United States Government Accountability Office

Report to the Committee on Armed Services, U.S. Senate

January 2020

DEFENSE ACQUISITIONS

Senior Leaders Should Emphasize Key Practices to Improve Weapon System Reliability

GAO-20-151

GAO Highlights

Highlights of GAO-20-151, a report to the Committee on Armed Services, U.S. Senate

Why GAO Did This Study

DOD invests tens of billions of dollars each year in major defense acquisition programs, designing and developing technologically advanced weapon systems that warfighters expect will meet specific performance requirements, including reliability requirements. Systems that are not reliable make it more difficult for warfighters to perform their missions.

GAO was asked to examine DOD weapon system reliability. This report addresses (1) how selected companies in the commercial sector address reliability, (2) how selected DOD acquisition programs addressed reliability, and (3) the extent to which DOD leadership has highlighted key reliability practices.

GAO collected information on leading commercial practices at the 2019 Reliability and Maintainability Symposium and from four commercial companies known for delivering reliable products. GAO also assessed how seven DOD acquisition programs—both older and newer, and representing all the military services—addressed reliability; reviewed key documents and interviewed knowledgeable officials; and reviewed reliability-related guidance and policy from senior DOD leaders.

What GAO Recommends

GAO recommends the Secretaries of the Air Force, Army, and Navy highlight the importance of three key reliability practices: leveraging reliability engineers, establishing realistic reliability requirements, and employing reliability engineering activities to improve a system's design throughout development. DOD agreed with GAO's recommendations.

View GAO-20-151. For more information, contact Michele Mackin at (202) 512-4841 or mackinm@gao.gov.

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What GAO Found

The commercial companies GAO reviewed proactively address reliability. They strive to identify reliability issues at the component level early in the development process to avoid expensive rework after producing an entire system. GAO found these companies focus on the following key practices:

1. Leveraging reliability engineers early and often
2. Establishing realistic reliability requirements
3. Emphasizing reliability with their suppliers
4. Employing reliability engineering activities to improve a system's design throughout development

GAO found that the seven Department of Defense (DOD) acquisition programs it reviewed did not consistently adhere to these key practices (see figure). These programs often prioritized schedule and cost over incorporating the key reliability practices, and these systems generally were not as reliable as promised.

Key Characteristics of Selected Acquisition Programs' Approach to Reliability

Program name and development start	Did not leverage government reliability engineers early	Initially pursued unrealistic reliability requirements	Did not effectively emphasize reliability with suppliers (contractors)	Deferred reliability engineering activities
V-22 Osprey, 1986		×	×	×
F-22 Raptor, 1991	×	×		×
Expeditionary Fighting Vehicle, 2000	×	×	×	×
F-35 Lightning II, 2001		×	×	×
Joint Light Tactical Vehicle, 2012				
Armored Multi-Purpose Vehicle, 2014			×	×
VH-92A Presidential Helicopter Replacement Program, 2014				

Source: GAO analysis of Department of Defense documentation and testimonial evidence. | GAO-20-151

In 2019, DOD highlighted in a policy memorandum the importance of emphasizing reliability with contractors. However, the other three key practices have not been similarly highlighted. DOD has taken steps to accelerate weapon system development, and decision-making authority has been delegated to the military services. In an environment emphasizing speed, without senior leadership focus on a broader range of key reliability practices, DOD runs the risk of delivering less reliable systems than promised to the warfighter and spending more than anticipated on rework and maintenance of major weapon systems.

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Abbreviations

AMPV	Armored Multi-Purpose Vehicle
DOD	Department of Defense
DOT&E	Director, Operational Test and Evaluation
EFV	Expeditionary Fighting Vehicle
JLTV	Joint Light Tactical Vehicle
NDAA	National Defense Authorization Act
OSD	Office of the Secretary of Defense
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment
USD(R&E)	Under Secretary of Defense for Research and Engineering

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

January 14, 2020

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

The Department of Defense (DOD) invests tens of billions of dollars each year designing and developing technologically advanced major defense acquisition systems which are expected to meet specific performance requirements. These performance requirements focus on capabilities like range and survivability, but law and DOD policy also mandate that defense weapon system acquisition programs address the performance requirement for reliability.[1] Reliability is the probability that a system will perform without failure over a particular timeframe and under specified conditions. For example, reliability requirements often address how long an aircraft or land vehicle should operate before needing repair. A weapon system's reliability directly affects a warfighter's ability to complete a mission, and how much DOD must spend to operate and support the weapon system over its lifetime, which often spans decades. Nonetheless, DOD acquisition programs continue to struggle to deliver reliable weapon systems. For example, DOD's Director, Operational Test and Evaluation (DOT&E) has identified poor reliability as the reason for some acquisition programs not delivering suitable weapon systems to the warfighter.

Decisions made early in the acquisition process influence reliability throughout a system's life cycle, and members of Congress have expressed concerns that DOD does not focus adequate attention on reliability when it is designing and developing weapon systems. Congress has passed legislation related to weapon system reliability. The fiscal year 2017 National Defense Authorization Act (NDAA) contained a

[1]National Defense Authorization Act for Fiscal Year 2018, Pub. L. No. 115-91 § 834 (2017); Weapon Systems Acquisition Reform Act of 2009, Pub. L. No. 111-23 § 139d (b)(5). Department of Defense Directive 5000.01, The Defense Acquisition System (May 2003 [incorporating change 2 (Aug. 2018)]) (DOD Directive 5000.01); Department of Defense Instruction 5000.02, Operation of the Defense Acquisition System (Jan. 2015) [incorporating change 3 (Aug. 2017)] ("DOD Instruction 5000.02").

provision that established an Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)).[2] Weapon system reliability has a significant impact on sustainment efforts. The following year, the fiscal year 2018 NDAA included a provision mandating that DOD program managers include certain reliability requirements in weapon system engineering and manufacturing development and production contracts.[3] For its part, DOD has also demonstrated an increased focus on weapon system reliability recently. In January 2019, the USD(A&S) working with the Under Secretary of Defense for Research and Engineering (USD(R&E)), according to a DOD official, issued a policy memorandum to senior acquisition leaders at the military services addressing several reliability-related concerns involving requirements, contract solicitations, and data collection.[4]

While there has been an increased focus on reliability, Congress provided DOD with additional tools to enable DOD to accelerate weapon system acquisitions. As we reported in June 2019, the 2016 NDAA devolved much of the decision-making authority for major defense acquisition programs from the Office of the Secretary of Defense (OSD) to the military services.[5] The 2016 NDAA 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 2016 NDAA, the guidance was to create an expedited and streamlined "middle tier" of acquisition programs intended to be completed within 5 years. Programs using this authority are generally to be exempt from DOD's traditional acquisition and requirements development policies.

You asked us to complete a body of work examining DOD weapon system sustainment issues, including weapon system reliability. In this report, we discuss (1) how selected companies in the commercial sector

[2]National Defense Authorization Act for Fiscal Year 2017, Pub. L. No. 114-328, § 901, § 133b(b)(2).

[3]Pub. L. No. 115-91, § 834 (2017).

[4]Department of Defense, Under Secretary of Defense (Acquisition and Sustainment) memorandum: *Implementation of title 10, United States Code, section 2443 - Sustainment Factors in Weapon System Design* (Jan. 31, 2019).

[5]National Defense Authorization Act for Fiscal Year 2016, Pub. L. No. 114-92, § 825 (2015).

address reliability, (2) how selected DOD acquisition programs addressed reliability, and (3) the extent to which DOD leadership has highlighted key reliability practices.

To examine how companies in the commercial sector address reliability, we collected information including presentations, papers, and tutorials from leading reliability engineers at the 2019 Reliability and Maintainability Symposium, an annual premier event in the area of reliability engineering. We attended in-depth sessions at the Symposium on a number of reliability-related topics. Symposium participants included representatives from commercial industry, academia, and government.[6] We also selected a non-generalizable sample of four companies with known success in demonstrating reliability based on literature searches and information obtained at the 2019 Reliability and Maintainability Symposium. These companies won awards in the areas of reliability, dependability, performance, or quality or have been recognized as experts in reliability skill development. We met with representatives from the four commercial companies to discuss reliability engineering and collect documentation about the practices they use to develop reliable products. We identified themes mentioned from these sources and used these to select the practices most frequently mentioned across all sources as key practices. The four commercial companies we spoke with are listed below in table 1.

[6]The 2019 Reliability and Maintainability Symposium included commercial representatives from Apple, Lockheed Martin, the Raytheon Company, and Tesla Inc., among others. Government representatives included the United States Nuclear Regulatory Commission, the United States Army including the Tank Automotive Research, Development and Engineering Center, Armament Research, Development, and Engineering Center, and the Combat Capabilities Development Command (CCDC) Data and Analysis Center (formerly Army Materiel Systems Analysis Activity) among others.

Table 1: Commercial Companies Included in This Review

Name	Description
Cummins Inc.	A leading manufacturer of diesel, electric, hybrid, and natural gas-powered engines and generators that is also developing other power technologies.
Ford	A leading designer and manufacturer of cars and trucks that is also pursuing electric and autonomous vehicle technologies.
HBM Prenscia, Inc.	A leader in providing technology and engineering software products and services for reliability and durability. It offers a broad range of engineering solutions to both government and industry clients for the design and development of reliable products, and to reduce life cycle costs.
Thermo Fisher Scientific	A leader in serving science that helps its customers to accelerate life sciences research, improve patient diagnostics, deliver medicines to market, and increase laboratory productivity.

Source: GAO presentation of commercial company information. GAO-20-151

To identify how selected DOD acquisition programs addressed reliability, we assessed a non-generalizable sample of seven major defense acquisition programs. We selected both older programs that have publicly reported reliability problems, including problems we have previously identified, as well as programs that started more recently, to see how they were addressing reliability during acquisition.[7] We reviewed key documentation, including operational test reports, Reliability, Availability, and Maintainability and Cost Rationale Reports, Life-Cycle Sustainment Plans, Systems Engineering Plans, Test and Evaluation Master Plans, and interviewed knowledgeable officials, including reliability engineers, testing officials, and program managers. We selected a mix of older and more recent acquisition programs representing all of the military services to account for changes in the acquisition environment. We excluded Navy shipbuilding programs because we have ongoing work in this area. Figure 1 shows the DOD acquisition programs included in our review.

[7]GAO, *Defense Acquisitions: The Expeditionary Fighting Vehicle Encountered Difficulties in Design Demonstration and Faces Future Risks,* GAO-06-349 (Washington, D.C.: May 1, 2006), *Defense Acquisitions: Assessments Needed to Address V-22 Aircraft Operational and Cost Concerns to Define Future Investments,* GAO-09-482 (Washington, D.C.: May 11, 2009), *Defense Acquisitions: Issues to Be Considered as DOD Modernizes Its Fleet of Tactical Wheeled Vehicles,* GAO-11-83 (Washington, D.C.: Nov. 5, 2010); *F-22 Modernization: Cost and Schedule Transparency Is Improved, Further Visibility into Reliability Efforts Is Needed,* GAO-14-425 (Washington, D.C.: May 15, 2014); and *F-35 Joint Strike Fighter: Action Needed to Improve Reliability and Prepare for Modernization Efforts,* GAO-19-341 (Washington, D.C.: Apr. 29, 2019).

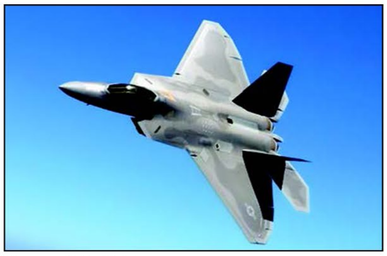
Figure 1: Selected Department of Defense (DOD) Acquisition Programs Included in This Review

Lead component: Air Force

Program: F-22 Raptor (F-22)

Development start: 1991

Air superiority and air-to-ground attack fighter



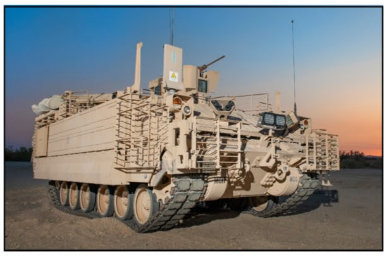
Source: U.S. Air Force.

Lead component: Army

Program: Armored Multi-Purpose Vehicle (AMPV)

Development start: 2014

Family of armored personnel carriers

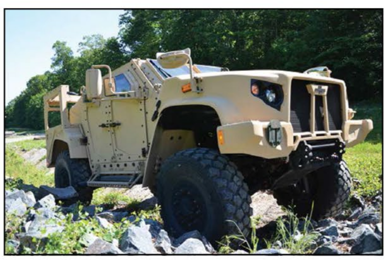


Source: BAE.

Program: Joint Light Tactical Vehicle (JLTV)

Development start: 2012

Family of tactical wheeled vehicles



Source: U.S. Army.

Lead component: Navy/Marine Corps

Program: Expeditionary Fighting Vehicle (EFV)

Development start: 2000

Amphibious assault and troop transport

Source: U.S. Marine Corps.

Program: VH-92A Presidential Helicopter Replacement Program (VH-92A)

Development start: 2014

Transportation of the President and other parties

Source: U.S. Marine Corps.

Program: V-22 Osprey (V-22)

Development start: 1986

Vertical takeoff and landing assault aircraft

Source: U.S. Navy.

Lead component: Joint DOD

Program: F-35 Lightning II (F-35)

Development start: 2001

Stealthy, strike fighter aircraft

Source: © Lockheed Martin.

Source: GAO analysis of DOD information. | GAO-20-151

To understand the extent to which DOD leadership has highlighted key reliability practices, we examined and compared the following documents to the key reliability practices identified in the commercial sector: DOD Instruction 5000.02, *Operation of the Defense Acquisition System*; the Systems Engineering Plan Preparation Guide; the Life Cycle Sustainment

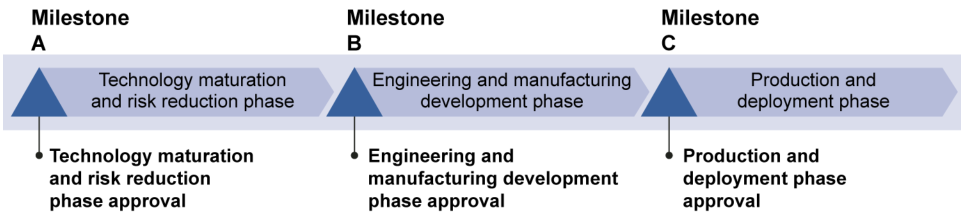
Plan Guide; DOD Product Support Manager Guidebook; DOD Operating and Support Cost Management Guidebook; DOD Reliability, Availability, Maintainability, and Cost Rationale Report Manual; DOD Guide for Achieving Reliability, Availability, and Maintainability; DOD Handbook on Reliability Growth Management; the 2018 Joint Capabilities Integration and Development System Manual; the January 2019 USD(A&S) Memorandum on Sustainment Factors in Weapon System Design; and service level reliability guidance. We also met with DOD officials—including the primary proponent for weapon system reliability from OSD and each of the military services—to discuss the extent to which these documents reflected key reliability practices and DOD's ongoing efforts to improve the reliability of its weapon systems.

We conducted this performance audit from July 2018 to January 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.

Background

DOD acquires new weapon systems for its warfighters through a management process known as the Defense Acquisition System. This system is implemented by two key acquisition policies: DOD Directive 5000.01, which establishes the overarching framework for the Defense Acquisition System; and DOD Instruction 5000.02, which provides detailed procedures for the operation of the Defense Acquisition System and the management of acquisition programs. These policy documents establish the guiding principles for all aspects of the DOD acquisition process. Additionally, each of the military services has its own acquisition policies which incorporate and enhance the DOD acquisition guidance. Figure 2 depicts DOD's acquisition process beginning with Milestone A in general terms.

Figure 2: Selected Phases of the Department of Defense Acquisition Process



Source: GAO analysis of Department of Defense information. | GAO-20-151

Several entities in the Office of the Secretary of Defense and the military departments play a role in the oversight of DOD weapon system acquisition programs, including the following:

- The Under Secretary of Defense for Research and Engineering is responsible for establishing policies on and supervising all aspects of defense research and engineering, technology development, technology transition, prototyping, experimentation, and developmental testing activities and programs, including the allocation of resources for defense research and engineering. DOD's Reliability and Maintainability Engineering lead reports to this Under Secretary.
- The Under Secretary of Defense for Acquisition and Sustainment is responsible for establishing policies on and supervising all matters relating to acquisition (including (1) system design, development, and production; and (2) procurement of goods and services) and sustainment (including logistics, maintenance, and materiel readiness). This organization has certain oversight responsibilities for major defense acquisition programs throughout the acquisition process, such as collecting and distributing performance data. The Under Secretary is the Defense Acquisition Executive and serves as the milestone decision authority for certain major defense acquisition programs, meaning the Under Secretary authorizes these programs to proceed through the DOD acquisition process's major milestones.
- At the military department level, the service acquisition executive, also known as the component acquisition executive, is a civilian official within a military department who is responsible for all acquisition functions within the department and can serve as the milestone decision authority. Congress has recently devolved much of the decision making authority for major defense acquisition programs

from OSD to these service acquisition executives.[8] According to a DOD official the service acquisition executive will normally assign a relevant program manager who will then assign a chief engineer or lead systems engineer and team members with responsibility for the engineering effort of a program, including the reliability engineering effort. The following officials serve as the service acquisition executive for the military departments:

  - the Assistant Secretary of the Air Force (Acquisition, Technology, and Logistics);
  - the Assistant Secretary of the Army (Acquisition, Logistics and Technology); and
  - the Assistant Secretary of the Navy (Research, Development and Acquisition) for both the Navy and the Marine Corps.

- Major defense acquisition program managers, who can be either civilian or military, are tasked with developing and delivering new weapon systems while balancing factors that influence cost, schedule, and performance and ensuring that systems are high quality, supportable, reliable, and effective.

DOD's Approach to Reliability

According to DOD guidance, reliability is the probability of an item to perform a required function under stated conditions for a specified period of time.[9] DOD's acquisition environment has changed over time and this has affected the way the Department addresses reliability. Until the late 1990s, DOD's goal was to achieve good reliability by focusing on specific reliability engineering tasks during design and manufacturing, and early testing to prevent, detect, and correct design deficiencies. In the late 1990s, in response to various NDAAs, DOD implemented certain acquisition reforms, eliminating and consolidating acquisition functions, and reducing the number of personnel assigned to the remaining functions.[10]

[8] Pub. L. No. 114-92 § 825 (2015).

[9] Department of Defense, *DOD Guide For Achieving Reliability, Availability, and Maintainability* (Aug. 3, 2005).

[10] National Defense Authorization Act for Fiscal Year 1996, Pub. L. No. 104-106, § 906 (1996); National Defense Authorization Act for Fiscal Year 1997, Pub. L. No. 104-201, § 902; National Defense Authorization Act for Fiscal Year 1998, Pub. L. No. 105-85, § 912.

According to the Defense Science Board Task Force on Developmental Test & Evaluation, these reforms altered several aspects of the military acquisition process and DOD's acquisition workforce.[11] As a result, DOD lost experienced acquisition management and technical personnel. DOD officials stated this loss included reliability personnel who contributed to developmental testing and evaluation. DOD also canceled the Military Standard pertaining to reliability at this time.[12] DOD officials explained that, after acquisition reform in the late 1990s, the department shifted much of the responsibility for reliability issues to contractors, and government personnel primarily focused on how systems performed during operational tests at the end of their development program.

In the mid to late 2000s, Congress and DOD took actions to increase the focus on reliability engineering during weapon system design and development. Both Congress and DOD took steps to elevate the importance of reliability, which has continued through 2019. Figure 3 depicts selected laws related to reliability and DOD reliability efforts over time.

[11]DOD Report of the Defense Science Board Task Force on Developmental Test and Evaluation (May 2008).

[12]MIL-STD-785B, Military Standard: Reliability Program for Systems and Equipment Development and Production (Sept 15, 1980).

Figure 3: Selected Laws and DOD Reliability-Related Efforts over Time

1990s	Congress passes various acquisition reforms in National Defense Authorization Acts (NDAA) for fiscal years 1996, 1997, 1998, and 1999
	Department of Defense (DOD) cancels Military Standard 785B for reliability and reduces the total number of reliability test and evaluation personnel
2003	DOD removes reliability language from DOD Instruction 5000.02
2005	DOD publishes Guide for Achieving Reliability, Availability, and Maintainability
2007	DOD adds sustainment key performance parameter (KPP), containing the reliability key system attribute (KSA), to the Joint Capabilities Integration and Development System process
2008	Defense Science Board Task Force issues a report assessing the causal factors for DOD programs previously evaluated as not operationally suitable. Task Force finds poor reliability to be a key factor
2009	DOD adopts American National Standards Institute/Government Electronics and Information Technology Association Standard (ANSI/GEIA-STD 0009)
	Congress passes the Weapon Systems Acquisition Reform Act to improve the organization and procedures of DOD for the acquisition of major weapon systems. The act included provisions related to key requirements—including reliability requirements—for major defense acquisitions programs
	Director, Operational Test and Evaluation issues memorandum outlining steps to improve system reliability
2011	DOD issues Directive-Type Memorandum 11-003 to enhance reliability in the acquisition process
2015	DOD updates DOD Instruction 5000.02 to make systems reliability mandatory in the planning stages for DOD weapon systems
2017	Congress passes the NDAA for fiscal year 2018 requiring program managers to include certain reliability requirements in weapon system engineering and manufacturing development and production contracts
2019	DOD issues memorandum implementing the NDAA for fiscal year 2018 reliability-related requirements for development and production contracts

Source: GAO analysis of DOD and NDAA information. | GAO-20-151

Note: Legislation was enacted by Congress and signed into law by the President.

Impacts of Poor Reliability on Warfighters

Poor reliability can negatively affect the warfighters through low operational availability; that is, the amount of time a system is available to execute its mission. For example, the MV-22 aircraft was less reliable than intended, and required many more spare parts than expected. When the Marine Corps deployed to Iraq, MV-22 maintainers had to cannibalize parts from some MV-22s to keep other MV-22s flying, and as a result, the Marine Corps had fewer aircraft available to fly missions.

Impacts of Poor Reliability on Operating and Support Costs

Reliability can significantly influence a weapon system's operating and support costs, which we have previously reported account for approximately 70 percent of a weapon system's total life-cycle cost.[13] Operating and support costs are a reflection of how programs achieve operational availability for weapon systems. Programs can achieve operational availability by building highly reliable weapon systems or, if the systems are not highly reliable, supporting them with an extensive logistics system that can ensure spare parts and other support items are available when needed. DOD has previously reported that deficiencies in DOD weapon systems—such as high failure rates and an inability to make significant improvements in reliability—have historically limited program performance and increased operating and support costs.[14]

Impacts of Poor Reliability on Commercial Companies

In the commercial world, the manufacturer carries most of the risks that would result from developing a product with poor reliability. Such risks include increased warranty expenses that decrease profits. For example, reliability personnel from Ford, Cummins, and Thermo Fisher Scientific explained that more reliable products cost their companies less because they do not have to dedicate as many resources to fixing systems that fail, which would lead to warranty claims.

In addition to increased costs, poor reliability can also negatively influence a company's reputation. Ford representatives said that failures and product recalls are not just financial costs; recalls are highly publicized. A Thermo Fisher Scientific product manager explained that a customer's bad experience can be shared in the media and negatively

[13]GAO, *Weapon System Sustainment: Selected Air Force and Navy Aircraft Generally Have Not Met Availability Goals, and DOD and Navy Guidance Need to Be Clarified,* GAO-18-678 (Washington, D.C.: Sept. 10, 2018).

[14]DOD Report of the Defense Science Board Task Force on Developmental Test and Evaluation (May 2008).

influence a company's reputation. This may alter future buying behavior, especially in industries with relatively small customer bases in closely linked professional communities. This person shared a prior experience at a different company, where a design risk was identified during development. Instead of addressing the risk effectively, a standard cycle test was done to prove or disprove the risk. However, the test did not apply the stress necessary to cause the failure. The product was released to the market based on this successful but inadequate test. In the field, the components failed, and the company had to remove the product from the market. This damaged the company's reputation and sales. We have previously reported that poor reliability is a concern for commercial companies because their customers demand products that work, or are reliable and do not experience failure, and the companies must develop and produce high-quality products to sustain their competitive position in the marketplace.[15]

Commercial Companies Proactively Address Reliability

In the commercial sector, reliability engineers told us their companies proactively address reliability from the beginning of the development process. We reviewed documentation from these companies and the 2019 Reliability and Maintainability Symposium and found engineers strive to identify reliability issues at the component and sub-system level early in the development process to avoid expensive rework after producing an entire system. We identified the following key practices in the commercial sector:

- leveraging reliability engineers early and often,
- establishing realistic reliability requirements—for example, not expecting a product to operate twice as long as its predecessor before failing,
- emphasizing reliability with their suppliers, and
- employing reliability engineering activities to improve a system's design throughout development.

Figure 4 shows some of the activities involved with these key practices.

[15]GAO, *Best Practices: Increased Focus on Requirements and Oversight Needed to Improve DOD's Acquisition Environment and Weapon System Quality,* GAO-08-294 (Washington, D.C.: Feb. 1, 2008).

Figure 4: Reliability Engineering Activities Associated with Key Reliability Practices

Leverage reliability engineers early and often	Establish realistic reliability requirements	Emphasize reliability with suppliers	Employ reliability engineering activities
▶ Include experienced reliability engineers on the development team ▶ Initiate reliability assessments early	▶ Ensure requirements are feasible and based on proven technologies ▶ Ensure requirements reflect customer usage and the operating environment	▶ Engage with suppliers early ▶ Clearly specify reliability requirements in contracts ▶ Evaluate and monitor the supplier to ensure deliverables are reliable	▶ Proactively identify failures and mitigate design risk throughout design and development ▶ Review and assess reliability data to inform development efforts

Source: GAO analysis of documents from reliability engineers in the commercial sector. | GAO-20-151

Leverage Reliability Engineers Early and Often

We found commercial companies in our review include reliability engineers as part of their development teams. In this role, reliability engineers implement reliability tools and methods that integrate statistics, physics, and engineering principles to help develop a reliable product. For example, HBM Prenscia identified that reliability engineers from several commercial companies said it was important to initiate their assessments early in the development life cycle when there is greatest opportunity to influence product design.

According to leading reliability engineers, engineering activities can add value to decision-making by providing direction and feedback that helps development teams refine designs that lead to more reliable and cost effective systems.[16] Researchers have reported reliability engineers should be empowered to influence decisions, such as delaying overall project schedule or negotiating for more resources when necessary.[17] In addition, our analysis of reliability engineers' documentation from the Reliability and Maintainability Symposium and commercial companies found it important that management provide sufficient resources and time dedicated specifically to improving reliability by discovering failures,

[16]Fred Schenkelberg and Carl S. Carlson, "Introduction to R & M Management"(paper presented at the 2019 Annual Reliability and Maintainability Symposium, Orlando, FL, January 2019).

[17]Carl Carlson; David J. Groebel; Adamantios Mettas; and Georgios Sarakakis, "Best Practices for Effective Reliability Program Plans" (paper presented at the 2010 Annual Reliability and Maintainability Symposium, San Jose, CA, January 2010).

implementing corrective actions, and verifying their effectiveness. Our analysis found that cost and schedule constraints can negatively influence reliability testing, which can limit development teams' ability to discover failures and improve designs through corrective actions.

Our analysis of documentation from the Symposium also highlighted the importance of having experienced reliability engineers. For example, Ford representatives told us they have a dedicated reliability engineering community that coaches the members of the company's different product development teams. Ford's reliability engineers said they focus on teaching development team members to ask the right questions at the right point in time with the right people in the room.

Establish Realistic Reliability Requirements Based on Proven Technologies

We found companies in our review emphasize that reliability requirements should be realistic, be based on proven technologies, and reflect customer usage and the operating environment. To determine feasibility of meeting a requirement, reliability engineers we spoke with at Cummins and Thermo Fisher Scientific recommend conducting comparative analysis with historical data and assessing risk due to new, unique, or difficult technology. In addition, an independent reliability engineer with over 40 years of experience told us programs should provide justifications for how reliability requirements were established to demonstrate they are within the realm of technological possibility.

If the reliability requirement turns out not to be technically feasible, it could have broad implications for the intended mission, life-cycle costs, and other aspects of the system. We have previously reported on the importance of making informed trade-offs when considering requirements to reduce program risk or total ownership costs.[18] HBM Prenscia representatives told us the commercial companies they work with regularly make trade-offs involving capability, reliability, and cost requirements. Reliability representatives at Ford told us it is important to have the right people involved in these trade-off decisions, and that they work with user representatives and reliability engineers to define their systems' reliability requirements.

[18]GAO, *Weapon System Requirements: Detailed Systems Engineering Prior to Product Development Positions Programs for Success,* GAO-17-77 (Washington, D.C.: Nov. 17, 2016) and *Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs,* GAO-03-57 (Washington, D.C.: Feb. 11, 2003).

Emphasize Reliability with Suppliers

Systems produced by commercial companies in our review include parts or components produced by suppliers, and reliability engineers repeatedly told us the reliability of those parts or components directly impacts the reliability of the overall system. According to a leading reliability engineer, vendor quality can affect a part's reliability, so it is critical that the reliability of vendors' parts be evaluated before being approved for use.[19] To emphasize reliability with suppliers, commercial companies in our review engage with suppliers early, clearly specify requirements with the supplier, and evaluate and monitor the supplier.

Cummins representatives stated engaging the supplier early is critical. They explained that they engage the supplier early, during concept development, and ask the supplier to demonstrate it can meet requirements. According to Cummins representatives, this is to ensure the supplier is able to meet quality standards and to ensure there is enough lead time and testing of components. Reliability engineers at the Reliability and Maintainability Symposium also emphasized that reliability requirements must be clearly specified with suppliers, and product teams must actively monitor suppliers and assess their deliverables. Cummins representatives explained their engineers work directly with the supplier and hold it responsible for meeting reliability requirements. Ford representatives told us they evaluate and monitor the supplier to ensure the components it is providing are reliable. For example, they visit their suppliers' testing facilities and evaluate their testing programs, focusing specifically on their failure analysis and reliability activities. We have previously reported that leading commercial companies use disciplined quality management practices to hold suppliers accountable for high quality parts through such activities as regular supplier audits and performance evaluations.[20]

A Thermo Fisher Scientific product manager provided a scenario where relying on an external supplier's quality assurances would be insufficient. For example, a compressor is a critical – and commonly outsourced— component in complex industrial equipment. The product manager recommended in-house testing for critical components like a compressor rather than relying on a supplier's testing that may not factor in real-world operating conditions. In house testing is recommended to avoid finding a

[19] Larry Crow. "Achieving High Reliability," *The Journal of the Reliability Analysis Center*, Fourth Quarter 2000.

[20] GAO-08-294.

failure after the product is brought to market. Post-sale failures result in dissatisfied customers, reputation damage, warranty claims and similar issues. The Thermo Fisher Scientific product manager said, in some cases, a company should establish a dedicated test facility for vital outsourced components provided by suppliers.

Employ Reliability Engineering Activities to Improve a System's Design throughout Development

Based on our review of commercial sector practices, we found companies use reliability engineering activities to identify potential product failures and their causes. They also use these activities to improve a system's design early and often throughout development to avoid surprises that lead to expensive rework or excessive repairs after integrating components and subsystems. For example, HBM Prenscia representatives told us that failures should be identified early, and that identification should be viewed as an opportunity to improve the design and make the product better. According to leading reliability engineers, the earlier changes are made to designs, the less costly they are to the program. It is expensive, time consuming, and risky to make changes late in development, as late changes jeopardize product reliability.[21] The commercial company representatives we spoke with also emphasized the need to conduct reliability engineering activities iteratively until the design is optimized. For example, HBM Prenscia has identified that a common mistake is establishing a reliability plan but not actively utilizing it throughout development.

Reliability engineers use various reliability engineering activities to increase system reliability, and generally refer to these activities as design for reliability tools. These tools can be tailored to meet the specific needs of a particular development project, and can complement one another and increase reliability prior to any testing. These tools can help identify how long a part or component will work properly, how a part or component's failure will affect a system, and what actions are needed to correct failures. See table 2 for some examples of design for reliability tools that can be used to help meet reliability goals.

[21]Carlson, Groebel, Mettas, and Sarakakis, "Best Practices for Effective Reliability Program Plans."

Table 2: Selected Design for Reliability Tools

Design for reliability tool	Description
Accelerated life testing	Increases stress—such as temperature, vibration, humidity, and voltage—on a component or subsystem to trigger failures more quickly to identify design flaws and enable predictions of reliability under normal use conditions
Design of experiments	Uses principles of statistics to plan, conduct, and analyze reliability tests in order to get the most information out of each test event; this information can be used to optimize reliability and identify a robust design well suited for a range of use environments
Failure modes and effects analysis	Identifies potential failures and their impact on system reliability; used to prioritize failures and take actions based on how serious the consequences are, how frequently they occur, and how easily they can be detected
Failure reporting, analysis, and corrective action system	Identifies and captures information about failures, which can be used to prioritize corrective and preventative actions, avoid recurrence of failures in future designs, and provide a centralized location for failure data that can be used for reliability analysis
Fault tree analysis	Uses a hierarchical diagram to model the pathways within a system that can lead to a foreseeable failure, and is used to identify and then analyze the causes or combinations of causes that can lead to the defined top event
Physics of failure	Involves modeling and simulation of the root causes of failure, such as fatigue, fracture, wear, and corrosion; used to design reliability into a product, perform reliability assessments, and focus reliability tests where they will be most effective
Reliability block diagrams	Illustrates relationships between components and subsystems graphically, using blocks to represent individual items; can be used to identify critical components and how the failure of a component or subsystem can impact reliability of the overall system
Reliability growth curves	Depicts management strategy to increase reliability, and are useful in determining appropriate test time and number of test units for a given reliability target; can be used to illustrate and report reliability growth

Source: GAO analysis of documentation from commercial sector reliability engineers. | GAO-20-151

We have previously reported that leading commercial companies use a knowledge-based development process that enables decision makers to be reasonably certain that product quality, reliability, and timeliness are assured.[22] Our analysis of documentation from reliability engineers found that reliability engineering activities should be integrated into the product development process, and their outputs should be reviewed at development milestones. These reviews can help ensure that reliability is a robust process rather than a paper exercise by providing an opportunity to assess data from reliability analysis or testing. For example, Cummins incorporates reliability reviews into its product development processes to ensure products meet reliability goals prior to moving to the next phase of development. This helps ensure the company is on track to fulfill its

[22] GAO-03-57.

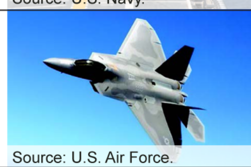
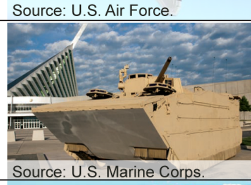
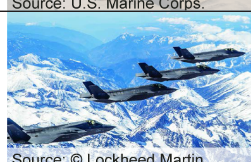
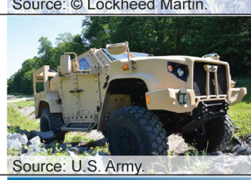
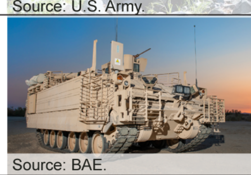
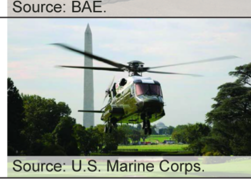
reliability commitments and will be able to deliver the promised product reliability to customers.

The leading commercial practices we reviewed highlight the importance of consistently collecting, sharing, and analyzing data from reliability engineering activities to inform development efforts. Commercial companies we spoke with recognized the value of reliability data. For example, Cummins representatives stated they capture reliability data and share it across different product development teams to help inform estimates of reliability for new product development efforts. In addition, Cummins representatives noted that they are moving to an interactive database that personnel throughout the entire company can access. Similarly, HBM Prenscia representatives told us that failures and lessons learned from previous projects should be captured and shared within a company, and that doing so could help inform future product development efforts.

Selected Major Defense Acquisition Programs Did Not Consistently Reflect Key Reliability Practices

We reviewed seven major defense acquisition programs and found they often reactively addressed reliability after identifying issues later in development. As shown below, these programs did not consistently reflect key practices we identified in the commercial sector, and instead prioritized other activities intended to have positive acquisition cost and schedule impacts. However, DOD officials noted that there has recently been a greater emphasis on reliability, and the three programs that started development in 2012 and 2014 reflected more of the key practices than the older programs. See figure 5, which notes a distinction between commercial companies' suppliers and DOD contractors. For more detailed information on each program, see appendix I.

Figure 5: Key Characteristics of Selected Major Defense Acquisition Programs’ Approach to Reliability

Program name and development start (Lead component)		Did not leverage government reliability engineers in decision making early	Initially pursued unrealistic operational requirements for reliability	Did not effectively emphasize reliability with suppliers (contractors)[a]	Deferred reliability engineering activities until later in development
V-22 Osprey 1986 (Navy/ Marine Corps)	 Source: U.S. Navy.		●	●	●
F-22 Raptor 1991 (Air Force)	 Source: U.S. Air Force.	●	●		●
Expeditionary Fighting Vehicle 2000 (Navy/ Marine Corps)	 Source: U.S. Marine Corps.	●	●	●	●
F-35 Lightning II 2001 (Joint DOD)	 Source: © Lockheed Martin.		●	●	●
Joint Light Tactical Vehicle 2012 (Army)	 Source: U.S. Army.				
Armored Multi-Purpose Vehicle 2014 (Army)	 Source: BAE.			●	●
VH-92A Presidential Helicopter Replacement Program 2014 (Navy/Marine Corps)	 Source: U.S. Marine Corps.				

Source: GAO analysis of Department of Defense (DOD) documentation, interviews with DOD officials, and prior GAO reports. | GAO-20-151

[a]In general, when commercial companies develop and manufacture products they rely on parts and components from suppliers. DOD acquires its weapon systems from contractors, which also depend on a network of subcontractors and suppliers for components and technologies.

Two of the Seven Selected Programs Did Not Leverage Government Reliability Engineers in Decision Making Early

The Expeditionary Fighting Vehicle (EFV) and F-22 programs did not involve reliability engineers early during system development. Instead, these programs leveraged engineers after reliability problems arose, including after they integrated components and subsystems and during system-level testing. At the end of system development, the programs brought in additional engineers and established more concerted reliability growth efforts.

In one example, the EFV program did not have an overall systems engineer.[23] Marine Corps acquisition officials stated that reliability was not a priority during the original system development process, and we have previously reported the program was instead focused on achieving other performance parameters, including water speed, survivability, and lethality.[24] Prime contractor representatives identified some of their design engineers who lacked experience and did not comply with engineering standards as a root cause for problems discovered late in the development process. We also reported the lack of early systems engineering discipline and knowledge undermined the EFV program's ability to develop informed and reasonable reliability requirements, delayed the identification of potential failures until integration, and contributed to poor vehicle reliability. In addition to frequent hydraulic system failures, leaks, and pressure problems, the EFV also suffered main computer failures that froze steering while operating in water.

As we have previously reported, the EFV program was subsequently restructured.[25] The program office hired additional engineers and consulted with Army reliability engineers to institute a reliability growth program. This program was intended to mitigate previously identified vehicle design issues related to reliability and other risks before proceeding into a second development and demonstration phase. However, the EFV program never got to fully realize the benefits of its new reliability approach, as less than 3 years after restarting development it was canceled due to continuing technology problems, development delays, and affordability concerns.

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[23]The Expeditionary Fighting Vehicle: Over Budget, Behind Schedule, and Unreliable, House of Representatives Committee on Oversight and Government Reform Majority Staff Report (Apr. 29, 2008).

[24]GAO-08-294.

[25]GAO, *Expeditionary Fighting Vehicle (EFV) Program Faces Cost, Schedule and Performance Risks,* GAO-10-758R (Washington, D.C.: July 2, 2010).

For the F-22 program, officials stated that at points during development the program did not have a leadership position focused on reliability, and the official who oversaw reliability was also responsible for supply chain management. The officials noted that at the time these were not focus areas because the Air Force expected the contractor to conduct the needed reliability engineering. In 2004, we reported that, as early as low-rate initial production, however, the Air Force identified 68 parts that had a high rate of failure and needed to be removed or replaced, requiring additional contractor work.[26] We also reported the F-22 canopy also experienced failures during testing, allowing it to achieve only about 15 percent of its expected lifetime. In 2014, we reported that later reliability maturation projects intended to address reliability deficiencies had a positive effect on availability over time, but as of 2018 the F-22 still had not met its availability target.[27]

Four of the Seven Selected Programs Initially Pursued Unrealistic Operational Requirements for Reliability

As we have found in our prior reports as well as in this review, the EFV, F-22, F-35, and V-22 programs set unrealistic operational requirements for reliability. These requirements were, therefore, unachievable during development and before fielding the systems to warfighters. As we have previously reported, when programs overpromise a weapon's prospective performance and deliver systems that cannot achieve their requirements, such as reliability goals, the warfighter receives less capability than originally promised.[28]

In one example, as we reported in 2019, more than 11 years after the start of F-35 production, none of the three aircraft variants (Air Force, Marine Corps, and Navy) had met the minimum targets for two of the program's five reliability metrics.[29] These include mean flight hours between part removals for replacement and mean flight hours between critical failures. We found that only the Navy variant had achieved the minimum target for a third goal, mean flight hours between maintenance

[26]GAO, *Tactical Aircraft: Changing Conditions Drive Need for New F/A-22 Business Case,* GAO-04-391 (Washington, D.C.: Mar. 15, 2004). Low-rate initial production is conducted during the production and deployment phase.

[27]GAO-14-425.

[28]GAO, *Defense Acquisitions: A Knowledge-Based Funding Approach Could Improve Major Weapon System Program Outcomes,* GAO-08-619 (Washington, D.C.: July 2, 2008).

[29] GAO-19-341

events. As we reported, while the program has instituted an effort intended to improve reliability, the effort does not align improvement projects with the F-35's reliability requirements.[30] That is, the reliability improvement projects being funded may not improve the F-35's performance against its reliability metrics. Ultimately, the program does not expect to achieve the unmet reliability metrics by full aircraft maturity, and program officials have acknowledged that the requirements should be reevaluated.[31] As a result, the warfighter may not receive an aircraft that is as reliable as was expected.

In a review of the V-22 program, DOD found that the program integrated complex technologies and unprecedented capabilities into its weapon system without accounting for unknown reliability risks.[32] Specifically, these capabilities included a conceptually new design and multiple service and mission needs. However, officials stated that the program derived its reliability requirements from antecedent helicopters, systems that were not representative of the V-22 given its increased complexity. With a limited understanding of the V-22's mission profile, program officials stated that they also underestimated the amount of time the system would be used in helicopter mode and its operating time on the ground. Subsequently, when the Marine Corps variant of the V-22—the MV-22—was deployed in Iraq from 2007 to 2009, a number of components experienced high rates of failure, affecting systems such as the engines and engine housing. This situation, combined with an immature parts supply chain, reduced the system's availability significantly below minimum levels. At the time, as we reported in May 2009, the MV-22 had a stated minimum mission capability rate of 82 percent, but the three MV-22 squadrons in Iraq demonstrated an average of 62 percent.[33]

[30]GAO-19-341.

[31]The F-35 aircraft reach maturity when all variants have flown a combined 200,000 hours, with each variant flying at least 50,000 hours. The F-35A reached its planned maturity in July 2018 but is still not meeting four of its eight metrics. The F-35B and C variants have more time to meet their metrics before they reach their planned maturity in 2021 and 2024 respectively.

[32]Department of Defense, *Report of the Panel to Review the V-22 Program* (Apr. 30, 2001).

[33]An aircraft that is mission capable is one that is in material condition to perform at least one of its designated missions. GAO-09-482.

The development and integration of new technologies on the F-22—stealth, supersonics, and integrated avionics—were critical to achieving operational success, but also presented significant reliability risks. Officials told us that the F-22 was initially expected to cost less to acquire and operate than one of its predecessors, the F-15, and be more reliable as well. However, they also stated this was an unrealistic expectation. We have previously reported that the immaturity of technologies at the start of and throughout development weaken a system's ability to achieve reliability requirements.[34] Since 2005, when full rate production of the F-22 began, the program has made substantial additional investments in increasing the system's reliability through various improvement programs. But the program also changed its mean time between maintenance reliability requirement to an operational availability metric, a target that as of 2018 it had yet to meet and may need to reevaluate, according to program officials. If the F-22 cannot achieve its current reliability requirement, warfighters will have to execute their missions with a less capable aircraft than expected.

Four of the Seven Selected Programs Did Not Effectively Emphasize Reliability with Contractors

The AMPV, EFV, F-35, and V-22 programs did not effectively emphasize reliability with DOD contractors. Specifically, according to DOD, the AMPV, EFV, and V-22 did not effectively incentivize reliability with the contractor and one program, the F-35, did not include all of the program's reliability metrics in the contract.

Each F-35 aircraft variant is measured against five reliability metrics, two of which are in part of the contract. Contractors are not responsible for achieving reliability requirements if programs do not include them in contracts. As of August 2018, two of the F-35's three variants had not met minimum targets for any of the three metrics that are not in the contract. The last variant (Navy) has met the minimum target for only one of the three metrics. As we have previously reported, the warfighter may have to accept F-35 aircraft that are less reliable and more costly than originally expected.[35]

As we have reported, the F-35 program tried to encourage the aircraft's manufacturer to improve reliability through an incentive fee in sustainment

[34] GAO-03-57.

[35] GAO-19-341.

contracts.[36] These contracts, for sustainment services, included incentives for meeting aircraft availability. Reliability of parts is one of the factors that influences aircraft availability, because broken parts prevent aircraft from flying. Program officials told us they hoped the incentive fee in the sustainment contract would incentivize the contractor to invest in and implement additional reliability activities, which would help improve aircraft availability, but according to the program office, the incentive has not been effective. Program officials told us the contractor has not pursued the incentive fee in the sustainment contract through efforts to improve aircraft reliability because it would have to invest significant resources to design and incorporate changes into production aircraft in order to do so. F-35 aircraft, especially early production aircraft, continue to face challenges related to parts that are failing more often than planned and are in short supply. For example, we have previously reported that DOD found the special coating on the F-35 canopy that helps maintain the aircraft's stealth failed more frequently than expected and that the manufacturer could not produce enough canopies to meet demand, ultimately degrading system capability.[37]

According to program officials, to ensure that reliability growth was on track, the AMPV program offered an incentive fee of up to $16 million if the contractor could demonstrate at least 80 percent of the system's reliability before low rate production. But officials stated that the AMPV contractor did not achieve the goal. The AMPV was a derivative system of the Army's Bradley Fighting Vehicle with an accelerated development schedule, and officials stated that for this reason the contractor assumed the government would accept much of the Bradley's initial design and changes to the AMPV's performance resulting from legacy reliability issues. As a result of these expectations, officials stated that the contractor did not put enough resources, including a robust reliability team, toward the work that was eventually needed to improve reliability, and the contractor understaffed in this area.

[36]GAO, *F-35 Aircraft Sustainment: DOD Needs to Address Challenges Affecting Readiness and Cost Transparency*, GAO-18-75 (Washington, D.C.: Oct. 26, 2017).

[37]GAO, *F-35* Aircraft *Sustainment: DOD Needs to Address Substantial Supply Chain Challenges*, GAO-19-321 (Washington, D.C.: Apr. 25, 2019).

Five of the Seven Selected Programs Deferred Key Reliability Engineering Activities until Later in Development

The AMPV, EFV, F-22, F-35, and V-22 programs deferred key reliability engineering activities, intended to improve system designs, until later in development. As a result, they missed opportunities to identify, understand, and mitigate reliability issues early in the development process. After realizing reliability shortfalls late in development, some programs initiated expensive redesign efforts that continued well into production and deployment, while others accepted degraded performance.

Based on our prior reporting, we found the EFV program did not implement a proactive reliability approach, which would include identifying challenges early and designing reliability into the system in a cost-effective manner.[38] Instead, the program used a test-fix-test approach that relied on identifying failure modes after the system-integration phase. Early in the acquisition process, officials noted in program documentation that the program had conducted little reliability growth planning before starting development, and officials stated that the EFV program did not plan for or conduct dedicated reliability testing. Then, the program prematurely conducted its critical design review, a key review during the development phase which confirms the system's design is stable and is expected to meet system performance requirements, before the EFV prototype's system-integration work was complete. The program did not have the time necessary to demonstrate design maturity as scheduled and officials stated that they did not schedule long enough corrective action periods to allow for proper failure mitigation. As a result, during a 2006 operational assessment, the EFV demonstrated very low reliability and failed to complete amphibious, gunnery, and land mobility tests.

F-22 program officials stated that many of the aircraft's components and subsystems had to be tested as part of an integrated system. This limited the discovery of reliability issues early in the development phase. DOD reliability experts told us programs should not use integrated system testing to demonstrate individual component reliability, and should instead use it to focus on how components work together and identify more complex system failure modes. F-22 officials also stated the program office frequently continued with development and other testing before implementing corrective actions for critical reliability issues. As we have previously reported, the F-22 program started a program to improve its reliability in 2005, near the start of full rate production, to mitigate

[38] GAO-06-349

hundreds of known reliability issues deferred from earlier in development. Nonetheless, we reported in 2012—nearly 3 years after DOD announced the end of F-22 production—that reliability deficiencies had increased support costs, and continued to prevent the aircraft from meeting its reliability requirement.[39]

According to program officials, the Army selected a derivative of the Bradley Fighting Vehicle to meet the AMPV requirements, even though that vehicle's transmission had known reliability problems. According to AMPV program officials, the Army selected this vehicle because it had prioritized controlling costs and accelerating schedule. Program officials stated that the focus on cost and schedule caused the contractor to underestimate the necessary reliability work at the start of development and led to a backlog of test incident reports and deferred corrective actions. According to 2018 program documentation we reviewed, the AMPV's reliability growth did not track to targets during development and the vehicle did not achieve its pre-production reliability goal. Moreover, some of the AMPV's deferred work may need to be addressed during a future corrective action period that could continue through fiscal year 2021.

[39]GAO, *Tactical Aircraft: F-22A Modernization Program Faces Cost, Technical, and Sustainment Risks,* GAO-12-447 (Washington, D.C.: May 2, 2012).

DOD Acquisition Policy and Guidance Documents Identify, but Do Not Emphasize, Key Reliability Practices

Although there are differences between the DOD and commercial sector stemming from the statutory and regulatory structures that govern DOD's acquisition processes, DOD has had long-established policy and guidance at both the department and service level that recognize the four key reliability practices we found in the commercial sector. For example, the Defense Acquisition Guidebook encourages acquisition programs to involve reliability engineers early and often, and DOD Instruction 5000.02 identifies the need for establishing realistic reliability requirements.[40] Additionally, the 2005 DOD Guide for Achieving Reliability, Availability, and Maintainability addresses the importance of emphasizing reliability with contractors, and the service-level policies at all three military departments establish the importance of reliability engineering activities.[41]

However, most of these documents cover a wide range of acquisition issues or many aspects of reliability engineering, and they do not specifically emphasize the four key practices we identified in our review of the commercial sector. For example, the DOD Instruction 5000.02 is an overarching policy document covering the entire acquisition life cycle at a high level, from concept development to live fire test and evaluation, and only one section provides significant detail and direction on reliability. The service level instructions and Defense Acquisition Guidebook similarly cover the entire acquisition life cycle, and reliability is one of dozens of

[40]Defense Acquisition University, Defense Acquisition Guidebook (Feb. 26, 2017). DODI 5000.02. DOD Instruction 5000.02 identifies the need for establishing realistic reliability and maintainability requirements using the Reliability, Availability, Maintainability, and Cost Rationale (RAM-C) analysis early, starting prior to Milestone A in the materiel solution analysis phase. According to the DOD RAM-C Report Manual, the RAM-C analysis requires early involvement from the program reliability and maintainability engineer, product support specialist, and cost analyst. DOD Instruction 5000.02 also addresses contracting for appropriate reliability and maintainability engineering activities as an integral part of the systems engineering process, developing a reliability growth strategy, and tracking reliability during systems engineering design reviews.

[41]Service-level instructions and regulation provide additional requirements of varying detail for implementing DOD policy. The Army reliability policy is contained within Army Regulation 702-19 "Reliability, Availability, and Maintainability." Reliability policy for the Air Force is found in two locations, the Secretary of the Air Force, Air Force Pamphlet 63-128, "Integrated Life Cycle Management" and Secretary of the Air Force, Air Force Instruction 63-101/20-101, "Integrated Life Cycle Management." The Navy documentation includes the Secretary of the Navy Instruction 5000.2F, Assistant Secretary of the Navy (Research, Development and Acquisition), "Defense Acquisition System and Joint Capabilities Integration and Development System Implementation." These service specific policies outline the implementation of DOD Instruction 5000.02 at the military service level Department of Defense, DOD Guide For Achieving Reliability, Availability, and Maintainability (Aug. 3, 2005).

characteristics addressed in each document. The DOD Guide for Achieving Reliability, Availability, and Maintainability is largely focused on achieving reliability, but the reliability proponents at OSD, the Army, and the Navy said the guide is not consistently used throughout DOD, noting that it was issued in 2005 and has not been updated since.

DOD policy provides decision makers flexibility to tailor regulatory activities that acquisition programs perform when developing weapon systems.[42] The process is inherently complex, and these decision makers must balance many factors when overseeing and executing the programs. In the absence of an emphasis on the key reliability practices we identified, we found decision makers for the programs we reviewed prioritized other activities intended to have positive acquisition schedule and cost impacts. For example, AMPV program officials told us the program eliminated 7,500 miles of contractor reliability testing in order to proceed to the next development phase more quickly, believing that there would be sufficient time later to complete corrective actions.

Recently, DOD has begun employing the Middle Tier Acquisition pathway—an alternative acquisition pathway with an objective of beginning production within 6 months and completing fielding within 5 years. This emphasis may encourage decision makers to prioritize activities that promise to reduce schedule. We found that for the programs we reviewed, however, such an approach can come at the expense of other activities, such as implementing effective reliability practices.

DOD has recently taken steps that could introduce more balance when decision makers consider trade-offs between schedule and reliability. Specifically, DOD has highlighted the importance of one of the four key reliability practices we identified: emphasizing reliability with contractors, and Congress has passed legislation related to reliability. The NDAA for fiscal year 2018 included a provision mandating DOD program managers to include certain reliability requirements in weapon system engineering and manufacturing development and production contracts.[43] In January 2019, the USD(A&S) implemented the NDAA by issuing a policy memorandum to Service Acquisition Executives and other DOD Directors echoing this key practice. However, USD(A&S) has not similarly

[42]DODI 5000.02.

[43]Pub. L. No. 115-91, § 834.

emphasized the three other key reliability practices we identified in the commercial sector, nor have the Secretaries of the Air Force, Army, and Navy, who now have ultimate responsibility for most of DOD's major acquisition programs. Specifically, these senior leaders have not emphasized the value of

- leveraging reliability engineers early and often,
- establishing realistic reliability requirements, and
- employing reliability engineering activities to improve a system's design throughout development.

As a result, it is less likely that acquisition programs will take the actions necessary to recognize and address potential reliability problems early in the development process. Without senior leadership emphasis on a broader range of key reliability practices, DOD runs the risk of delivering less reliable systems than promised to the warfighter and spending more than anticipated on rework and maintenance of major weapon systems. This risk is exacerbated in an environment where decision makers are striving to deliver systems in an accelerated manner.

Conclusions

The best opportunity to influence the reliability of a weapon system is early on during the design of the system. Decisions and tradeoffs made at that time can increase the weapon system's reliability, help warfighters execute their missions, and decrease operating costs for years to come. However, these decisions and tradeoffs are not easy, as acquisition decision makers are tasked with managing competing priorities such as cost, schedule, and performance. Many of the DOD acquisition program examples in this report illustrate what can happen when reliability is not prioritized. The programs often approached reliability in a reactive manner, discovered problems late in the development process, and then tried to fix them through costly and time-consuming rework. The programs did not consistently adhere to key practices we identified in the commercial sector:

- reliability engineers were not leveraged early in the development process,
- reliability requirements were not realistic,
- reliability was not emphasized with contractors, and
- reliability engineering activities were not utilized throughout design and development.

Recent DOD actions have highlighted the importance of emphasizing reliability with contractors. DOD senior leaders can help improve reliability by highlighting the importance of the three other key reliability practices we identified in the commercial sector. In light of the current focus on accelerating the acquisition process, balancing the desire for speed with reliability considerations is critical. Given the delegation of acquisition decision authority to the military services, the Secretaries of the Air Force, Army, and Navy are in the best position to do so.

Recommendations for Executive Action

We are making a total of three recommendations: one each to the Air Force, the Army, and the Navy.

We recommend the Secretary of the Air Force issue policy emphasizing the following three key reliability practices when planning and executing acquisition programs:

- leveraging reliability engineers early and often,
- establishing realistic reliability requirements, and
- employing reliability engineering activities to improve a system's design throughout development. (Recommendation 1)

We recommend the Secretary of the Army issue policy emphasizing the following three key reliability practices when planning and executing acquisition programs:

- leveraging reliability engineers early and often,
- establishing realistic reliability requirements, and
- employing reliability engineering activities to improve a system's design throughout development. (Recommendation 2)

We recommend the Secretary of the Navy issue policy emphasizing the following three key reliability practices when planning and executing acquisition programs:

- leveraging reliability engineers early and often,
- establishing realistic reliability requirements, and
- employing reliability engineering activities to improve a system's design throughout development. (Recommendation 3)

Agency Comments and Our Evaluation

We provided a draft of this report to DOD for review and comment. DOD's written comments are reprinted in appendix II. DOD stated that the Air Force, Army, and Navy concur with our recommendations to their respective Departments. The comments also state that the Air Force and Navy plan to update their policies in response to our recommendations. As for the Army, the comments state that the Army Acquisition Executive will issue direction emphasizing the three key reliability practices and highlight an existing Army regulation focused on reliability engineering.

In addition to the responses to our recommendations, DOD's written comments included technical comments that we addressed as appropriate. For example, we provided additional detail on an existing DOD policy, and clarified how a program engaged with a contractor.

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 http://www.gao.gov.

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

Michele Mackin
Managing Director, Contracting and National Security Acquisitions

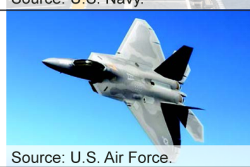
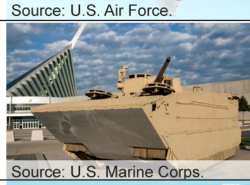
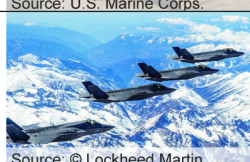
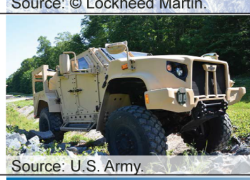
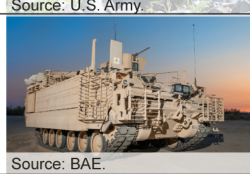
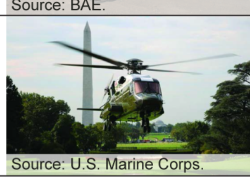
Appendix I: Key Characteristics of Selected Major Defense Acquisition Programs' Approach to Reliability

This appendix summarizes key characteristics of seven selected major defense acquisition programs' approach to reliability. The four key characteristics are categorized as:

- did not leverage government reliability engineers in decision making early;
- initially pursued unrealistic operational requirements for reliability;
- did not effectively emphasize reliability with contractors; and,
- deferred key reliability engineering activities until later in development.

These summaries do not address all the reliability actions taken by each program; rather they focus on key characteristics we identified in our review of commercial companies and associated deficiencies. See figure 6, which notes a distinction between commercial companies' suppliers and DOD contractors.

Figure 6: Key Characteristics of Selected Major Defense Acquisition Programs' Approach to Reliability

Program name and development start (Lead component)		Did not leverage government reliability engineers in decision making early	Initially pursued unrealistic operational requirements for reliability	Did not effectively emphasize reliability with suppliers (contractors)[a]	Deferred reliability engineering activities until later in development
V-22 Osprey 1986 (Navy/ Marine Corps)	 Source: U.S. Navy.		●	●	●
F-22 Raptor 1991 (Air Force)	 Source: U.S. Air Force.	●	●		●
Expeditionary Fighting Vehicle 2000 (Navy/ Marine Corps)	 Source: U.S. Marine Corps.	●	●	●	●
F-35 Lightning II 2001 (Joint DOD)	 Source: © Lockheed Martin.		●	●	●
Joint Light Tactical Vehicle 2012 (Army)	 Source: U.S. Army.				
Armored Multi-Purpose Vehicle 2014 (Army)	 Source: BAE.			●	●
VH-92A Presidential Helicopter Replacement Program 2014 (Navy/Marine Corps)	 Source: U.S. Marine Corps.				

Source: GAO analysis of Department of Defense (DOD) documentation, interviews with DOD officials, and prior GAO reports. | GAO-20-151

[a]In general, when commercial companies develop and manufacture products they rely on parts and components from suppliers. DOD acquires its weapon systems from contractors, which also depend on a network of subcontractors and suppliers for components and technologies.

Table 3: V-22 Osprey (V-22)

Lead Service: Navy/Marine Corps

Development Start: 1986

Current Program Status: Sustainment

Next Major Milestone: Not applicable

System Reliability: Throughout developmental testing that began in the 1980s, the V-22 demonstrated 0.4 hours of a required 1.4 hours or more mean time between failure. During operational evaluation conducted in 2000, the system demonstrated just 0.5 to 0.7 hours mean time between failure. A number of components and sub-systems in the Marine Corps variant—the MV-22—experienced high rates of failure, including new engine housing, engine air particle separator, and gearboxes and generators.

Key characteristics of program's approach to reliability	
Initially pursued unrealistic operational requirements for reliability	The V-22 introduced a number of new capabilities simultaneously and involved a conceptually new design. Officials stated the program derived its reliability requirements from unrepresentative antecedent helicopters, including a helicopter system that was not considered reliable. Officials also stated that the program underestimated the system's usage in helicopter mode and operating time on the ground. Operational testing of the V-22, which concluded in July 2000, demonstrated marginal reliability, excessive maintenance manpower and logistics support requirements, and inadequate availability, among other things. The V-22 failed to meet several important Joint Operational Requirement Document-established thresholds. For example, it did not achieve the established thresholds for mean flight hours between aborts or mean time between failure. Moreover, officials stated that the performance of the air vehicle was the primary focus of the program. The V-22 systems engineering program explicitly prioritized design requirements for performance characteristics related to payload, range, speed, and size over reliability and affordability. The program ranked reliability and maintainability characteristics at roughly half the weight of other major performance measures.
Did not effectively emphasize reliability with suppliers (contractors)	Following the V-22's return to flight after a December 2000 crash, the program implemented a new requirement for mean flight hours between critical failures applicable only to the Air Force version, the CV-22. However, according to written responses from program officials, the new requirement was not funded and was not included in the contractor's specification because it was implemented after much of the aircraft had already been designed, and officials stated that achieving the metric would have required significant design reliability improvements to multiple aircraft systems. A V-22 review panel report also recommended that the program assess contractor processes for predicting component reliability for the engine hydraulics and remain actively involved in contractor quality assessments and improvements.[a] Variances in aircraft construction contributed to aircraft quality problems, which can seriously affect reliability and maintainability and became a key area of focus for contractor process improvements and reassessment later in development.
Deferred key reliability engineering activities until later in development	GAO previously reported that the V-22 program lacked knowledge throughout development due to inadequate test and evaluation. Developmental testing was deleted, deferred, or simulated, and actual testing conducted was less than a third of what was originally planned.[b] Officials stated that the program identified reliability issues at integration, having set reliability requirements mainly at the aircraft level. The program found that components and sub-systems were failing early and prematurely. The program also delayed corrective action until late in development and into production in order to get the aircraft to the fleet as quickly as possible.

Source: GAO analysis of Department of Defense (DOD) documentation, interviews with DOD officials, and prior GAO reports. | GAO-20-151

[a]Department of Defense, Report of the Panel to Review the V-22 Program (Apr. 30, 2001).

[b]GAO, *Defense Acquisitions: Readiness of the Marine Corps' V-22 Aircraft for Full-Rate Production*, GAO-01-369R (Washington, D.C.: Feb. 20, 2001).

Table 4: F-22 Raptor (F-22)

Lead Service: Air Force

Development Start: 1991

Current Program Status: Sustainment

Next Major Milestone: Not applicable

System Reliability: As of October 2003, more than 2 years after the program's decision to begin low rate production, the F-22 had yet to achieve 83 percent of its reliability requirement. The Air Force could demonstrate only 0.5 flying hours between maintenance actions of the 1.95-hours mean time required at the end of system development. Before the start of operational testing, some components, such as the canopy, were not lasting as long as expected, and the avionics were still unstable. In 2014, the Air Force indicated that it did not expect the F-22 to achieve its reliability requirement. According to the Air Force, from fiscal year 2012 through 2016, the F-22 fleet availability rate was below the Air Force's annual F-22 availability standard by 4 to 19 percent. The aircraft availability standard is based on Air Force evaluation of requirements, including operational and training requirements, and is not resource constrained, according to Air Force officials. The Air Force's aircraft availability standard for the F-22 was 66.7 percent for fiscal year 2012, rose to 72.6 percent in fiscal year 2015, and was 72 percent in fiscal years 2016 and 2017.[a]

Key characteristics of program's approach to reliability	
Did not leverage government reliability engineers in decision making early	According to program officials, the F-22 did not have a single program leader responsible for reliability and maintainability because it was not a focus area, and some aircraft integrity programs responsible for developing performance metrics did not work together early in development.
Initially pursued unrealistic operational requirements for reliability	Program officials stated that the F-22 was expected to cost less but be twice as reliable and perform twice as well as the F-15, requirements that were unrealistic given the addition of new technologies, such as stealth, supersonics, and integrated avionics. According to program officials, the F-22's only reliability key performance parameter—mean time between maintenance—was not well defined, did not provide adequate information about the aircraft, and was open to different interpretations. After the F-22 could not achieve this metric, the Air Force changed the requirement to overall aircraft availability, a requirement that the aircraft has not met.
Deferred key reliability engineering activities until later in development	Program officials stated that F-22 testing focused primarily on the integrated system rather than components and subsystems. In 2003, the Air Force identified 68 parts that had a high rate of failure and which needed to be removed or replaced. GAO previously reported that the program was slow to fix and correct problems that affected reliability. After the start of production, program officials had identified about 260 different types of failures and had identified fixes for less than 50 percent of the failures.[b] According to program documentation, the F-22's Reliability and Maintainability Maturation Program has had to address hundreds of known reliability issues that were previously identified and deferred during design and development.

Source: GAO analysis of Department of Defense (DOD) documentation, interviews with DOD officials, and prior GAO reports. | GAO-20-151

[a]GAO, *Force Structure: F-22 Organization and Utilization Changes Could Improve Aircraft Availability and Pilot Training*, GAO-18-190 (Washington, D.C.: July 19, 2018).

[b]GAO, *Best Practices: Better Acquisition Outcomes Are Possible If DOD Can Apply Lessons from F/A-22 Program*, GAO-03-645T (Washington, D.C.: Apr. 11, 2003).

Table 5: Expeditionary Fighting Vehicle (EFV)

Lead Service: Navy/Marine Corps

Development Start: 2000

Current Program Status: Canceled, 2011

Next Major Milestone: Not applicable

System Reliability: During the EFV's first operational assessment in 2006, the system demonstrated just 4.5 hours of the anticipated 17 hours-mean time between operational mission failure. Throughout its first phase of development and demonstration, the system exhibited reliability issues with its hydraulics, hydrodynamic appendages, and key electronic systems. The program was subsequently restructured and entered a second development and demonstration phase aimed at improving system reliability. However, the EFV program never got to fully realize the benefits of its new reliability approach, because less than 3 years after restarting development it was canceled due to continuing development delays and affordability concerns.

Key characteristics of program's approach to reliability	
Did not leverage government reliability engineers in decision making early	The program's Reliability, Availability, Maintainability, and Durability Rationale Report indicated that the program conducted little reliability growth effort during concept exploration and development. The program did not have an overall system engineer responsible for ensuring the different components of the vehicle worked together. GAO previously found that a lack of systems engineering discipline early in the program led to significant quality and reliability issues.[a]
Initially pursued unrealistic operational requirements for reliability	According to the Marine Corps, the EFV's reliability metrics were excessively high when compared to similar types of vehicles. The Director, Operational Test and Evaluation reported that reliability was a challenge given the system's harsh mission environment and the vehicle's complexity, which program officials determined was more analogous to a helicopter than legacy ground vehicles. During development, the EFV's reliability key performance parameter—mean time between operational mission failures—was significantly reduced to more accurately reflect the vehicle's mission profile. During operational testing, the EFV demonstrated only 4.5 hours between breakdowns and 645 unscheduled maintenance actions. As part of the program's subsequent restructuring, the program implemented a robust reliability growth program to implement design changes to improve reliability.
Did not effectively emphasize reliability with suppliers (contractors)	The EFV contractor continually received award fees during the system's first development and demonstration phase. At the same time there were reports citing poor reliability, among other cost, schedule, and performance issues. The government awarded the same contractor a second development contract following the program's restructuring that required a design for reliability approach to correct previously identified reliability issues.[b]
Deferred key reliability engineering activities until later in development	The EFV program implemented a test-fix-test reliability approach that relied on integrated testing to identify failures rather than early design activities to anticipate and mitigate potential challenges. GAO previously reported that the program's development schedule did not allow adequate time for testing, evaluating the results, fixing the problems, and retesting to make certain that problems were fixed before moving forward.[c] According to program officials, the first development phase of the program did not include dedicated reliability testing and had a test schedule with corrective action periods that were too short and too close together to properly correct failures.

Source: GAO analysis of Department of Defense (DOD) documentation, interviews with DOD officials, and prior GAO reports. | GAO-20-151

[a]GAO, *Best Practices: Increased Focus on Requirements and Oversight Needed to Improve DOD's Acquisition Environment and Weapon System Quality*, GAO-08-294 (Washington, D.C.: Feb. 1, 2008).

[b]The Expeditionary Fighting Vehicle: Over Budget, Behind Schedule, and Unreliable, House of Representatives Committee on Oversight and Government Reform Majority Staff Report (Apr. 29, 2008).

[c]GAO, *Defense Acquisitions: The Expeditionary Fighting Vehicle Encountered Difficulties in Design Demonstration and Faces Future Risks*, GAO-06-349 (Washington, D.C.: May 1, 2006).

Table 6: F-35 Lightning II (F-35)

Lead Service: Joint, Department of Defense

Development Start: 2001

Current Program Status: Operational testing

Next Major Milestone: Full-rate production, 2019

System Reliability: Throughout development, the program's three aircraft variants lagged behind their planned reliability growth. In 2017, aircraft were experiencing failures resulting in the loss of capability to perform a mission-essential function at more than twice the rate expected across all variants. In January 2018, the Director, Operational Test and Evaluation reported that the program was unlikely to achieve the majority of threshold reliability metrics from the operational requirements document at maturity. System reliability growth has stagnated and a reliability and maintainability improvement plan has not prioritized achieving reliability metrics.

Key characteristics of program's approach to reliability	
Initially pursued unrealistic operational requirements for reliability	Although not yet at maturity, 11 years after the start of production the aircraft variants had not met three of their five reliability metrics from the operational requirements document. While program officials have acknowledged the need to reevaluate the metrics and determine more achievable performance targets, GAO previously reported that the program has not yet taken actions to reevaluate the metrics or pursue projects that would help achieve the metrics.[a] The F-35 incorporated technologies and capabilities that were considered a quantum leap on legacy tactical aircraft systems. GAO previously found that using immature technologies to meet performance goals weakens the ability to design for system reliability.[b]
Did not effectively emphasize reliability with suppliers (contractors)	GAO previously reported that of the F-35's five reliability metrics in the operational requirements document, only two were contractually required. The program is responsible for achieving all five of the metrics regardless of whether they were included in the contract.[c] The F-35 program attempted to incentivize aircraft availability through incentive fees in its annual sustainment contracts. Officials stated they hoped this would encourage the contractor to make reliability and maintainability improvements, but according to program officials the contractor has not pursued the incentive due to the contract's short period of performance.
Deferred key reliability engineering activities until later in development	Officials stated that throughout development reliability demonstrations were eliminated and the reliability plan was re-scoped, impacting the program's ability to improve reliability through design actions. In addition, according to program officials, the F-35's initial reliability efforts relied on an unacceptable failure reporting, analysis and corrective action system that, according to the program's life cycle sustainment plan, is manpower intensive, no longer effectively supports program activities, and has not been funded for replacement. GAO previously reported that at the start of development, neither DOD nor the contractor had conducted detailed systems engineering to adequately retire reliability risks, among other risks, and truly understand the challenge posed by the aircraft's requirements.[d] Moreover, demonstrations of an early prototype needed to validate reliability and maintainability models took place after critical design review, limiting the program's understanding of design changes on system reliability. As of 2017, the Reliability and Maintainability Improvement Program was identifying, implementing, and completing more than 100 projects, but the program did not have a dedicated budget line.

Source: GAO analysis of Department of Defense (DOD) documentation, interviews with DOD officials, and prior GAO reports. | GAO-20-151

[a]GAO, *F-35 Joint Strike Fighter: Action Needed to Improve Reliability and Prepare for Modernization Efforts*, GAO-19-341 (Washington, D.C.: Apr. 29, 2019).

[b]GAO, *Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs*, GAO-03-57 (Washington, D.C.: Feb. 11, 2003).

[c]GAO-19-341.

[d]GAO, *Weapon System Requirements: Detailed Systems Engineering Prior to Product Development Positions Programs for Success*, GAO-17-77 (Washington, D.C.: Nov. 17, 2016).

Table 7: Joint Light Tactical Vehicle (JLTV)

Lead Service: Army

Development Start: 2012

Current Program Status: Full-rate production

Next Major Milestone: Initial capability, 2019

System Reliability: In 2018, the Director, Operational Test and Evaluation found all JLTV variants not operationally suitable because of deficiencies related to reliability, among other issues. Operational mission failures resulted from engine wiring problems, flat and damaged tires, and the brake system. Program officials attributed some of the failures to operator error and stated that, as of 2019, the program had addressed seven of 12 operational mission failures identified during testing.

Source: GAO analysis of Department of Defense (DOD) documentation, interviews with DOD officials, and prior GAO reports. | GAO-20-151

Table 8: Armored Multi-Purpose Vehicle (AMPV)

Lead Service: Army

Development Start: 2014

Current Program Status: Low-rate initial production

Next Major Milestone: Start operational testing, 2021

System Reliability: The AMPV has inherited known reliability issues from the Bradley Fighting Vehicle—with which it shares a number of sub-systems—particularly problems with the legacy powertrain. During development, the AMPV's reliability tracked below target levels, and in 2018 the AMPV had not achieved its production entrance criteria for mean miles between system aborts. Officials believe they have corrected failure modes unique to the AMPV design and that only legacy reliability issues remain.

Key characteristics of program's approach to reliability	
Did not effectively emphasize reliability with suppliers (contractors)	According to program officials, the program offered an incentive fee of up to $16 million if the contractor could demonstrate approximately 80 percent of the system's reliability requirement—mean miles between system abort—before production. According to program officials, the contractor did not pursue the incentive because the work would have modified shared systems and required approval from multiple other programs. The AMPV program and contractor had different expectations for the level of design effort needed early in the program, including for reliability. According to program documentation, the contractor's accepted proposal price was well below the independent cost estimate and request for proposal funding profile. After the start of development, the system needed more reliability design work than originally planned, and the contractor experienced manpower shortages. Program officials found that contractor reliability engineering activities were not sufficient and that reliability requirements were not flowed down to all subcontractors and vendors.
Deferred key reliability engineering activities until later in development	Program officials stated that under-resourced reliability work resulted in a backlog of test incident reports and deferred corrective actions. The contractor had to prioritize responding primarily to failures that would cause mission aborts. The program eliminated 7,500 miles of contractor reliability, availability, and maintainability developmental testing. While officials stated that the program eventually conducted this testing later in development, the delay prevented earlier discovery of some failure modes and the use of the prototypes as test beds for corrective actions. Officials also stated that the program's aggressive production and delivery schedule did not allow time to address reliability issues common to other systems. Additional corrective action testing may need to take place concurrent with low rate initial production.

Source: GAO analysis of Department of Defense (DOD) documentation, interviews with DOD officials, and prior GAO reports. | GAO-20-151

Table 9: VH-92A Presidential Helicopter Replacement Program (VH-92A)

Lead Service: Navy/Marine Corps

Development Start: 2014

Current Program Status: Low-rate initial production

Next Major Milestone: Start operational test, 2020

System Reliability: The VH-92A program, a program that replaces a failed VH-71 replacement helicopter program, pursued a modified commercial system with known reliability and no designated critical technologies. During a 2019 operational assessment of the integrated system, the Navy assessed the VH-92A's suitability risk as high due to mission critical subsystem failures caused by the government-designed mission communications system and environmental control systems, which manage air supply, temperature, and pressure. However, according to program officials, as of September 2019, the program is addressing and mitigating recently-identified reliability issues with the helicopter and mission systems. Officials stated that the fixes have been identified and are being implemented in support of initial operational test and evaluation.

Source: GAO analysis of DOD documentation, interviews with DOD officials, and prior GAO reports. | GAO-20-151

Appendix II: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3030 DEFENSE PENTAGON
WASHINGTON, DC 20301-3030

RESEARCH AND ENGINEERING

DEC 17 2019

Ms. Michele Mackin
Director, Contracting and National Security Acquisitions
U.S. Government Accountability Office
441 G Street, NW
Washington DC 20548

Dear Ms. Mackin,

This is the Department of Defense (DoD) response to the GAO Draft Report GAO-20-151, "DEFENSE ACQUISITIONS: Senior Leaders Should Emphasize Key Practices to Improve Weapon System Reliability," dated November 8, 2019 (GAO Code 102948).

Attached is DoD's proposed response to the subject report. My point of contact is Andrew N. Monje who can be reached at andrew.n.monje.civ@mail.mil and (703) 692-0841.

Sincerely,

Sandra H. Magnus
Deputy Director, Engineering

GAO DRAFT REPORT DATED NOVEMBER 8, 2019
GAO-20-151 (GAO CODE 102948)

"DEFENSE ACQUISITIONS: SENIOR LEADERS SHOULD EMPHASIZE KEY PRACTICES TO IMPROVE WEAPON SYSTEM RELIABILITY"

DEPARTMENT OF DEFENSE COMMENTS TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommends the Secretary of the Air Force issue policy emphasizing the following three key reliability practices when planning and executing acquisition programs:

- leveraging reliability engineers early and often,
- establishing realistic reliability requirements, and
- employing reliability engineering activities to improve a system's design throughout development.

DoD RESPONSE: The Department of the Air Force concurs with GAO Recommendation 1 (ref. GAO-20-151). SAF/AQRE Policy Team has reviewed the draft GAO report (GAO-20-151) and agrees with the assessment and recommendation that early engagement, realistic requirements, and employing reliability-engineering activities to improve a systems design is necessary to improve availability and performance throughout the systems' life cycle. SAF/AQ will update AF policy AFI 63-101_20-101 Integrated Life Cycle Management, R&M engineering section or other appropriate directive publication and include GAO's recommendation by December 2020.

RECOMMENDATION 2: The GAO recommends the Secretary of the Army issue policy emphasizing the following three key reliability practices when planning and executing acquisition programs:

- leveraging reliability engineers early and often,
- establishing realistic reliability requirements, and
- employing reliability engineering activities to improve a system's design throughout development.

DoD RESPONSE: Concur. The Assistant Secretary of the Army (Acquisition, Logistics, and Technology) (ASA(ALT)) will issue direction to the Program Executive Officers emphasizing the three key practices already covered in Army Regulation (AR) 702-19 Reliability, Availability, and Maintainability (RAM). AR 702-19, issued on 22 May 2018, emphasizes the three key reliability practices as follows-

a. GAO key practice: leveraging reliability engineers early and often. AR 702-19 addresses this key practice throughout. Reliability engineers are involved beginning with requirements generation and continue to be involved through development and fielding. AR 702-19 provides RAM policy throughout the life cycle, which is executed by RAM engineers at organizations within the Army.

b. GAO key practice: establishing realistic reliability requirements. AR 702-19 addresses this key practice throughout, but primarily in chapter 4 RAM Requirements Generation. RAM requirements are generated by the capability developer's RAM engineers and coordinated with the materiel developer and the Army Test and Evaluation Command (ATEC) to ensure requirements are achievable, feasible, cost effective, and testable/verifiable. In addition, the Army will issue a policy memorandum from the Assistant Secretary of the Army (Acquisition, Logistics, and Technology) (ASA (ALT)) to the Program Executive Officers (PEOs) to require use of a failure reporting, analysis, and corrective action system (FRACAS). Implementation of a FRACAS, especially in sustainment, will improve the ability of programs to measure reliability performance in the field and inform requirements of future weapon systems. The FRACAS policy memorandum will be issued not later than 30 September, 2020 and will be incorporated into AR 702-19 during the next scheduled update.

c. GAO key practice: employing reliability engineering activities to improve a system's design throughout development. AR 702-19 addresses this key practice throughout, but primarily in chapter 2 RAM Policy. Paragraph 2-3, RAM Engineering and Design, requires the materiel developer to tailor RAM engineering activities to each acquisition program to ensure reliable and maintainable systems are delivered, with a focus on achieving design maturity as early as possible.

RECOMMENDATION 3: The GAO recommends the Secretary of the Navy issue policy emphasizing the following three key reliability practices when planning and executing acquisition programs:

- leveraging reliability engineers early and often,
- establishing realistic reliability requirements, and
- employing reliability engineering activities to improve a system's design throughout development.

DoD RESPONSE: DON concurs with the recommendation and will engage in issuing policy.

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Michele Mackin, 202-512-4841 or mackinm@gao.gov

Staff Acknowledgments

In addition to the contact named above, Nathan Tranquilli (Assistant Director), Julie A. Clark (Analyst-in-Charge), Lori Fields, Laura Greifner, Brendan K. Orino, LeAnna Parkey, Christine Pecora, Andrew N. Powell, Timothy Saunders, and Michael J. Sullivan made key contributions to this report.

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U.S. Government Accountability Office, 441 G Street NW, Room 7814, Washington, DC 20548