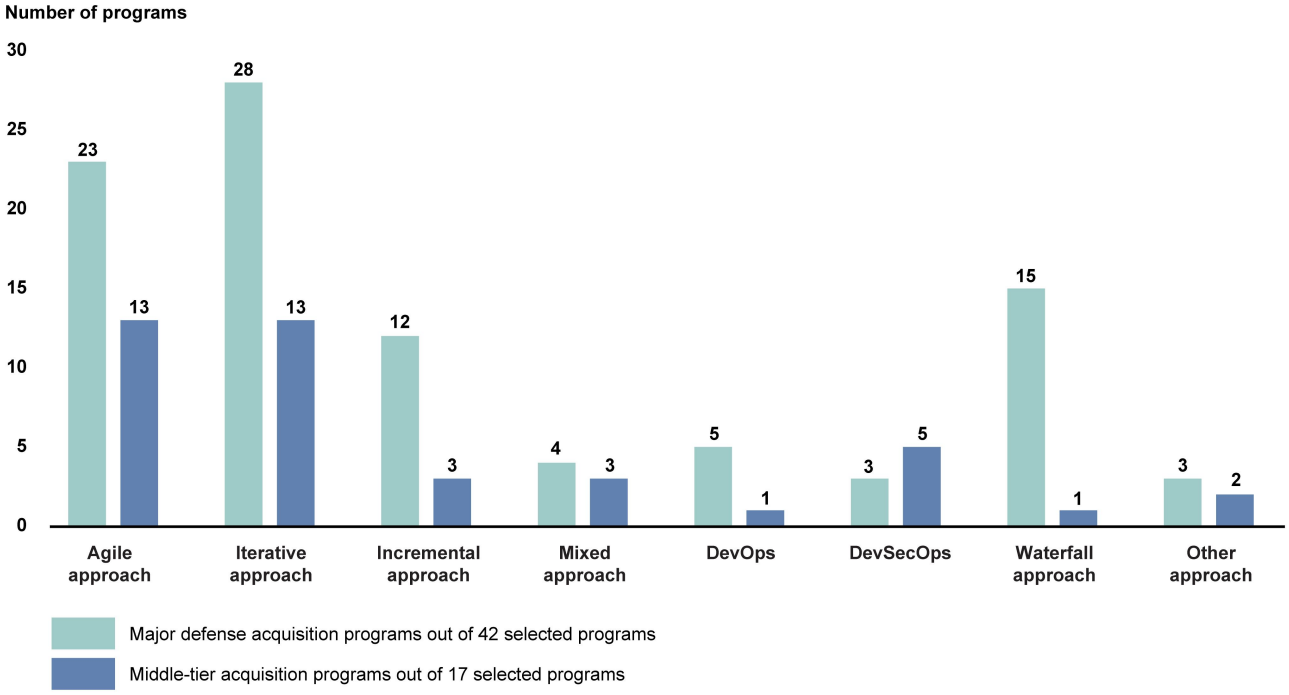
This appendix provides additional details on our findings on the Department of Defense's (DOD) weapon program's software development practices from our 2021 annual assessment of DOD weapon systems.[1] These findings are based on questionnaire responses from 42 major defense acquisition programs (MDAP) that were either between the start of development and the early stages of production or well into production but introducing new increments of capability or significant changes; and 17 programs using the middle-tier acquisition pathway (MTA programs) with costs above the thresholds for designation as an MDAP.

Employment of Modern Software Development Approaches

Just over half of MDAP (23 of 42 programs) and about three-quarters of MTA programs (13 of 17 programs) reported using Agile. In some cases, programs reported using multiple software development approaches to generate their systems' required software. For example, DevOps and DevSecOps are often based on an Agile software development approach, and some programs likewise reported using both Agile and DevSecOps or Agile and DevOps. Other programs used different software development practices for separate software efforts. Figure 3 shows software development models employed by weapon programs we reviewed.

[1]GAO, *Weapon Systems Annual Assessment: Updated Program Oversight Approach Needed,* GAO-21-222 (Washington, D.C.: June 8, 2021).

Figure 3: Software Development Approaches Employed by Acquisition Pathway, as of January 2021



Source: GAO analysis of programs' questionnaire responses. I GAO-21-105298

Accessible Data Table for Figure 3

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

Note: Programs could select more than one option.

Early and Continuous Delivery of Working Software

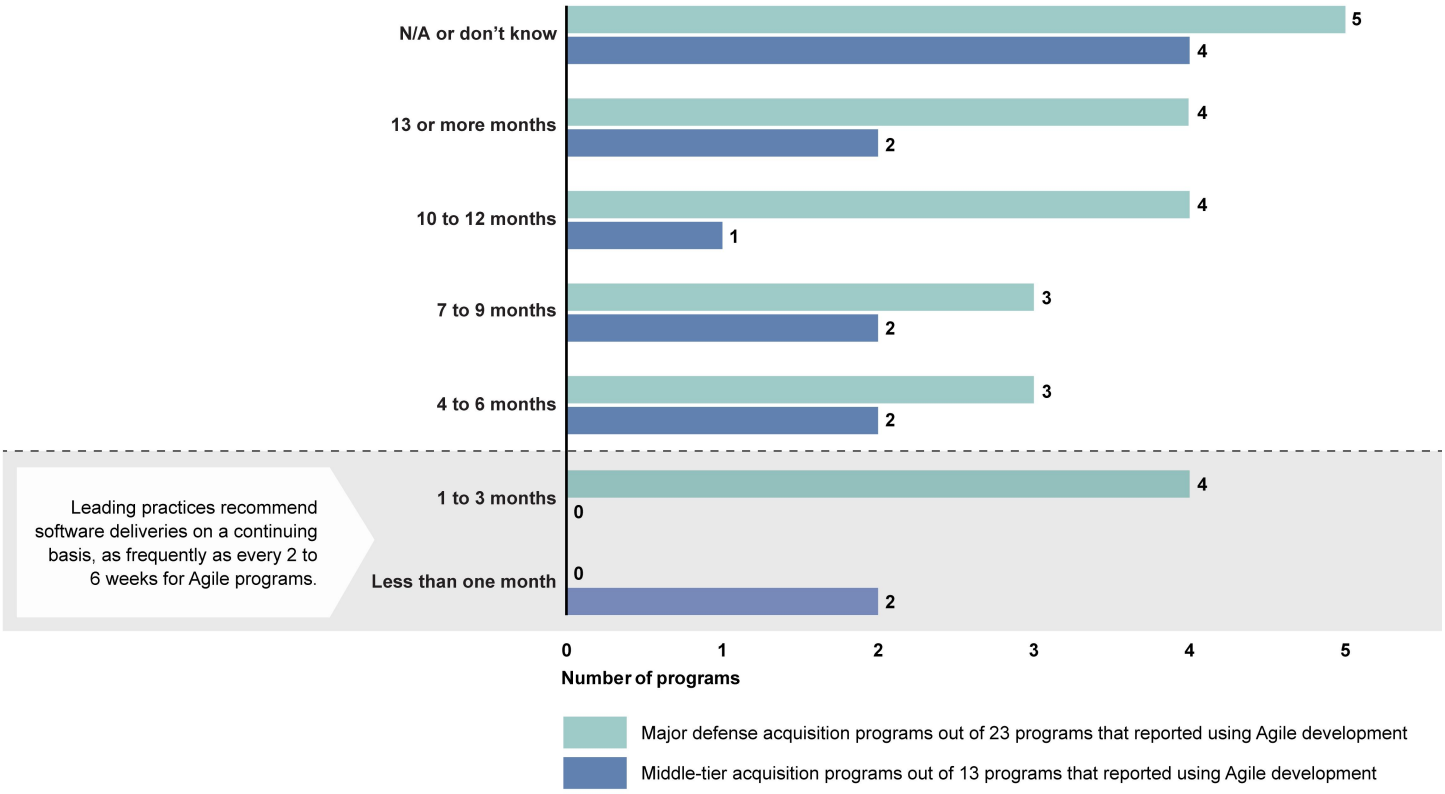
Only one-sixth of weapon programs that reported using Agile (6 of 36 programs) told us they deliver software to users in less than 3 months.

- Four of 23 (17 percent) MDAPs that reported using Agile also reported software delivery times of 3 months or less.
- Two of 13 (15 percent) MTAs that reported using Agile also reported software delivery times of 3 months or less.

Programs cited varying factors that affected delivery timeframes. For example, while the Army's Integrated Air and Missile Defense program reported using Agile development, officials reported software delivery times of 10 to 12 months. This program was selected to participate in a pilot program required by Section 873 of the National Defense Authorization Act (NDAA) for Fiscal Year 2018, which was to tailor and simplify software development requirements and methods for certain systems. At the time of our audit, program officials noted the program is still going through a transition to Agile software development practices as part of this pilot effort, which prioritized the inclusion of major software-intensive warfighting programs that have identified software development as high risk and have experienced cost growth and schedule delays. In contrast, the Army's Integrated Visual Augmentation System program—which aims to provide warfighters with augmented reality head gear to fight, rehearse, and train—is an example of a program using Agile software development approach and reporting software delivery times of 3 months or less. According to program officials, they adopted Microsoft's development practices to deliver customized commercial software. Software is delivered in small segments of functionality every 3 weeks to end users for feedback, and working software is deployed to warfighters for evaluation at each of the four capability set demonstrations.

Figure 4 illustrates the reported software delivery times for programs that told us they use Agile development.

Figure 4: Reported Software Delivery Times for Programs That Indicated Use of Agile Development, as of January 2021



Source: GAO analysis of programs' questionnaire responses. I GAO-21-105298

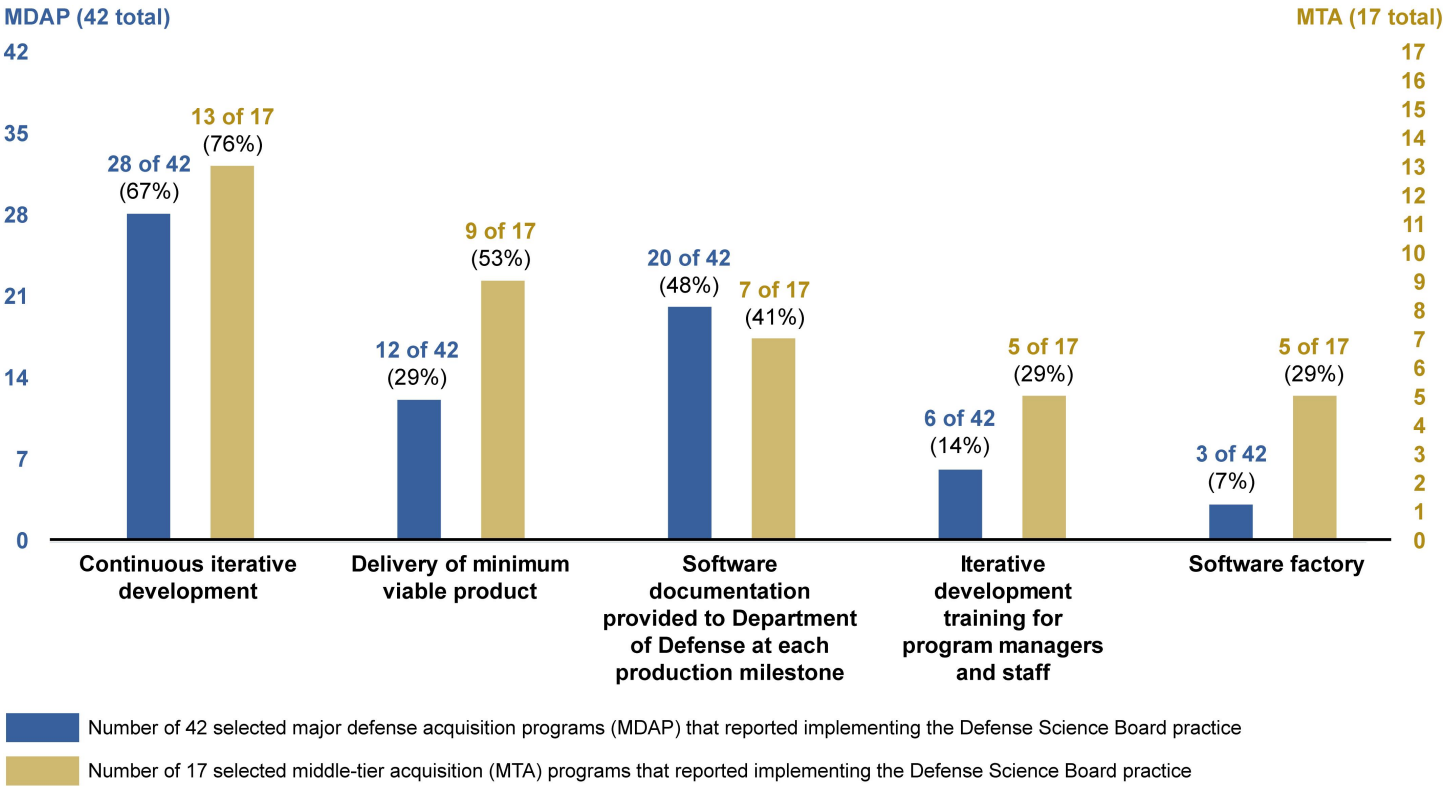
Accessible Data Table for Figure 4

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

Implementation of Defense Science Board Recommendations

We found that the majority of MDAPs had yet to implement certain practices recommended by the Defense Science Board in 2018; however, proportionally more MTA programs reported they had implemented these practices. Figure 5 illustrates the extent to which programs reported using software practices recommended by the Defense Science Board.

Figure 5: GAO-Reviewed Programs Reporting Implementation of Selected Software Practices, as of January 2021



Source: GAO analysis of programs' questionnaire responses. | GAO-21-105298

Accessible Data Table for Figure 5

Software Practice	MDAP (%)	MTA (%)	MDAP (# programs)	MTA (# programs)
Software factory	7%	29%	3	5
Delivery of minimum viable product	29%	53%	12	9
Continuous iterative development	67%	76%	28	13
Iterative development training for program managers and staff	14%	29%	6	5
Software documentation provided to Department of Defense at each production milestone	48%	41%	20	7
Total number of MDAPs: 42				
Total number of MTAs: 17				

Appendix II: Software Development Findings from GAO's 2021 Information Technology Program Annual Assessment

This appendix provides additional detail on the findings related to software development practices from our 2021 annual assessment of Department of Defense (DOD) Information Technology (IT) systems. For this assessment, we provided a questionnaire to and received responses from 29 major business IT programs, including 22 programs that were actively developing software.[1]

Employment of Modern Software Development Approaches

Officials from 18 of the 22 programs that were developing software reported using at least one of the software development approaches that supports continuous, iterative development.[2] Conversely, officials from 11 programs reported that they were using a waterfall approach. In particular, three of the 11 reported that they were only using a waterfall approach and the remaining eight reportedly used waterfall in combination with an iterative approach, including Agile. Table 3 defines the software development approaches and shows the approaches that

[1]For the purposes of this assessment, programs are considered to be developing software if they did not report being in the sustainment phase of acquisition, or if they reported being in sustainment but also reported being in another phase of acquisition. The 22 programs discussed in this section reported being in the development and production, deployment, and sustainment phases. Officials from some programs also reported being in other phases or a combination of multiple phases. Program officials from the seven programs not included in this section only reported that their programs were in sustainment.

[2]The software development approaches are not mutually exclusive, and some program officials reported using multiple software development approaches.

officials from the major business IT programs that were developing software reported using.

Table 3: Software Development Approaches That Major Business Information Technology (IT) Programs Reported Using, as of December 2020

Approach	Number of programs that reported using each approach[a]
Approaches that support continuous, iterative development.	18 of 22
Agile	14 of 22
DevOps	6 of 22
DevSecOps	5 of 22
Incremental	11 of 22
Approaches that may or may not support continuous, iterative development.	8 of 22[a]
Mixed	8 of 22
Other	1 of 20[b]
Approach that likely does not support continuous, iterative development	11 of 22[a]
Waterfall	11 of 22

Source: GAO analysis of Department of Defense questionnaire responses. | GAO-21-105298

[a]Officials from some programs reported using multiple approaches.

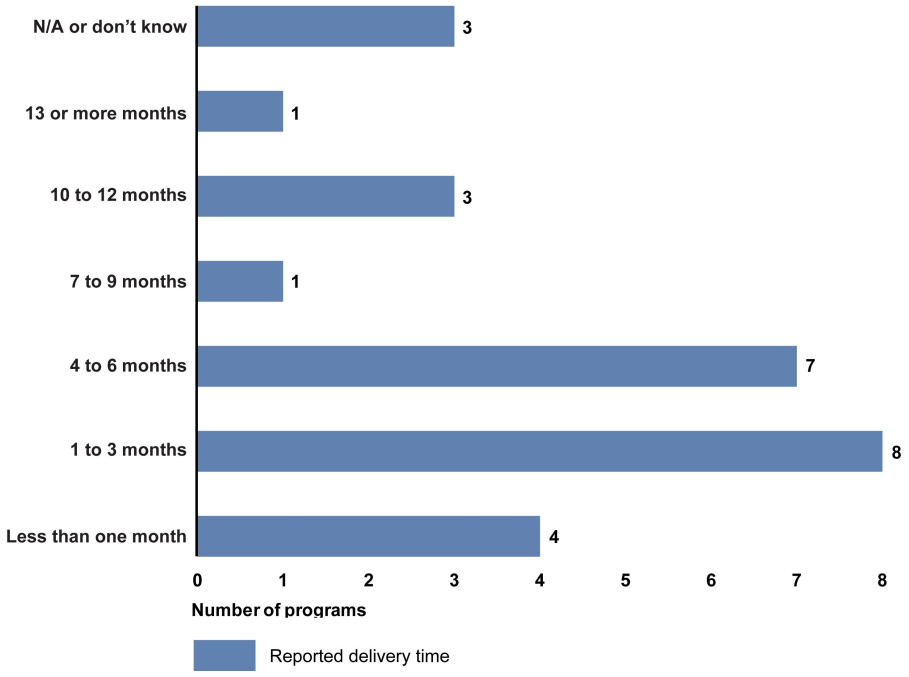
[b]Not all program officials responded to every response option.

Early and Continuous Delivery of Working Software

Officials from 16 of the 22 programs actively developing software reported delivering software functionality every 6 months or less, as called for in Office of Management and Budget (OMB) guidance.[3] Officials from four programs reported that the average length of time between software releases was greater than 6 months. Figure 6 illustrates the reported average length of time between software delivery releases for major business IT programs.

[3]Some programs reported multiple average lengths of time between software releases, including one program that reported releases both less than and greater than every 6 months.

Figure 6: Reported Average Length of Time between Software Delivery Releases for Major Business Information Technology (IT) Programs, as of December 2020



Source: GAO analysis of programs' questionnaire responses. I GAO-21-105298

Accessible Data Table for Figure 6

Reported delivery time	Number of programs
N/A or don't know	3
More than 13 months	1
10 and 12 months	3
7 and 9 months	1
4 and 6 months	7
1 and 3 months	8
Less than one month	4

Note: "N/A or don't know" was a single option provided to program officials. Officials from one program that selected this option reported that the program is changing the frequency of its releases, and officials from another reported that the program's users may not have access to capabilities for a long time after developers release new software. Officials from the third program reported that they were only planning one software release.

Implementation of Defense Science Board Recommendations

Programs reported using a variety of iterative software processes that the Defense Science Board reported in 2018 could result in cost or schedule benefits for DOD's IT programs.[4] Table 4 shows the iterative software development processes that officials from the 22 major business IT programs reported using.

Table 4: Major Business Information Technology (IT) Programs That Reported Using Iterative Software Development Processes, as of December 2020

Iterative development process	Number of programs that reported using each process
Software factory	8 of 22
Delivery of minimum viable product, followed by successive next viable product	13 of 22
Continuous iterative development	16 of 22
Iterative development training for program managers and staff	12 of 22
Software documentation	18 of 22
Independent verification and validation for machine learning	5 of 22
None of the above	4 of 22

Source: GAO analysis of Department of Defense questionnaire responses. | GAO-21-105298

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

Appendix III: GAO Contact and Staff Acknowledgments

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Shelby S. Oakley, 202-512-4841 or OakleyS@gao.gov.

Staff Acknowledgments

In addition to the contact named above, the following staff members made key contributions to this report: Kevin Walsh (Director), Anne McDonough (Assistant Director), Michael Holland (Assistant Director), Jessica Karnis (Analyst in Charge), and Jaeyung Kim. Other contributions were made by Vinayak Balasubramanian, Rose Brister, Garret Chan, Lori Fields, and Gina Hoover.

Related GAO Products

Software Development: DOD Faces Risks and Challenges in Implementing Modern Approaches and Addressing Cybersecurity Practices. GAO-21-351. Washington, D.C.: June 23, 2021.

Weapon Systems Annual Assessment: Updated Program Oversight Approach Needed. GAO-21-222. Washington, D.C.: June 8, 2021.

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DOD Space Acquisitions: Including Users Early and Often in Software Development Could Benefit Programs. GAO-19-136. Washington D.C.: March 18, 2019.

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