United States Government Accountability Office

Report to Congressional Requesters

August 2020

NEXT GENERATION COMBAT VEHICLES

As Army Prioritizes Rapid Development, More Attention Needed to Provide Insight on Cost Estimates and Systems Engineering Risks

GAO-20-579

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GAO Highlights

Highlights of GAO-20-579, a report to congressional requesters

Why GAO Did This Study

The Army views the NGCV portfolio as one of its most critical and urgent modernization priorities, as many current Army ground combat vehicles were developed in the 1980s or earlier. Past efforts to replace some of these systems failed at a cost of roughly $23 billion. In November 2017, the Army began new efforts to modernize this portfolio.

GAO was asked to review the Army's plans for modernizing its fleet of ground combat vehicles. This report examines (1) the acquisition approaches and contracting strategies the Army is considering for the NGCV portfolio, (2) the extent to which the Army's efforts to balance schedule, cost, and technology are reducing acquisition risks for that portfolio, and (3) how the Army is communicating internally and externally to reduce acquisition risks.

GAO reviewed the acquisition and contracting plans for each of the vehicles in the portfolio to determine their approaches; assessed schedule, cost, and technology information—where available—against GAO's leading practice guides on these issues as well as other leading practices for acquisition; and interviewed Army and DOD officials.

What GAO Recommends

GAO is making three recommendations, including that the Army follow leading practices on cost estimation and systems engineering to mitigate program risk. In its response, the Army concurred with these recommendations and plans to take action to address them.

View GAO-20-579. For more information, contact Jon Ludwigson at (202) 512-4841 or ludwigsonj@gao.gov.

What GAO Found

The four efforts within the Next Generation Combat Vehicles (NGCV) portfolio all prioritize rapid development, while using different acquisition approaches and contracting strategies. Some of the efforts use the new middle-tier acquisition approach, which enables rapid development by exempting programs from many existing DOD acquisition processes and policies. Similarly, the efforts use contracting strategies that include both traditional contract types as well as more flexible approaches to enable rapid development of technology and designs.

Vehicles of the Next Generation Combat Vehicles Portfolio

Armored Multi-Purpose Vehicle | Mobile Protected Firepower | Optionally Manned Fighting Vehicle | Robotic Combat Vehicle-Light

Source: (left to right): BAE, U.S. Army, Combat Capabilities Development Command Ground Vehicle Systems Center. | GAO-20-579

The two programs within the portfolio that recently initiated acquisitions—Mobile Protected Firepower and Optionally Manned Fighting Vehicle—have taken some steps to mitigate risks in cost and technology consistent with GAO's leading practices. The Army's use of the middle-tier approach for these efforts may facilitate rapid development, but the programs could benefit from additional application of GAO's leading practices. For example, the programs identified some risks in their cost estimates, but because each presented a single estimate of the total cost—referred to as a point estimate—these estimates do not fully reflect how uncertainty could affect costs. Similarly, the programs took some steps to mitigate technical risk by limiting development to 6 years or less and incrementally introducing new technologies, steps consistent with GAO's leading practices. However, by delaying key systems engineering reviews, the programs took some steps not consistent with leading practices, which could increase technical risk. While trade-offs may be necessary to facilitate rapid development, more consistent application of GAO's leading practices for providing cost estimates that reflect uncertainty and conducting timely systems engineering reviews could improve Army's ability to provide insight to decision makers and deliver capability to the warfighter on time and at or near expected costs.

The Army has taken actions to enhance communication, both within the Army and with Department of Defense stakeholders, to mitigate risks. Within the Army, these actions included implementing a cross-functional team structure to collaboratively develop program requirements with input from acquisition, contracting, and technology development staff. Program officials also coordinated with other Army and Department of Defense stakeholders responsible for cost and test assessment, even where not required by policy, to mitigate risk.

Contents

Abbreviations

AMPV	Armored Multi-Purpose Vehicle
FAR	Federal Acquisition Regulation
MPF	Mobile Protected Firepower
NGCV	Next Generation Combat Vehicles
OMFV	Optionally Manned Fighting Vehicle
OSD	Office of the Secretary of Defense
RCV	Robotic Combat Vehicle
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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August 6, 2020

The Honorable Donald Norcross
Chairman
The Honorable Vicky Hartzler
Ranking Member
Subcommittee on Tactical Air and Land Forces
Committee on Armed Services
House of Representatives

The Honorable Michael Turner
House of Representatives

The Army views the Next Generation Combat Vehicles (NGCV) portfolio as one of its most critical modernization priorities, citing concerns that potential adversaries have achieved parity with its current ground combat vehicle fleet. The need for modernization is considered urgent, as many current Army ground combat vehicles—including the Bradley infantry fighting vehicle and the Abrams main battle tank—were developed in the 1980s or earlier. The Army noted this urgency as early as 2010, but past efforts to replace some of these systems failed due to immature technology and changing and complex requirements at a cost to taxpayers of roughly $23 billion. In November 2017, the Army began efforts to modernize its portfolio of ground combat vehicles and provide new capabilities through the NGCV effort.

You asked us to review the Army's plan for modernizing its fleet of ground combat vehicles and to assess the cost, schedule, and technologies for that fleet. This report examines (1) the acquisition approaches and contracting strategies the Army is considering for the NGCV portfolio, (2) the extent to which the Army's efforts to balance schedule, cost, and technology are reducing acquisition risks for the NGCV portfolio, and (3) how the Army is communicating internally and externally to reduce acquisition risks for the NGCV portfolio.

To describe the Army's approach for each class of vehicle in the portfolio, we reviewed Army documents to identify its acquisition approach, called a "pathway." These included the major capability acquisition pathway and the middle-tier acquisition pathway. We also identified the Army's contracting strategy, such as using contracts based on the Federal Acquisition Regulation (FAR) or agreements using other transaction

authorities, which allow for more flexible, nontraditional agreements.[1] To assess the extent to which the Army's decision-making is reducing schedule, cost, and technology risk, we used criteria from GAO's Schedule Assessment Guide, Cost Estimating and Assessment Guide, and Technology Readiness Assessment Guide, and our prior work on leading practices for acquisition to assess the Army's estimates and plans for the NGCV portfolio. To describe how the Army is communicating with internal and external stakeholders, we examined how the program offices and the NGCV cross-functional team share information within the Army and with the Office of the Secretary of Defense (OSD). For all objectives, we interviewed Army and OSD officials to gain a deeper understanding of collected documentation. See appendix I for more information on our objectives, scope, and methodology.

We conducted this performance audit from May 2019 to August 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

The primary classes of ground combat vehicle in the current fleet, some of which have been in service for decades, include the

- M113 armored personnel carrier,
- Bradley M2 infantry fighting vehicle, and
- Abrams M1 main battle tank.

Over the years, the Army has upgraded these vehicles with additional technologies, including new communications systems, heavier armor, and more powerful engines. The original systems were designed with a margin for additional space, weight, and power to accommodate such upgrades. However, the accumulation of past upgrades has consumed much of this margin and the fleet of Army ground combat vehicles faces increasing constraints on its ability to upgrade, due to lack of available vehicle space, weight, and power.

[1]FAR § 1.101. The Federal Acquisition Regulation is for the codification and publication of uniform policies and procedures for acquisition by all executive agencies.

In response to the limited ability to upgrade the vehicles in the current ground combat fleet and the need for additional capabilities, the Army has begun to take steps to develop the NGCV portfolio to replace and extend this fleet. The vehicles currently in the portfolio include the

- Armored Multi-Purpose Vehicle (AMPV), replacement for the M113;
- Mobile Protected Firepower (MPF), a light tank to support infantry;
- Optionally Manned Fighting Vehicle (OMFV), replacement for Bradley with additional capabilities; and
- Robotic Combat Vehicle (RCV), a new capability to supplement existing vehicles.

The Army made two previous efforts to modernize into a lighter, more agile, and more capable ground combat force. Neither effort produced vehicles that are in use today. In both cases, we reported on missteps that led to significant problems with the development and acquisition efforts and their eventual cancellations, as shown in table 1.[2]

Table 1: Previous Army Efforts to Modernize Combat Vehicles

Name of program	Duration of program	Cost as of cancellation (dollars in billions)	Description	Reasons canceled
Future Combat Systems	2000-2009	21.8	Family of light and mobile crewed and autonomous vehicles	Overly ambitious requirements, immaturity of key technologies, cost increases, and schedule delays
Ground Combat Vehicle	2010-2014	1.5	Replacement for the Bradley Infantry Fighting Vehicle	Infeasible requirements

Source: GAO review of DOD documentation | GAO-20-579

Note: All amounts in fiscal year 2020 dollars.

Army Modernization Efforts Since 2017

In the fall of 2017, the Army began the current modernization effort to rapidly develop and field new capabilities. The Army identified near-term priorities and realigned over $1 billion in science and technology funding for long-term modernization to support efforts with a 5-year budget of approximately $7.5 billion. The Army also established a new command,

[2]For additional information, see GAO, *Defense Acquisitions: Future Combat Systems Challenges and Prospects for Success,* GAO-05-442T (Washington, D.C.: Mar. 16, 2005); and *Defense Acquisitions: Key Questions Confront the Army's Ground Force Modernization Initiatives,* GAO-11-425T (Washington, D.C.: Mar. 9, 2011).

Army Futures Command, to be led by a four-star general to oversee modernization.[3]

As a part of this effort, in October 2017 the Army's then-Acting Secretary and the Chief of Staff identified six priorities to guide Army modernization:

- Long-Range Precision Fires, munitions that restore Army dominance in range, lethality, and target acquisition;
- Next Generation Combat Vehicles, piloted and autonomous combat vehicles with modern firepower, protection, mobility, and power generation;
- Future Vertical Lift, piloted and autonomous platforms capable of attack, lift, and reconnaissance missions on modern and future battlefields;
- Army Network, a mobile system of hardware, software, and infrastructure used to fight cohesively where the electromagnetic spectrum is denied or degraded;
- Air and Missile Defense, capabilities that ensure future combat formations are protected from modern and advanced air and missile threats; and
- Soldier Lethality, capabilities, equipment, and training for all fundamentals of combat.

In a January 2019 assessment of Army modernization efforts, we found that the creation of eight cross-functional teams to support these six priorities realized some initial successes, including promoting communication between the officials responsible for developing system

[3]The Secretary of the Army established the Army Futures Command through the issuance of a general order in June 2018. This organization is led by a four-star general like its organizational peers—Army Materiel Command, Training and Doctrine Command, and Forces Command—and to allow the ability to command lower ranking generals in sub-divisions of the new command such as the Combat Capabilities Development Command. The Army completed establishment of the Command in July 2019.

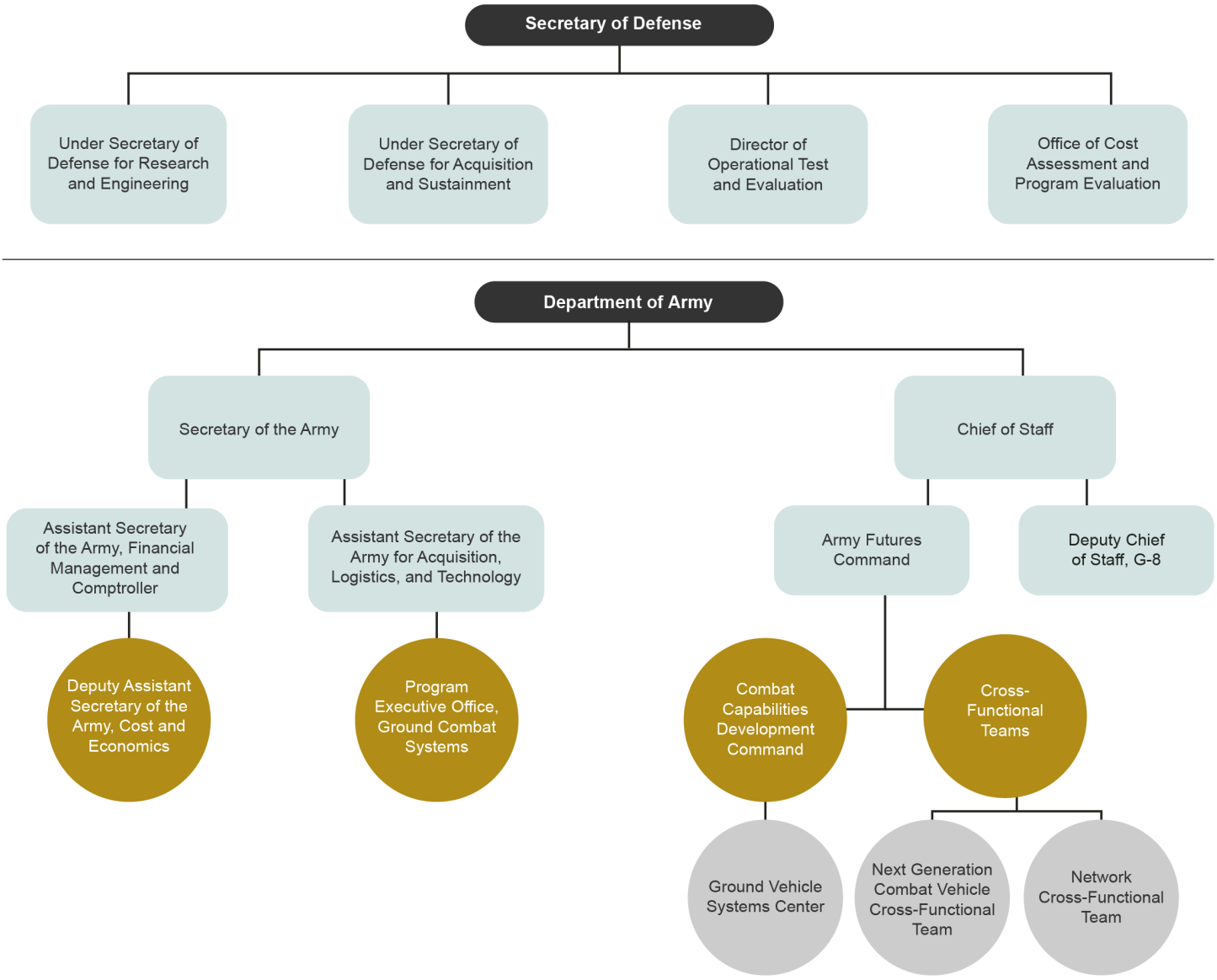
requirements and the end-users those systems will support.[4] We also found that it was not clear how Army Futures Command would coordinate its responsibilities with existing acquisition organizations within the Army that do not directly report to it, such as the civilian authority responsible for the overall supervision of acquisition matters for the Army.[5]

Figure 1 shows the Army and OSD offices relevant to this review.

[4]GAO, *Army Modernization: Steps Needed to Ensure Army Futures Command Fully Applies Leading Practices*, GAO-19-132 (Washington, D.C.: Jan. 23, 2019). The goal of the cross-functional teams is to ensure that each team has individuals who specialize in acquisition, requirements, science and technology, test and evaluation, resourcing, contracting, cost analysis, sustainment, and military operations. The goal of bringing these different experts together is to facilitate collaboration and immediate opportunities for stakeholders to provide input as opposed to the more traditional requirements development process, in which input was typically provided separately.

[5]In GAO-19-132 we made four recommendations, DOD concurred with all of them. We continue to monitor the Army's progress in addressing these recommendations.

Figure 1: Organizational Chart of Relevant Army and Department of Defense Offices for Next Generation Combat Vehicles



Source: GAO presentation of DOD information. | GAO-20-579

Recent Defense Acquisition Reforms

In the National Defense Authorization Acts for Fiscal Years 2016 and 2017, Congress included numerous reforms that could help to streamline

acquisition oversight and field capabilities faster.[6] One feature of this effort was to shift responsibilities for major defense acquisition program oversight to give significantly more authority to the military departments. For example, Section 825 of the National Defense Authorization Act for Fiscal Year 2016 generally shifted responsibility for decision-making—known as milestone decision authority—for most major defense acquisition programs from OSD to the military departments.[7] As a result, OSD oversight is potentially limited.

In addition, Section 804 of the National Defense Authorization Act for Fiscal Year 2016 required DOD to issue guidance establishing two new acquisition pathways for DOD—rapid prototyping and rapid fielding—to create an expedited and streamlined "middle tier" of acquisition programs intended to be completed within 5 years. Rapid prototyping provides for development of new technologies that demonstrate new capabilities and rapid fielding provides for the use of existing technologies to rapidly deliver capability to the warfighter. For example, the objective of the rapid prototyping pathway is to field a prototype meeting defined requirements that can be demonstrated in an operational environment within 5 years of the start date. Middle-tier acquisition pathways are distinct from the traditional acquisition system, in that they are generally not subject to the acquisition and requirements processes that guide traditional acquisition programs.[8] The pathways are also distinct from rapid acquisition authorities that generally are completed within 2 years. To support these new pathways, the Under Secretary of Defense for Acquisition and Sustainment issued interim guidance in April 2018 on middle-tier acquisitions and issued a final instruction in December 2019.[9] In January 2020, the same office issued restructured defense acquisition guidance to

[6]Pub. L. No. 114-92 (2015) and Pub. L. No. 114-328 (2016).

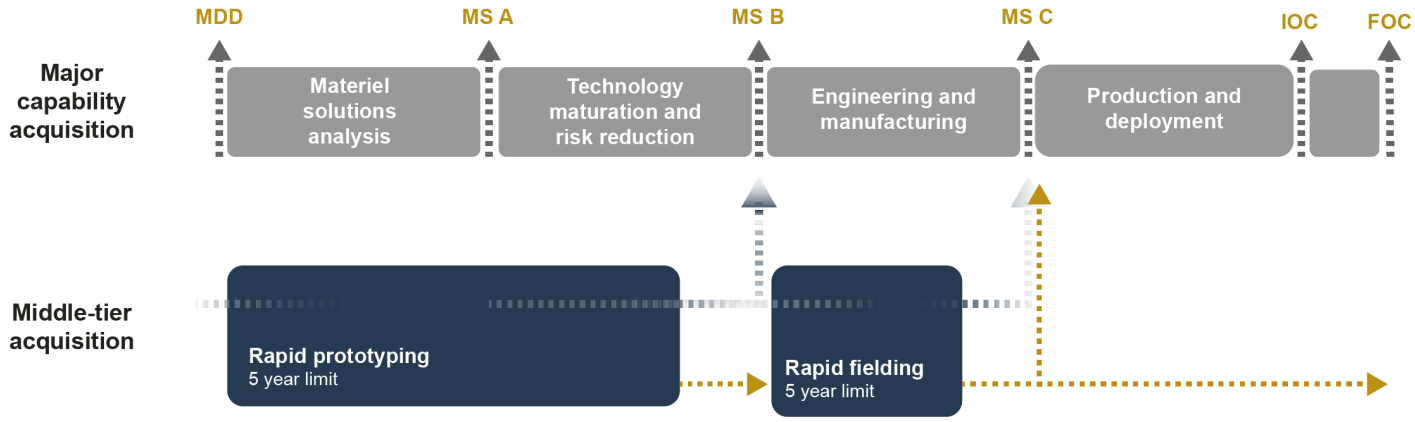
[7]The Secretary may designate an alternate milestone decision authority under certain circumstances, such as if the program is critical to a major interagency effort.

[8]Middle-tier acquisition programs are not subject to the guidance in Chairman of the Joint Chiefs of Staff Instruction 5123.01H, *Charter of the Joint Requirements Oversight Council (JROC) and Implementation of the Joint Capabilities Integration and Development System (JCIDS)* (Aug. 31, 2018) and DOD Directive 5000.01, *The Defense Acquisition System* (May 12, 2003, Incorporating Change 2, Aug. 31, 2018).

[9]DOD Instruction 5000.80, *Operation of the Middle Tier of Acquisition (MTA)* (Dec. 30, 2019).

incorporate these and other changes.[10] As part of these changes, the "traditional" milestone-based approach is now called the "major capability acquisition pathway" and DOD added the two middle-tier acquisition pathways, as shown in figure 2.

Figure 2: Comparison of Department of Defense Acquisition Processes for Major Capability Acquisition Pathway and Examples of Middle-Tier Pathways



MDD Materiel Development Decision
MS Milestone
IOC Initial Operational Capability
FOC Full Operational Capability

Source: GAO. | GAO-20-579

Note: Department of Defense Instruction 5000.80 states that acquisition programs following the middle-tier acquisition rapid prototyping or rapid fielding pathways may not be planned to exceed 5 years to completion, and in execution, may not exceed 5 years after middle-tier acquisition program start without a waiver from the Under Secretary of Defense for Acquisition and Sustainment.

Congress has also passed legislation on the use of other transaction authorities. The National Defense Authorization Act for Fiscal Year 2018 contained a provision titled "expanded other transaction authority for prototype projects" that increased the dollar values of the DOD-internal

[10]DOD Instruction (DODI) 5000.02, *Operation of the Adaptive Acquisition Framework* (Jan. 23, 2020). The DOD transition plan for the restructured guidance is that DODI 5000.02 lays the groundwork for operation of the Adaptive Acquisition Framework and will eventually cancel the January 7, 2015, version of DODI 5000.02, which was renumbered DODI 5000.02T (Transition) to establish a distinction between the two issuances. DODI 5000.02T, *Operation of the Defense Acquisition System* (Jan. 7, 2015, Incorporating Change 7, Apr. 21, 2020), will remain in effect, with content removed as it is canceled or transitions to a new issuance.

approval thresholds. Other transaction agreements generally do not include all the terms and conditions required for traditional acquisitions subject to the FAR. Other transactions enable DOD and companies to negotiate terms and conditions specific to a project without requiring them to comply with most federal regulations that apply to government procurement contracts. This flexibility can also help DOD address non-traditional companies' concerns about establishing a government-unique cost accounting system or concerns about intellectual property rights, among other issues. We and others have previously reported that, while these flexibilities can be beneficial, their use carries the risk of reduced accountability and transparency, in part because such transactions are not subject to the FAR and the related controls and oversight mechanisms that apply to government procurement contracts. In November 2019, we reported that the Army was responsible for over two-thirds of DOD's new other transaction awards made between fiscal years 2016 and 2018, including some made on behalf of other DOD components.[11]

Relevant GAO Leading Practices

GAO has identified leading practices that cover a wide range of topics relating to effective management and oversight of government programs and acquisitions, including our:

- **Schedule Assessment Guide**, which identifies scheduling concepts and presents them as leading practices associated with developing and maintaining a reliable, high-quality schedule;[12]
- **Cost Estimating and Assessment Guide**, which provides a consistent methodology based on cost-estimating leading practices that can be used across the federal government for developing, managing, and evaluating program cost estimates;[13] and
- **Technology Readiness Assessment Guide**, which identifies a methodology for evaluating technology maturity based on leading practices for determining a program or project's readiness to move past key decision points that typically coincide with major

[11]GAO, *Defense Acquisitions: DOD's Use of Other Transactions for Prototype Projects Has Increased*, GAO-20-84 (Washington, D.C.: Nov. 22, 2019).

[12]GAO, *Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: December 2015).

[13]GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: March 2009).

commitments of resources.[14] We measure the maturation of technology through technology readiness levels, which tracks the progress of technology from concept development through testing in laboratory, relevant, and operational environments.[15]

Additionally, our body of work on leading acquisition and product development practices, dating back to 1999, found that successful programs take steps to develop a high level of knowledge at key decision points to demonstrate that technologies are mature, designs stable, and that production processes are in control. According to our leading practices, utilizing systems engineering reviews at or before these decision points can help demonstrate that programs have achieved the level of knowledge required. Systems engineering is a disciplined learning process that translates program requirements into specific design features and thus develops knowledge about key risks to be resolved, as well as trade-offs and additional investments that can help mitigate these risks. In general, programs that implemented these knowledge practices—thus reducing risk—before the start of system development had better cost and schedule outcomes than those that did not. In contrast, we found that when programs enter development with insufficient knowledge, there is a greater likelihood of increased costs, schedule delays, and failures to deliver the capabilities needed by the warfighter. For further information on our leading practices, see Related GAO Products at the back of this report.

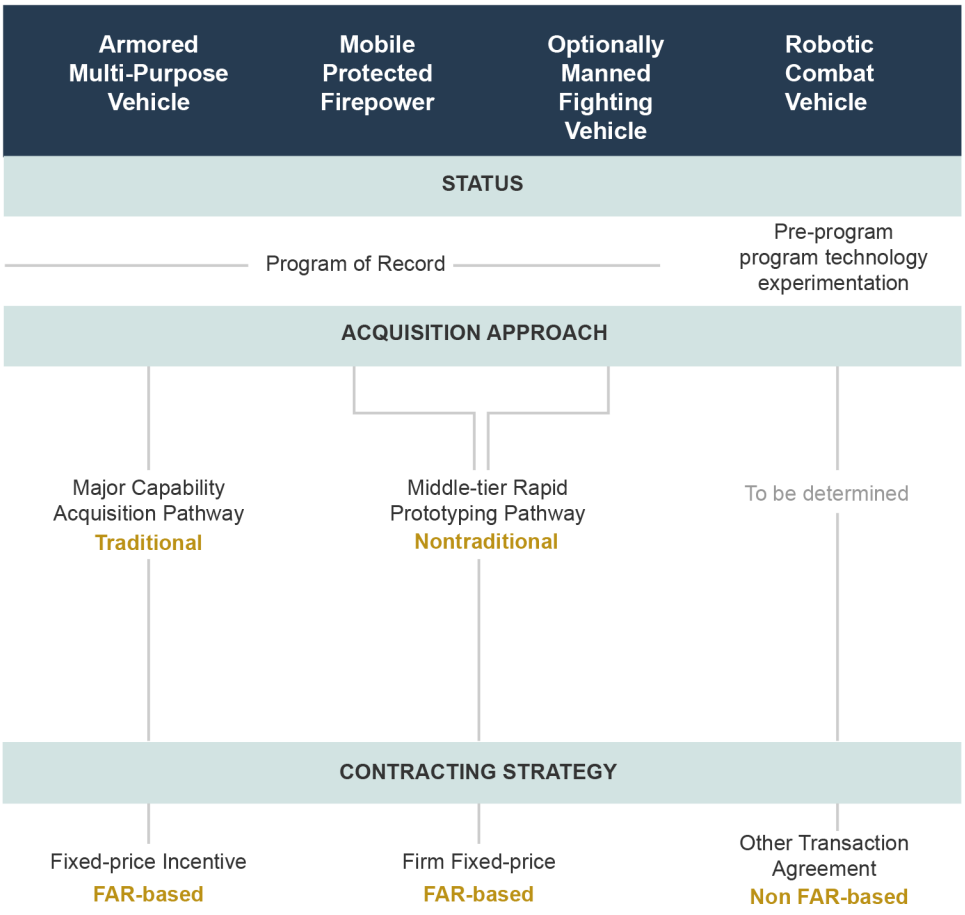
[14]GAO, *Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects*, GAO-20-48G (Washington, D.C.: January 2020).

[15]Testing in a laboratory environment includes demonstrations with basic technological components integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. This represents a technology readiness level 5. Testing in a relevant environment includes high-fidelity laboratory or limited flight demonstrations of a prototype that is very close to form, fit, and function of the final design. This represents a technology readiness level 6. Testing in an operational environment requires a prototype near or at the form, fit, and function of the planned operational system. This represents a major step up from testing in a relevant environment, requiring the realistic demonstration of an actual system prototype in an aircraft or other vehicle. This represents a technology readiness level 7.

Acquisition Approaches and Contracting Strategies for Next Generation Combat Vehicles Portfolio Prioritize Rapid Development

The four efforts within the Next Generation Combat Vehicles portfolio prioritize rapid development, while using different acquisition approaches and contracting strategies. The efforts use acquisition approaches that include both the traditional major capability acquisition pathway and the middle-tier acquisition pathway. Similarly, officials for these efforts reported contracting strategies that include both traditional contract types outlined in the FAR and the more flexible approach offered by other transaction agreements. In each case, program documentation identified increased development speed as an important factor in the planning behind these decisions. Figure 3 shows the acquisition approach and contracting strategy for each vehicle.

Figure 3: Reported Current Acquisition Approaches and Contracting Strategies for Next Generation Combat Vehicles Efforts



FAR Federal Acquisition Regulation

Source: GAO analysis of Army documents and interview with Army officials. | GAO-20-579

Note: The Optionally Manned Fighting Vehicle program office has not yet implemented its contracting strategy.

Additional details on each effort follows.

Armored Multi-Purpose Vehicle

The Armored Multi-Purpose Vehicle program is the replacement for the M113 family of vehicles and is expected to provide improvements in areas including mobility, survivability, force protection, and the potential to incorporate future technologies.

Source: BAE. | GAO-20-579

Armored Multi-Purpose Vehicle. The Armored Multi-Purpose Vehicle (AMPV) program follows the major capability acquisition approach. In January 2019, the program reported that it exercised a FAR-based, fixed-price incentive option for initial production.[16] The Army initiated AMPV prior to the creation of the middle-tier acquisition pathway. Nonetheless, even without this pathway, the Army prioritized rapid development on AMPV by constraining development to 5 years, consistent with one of our leading practices. Our prior work on knowledge-based acquisitions states that constraining the development phase of a program to less than 6 years aligns it with DOD's budget planning process and fosters the negotiation of trade-offs in requirements and technologies. The initial options exercised for production included roughly 300 vehicles at a cost of over $800 million. AMPV is scheduled to enter full-rate production in March 2022 and plans to use a fixed-price incentive contract for the remaining vehicles.

Mobile Protected Firepower

The Mobile Protected Firepower program is a new light tank designed to provide fire support of infantry units.

Source: U.S. Army. | GAO-20-579

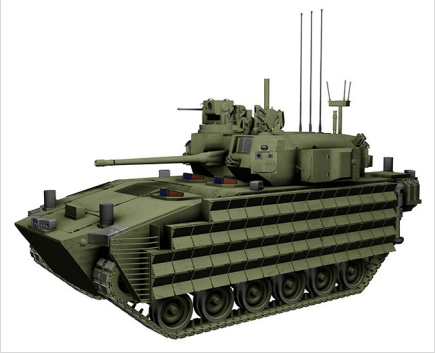
Mobile Protected Firepower. The Mobile Protected Firepower (MPF) program uses the middle-tier rapid prototyping pathway and has awarded two FAR-based, firm-fixed-price research and development contracts. The program originally planned to follow the major capability acquisition pathway but, in September 2018, it shifted to a middle-tier acquisition pathway to enable rapid prototyping and prioritize getting to production and timely delivery of capability to the field. To begin system development under the middle-tier rapid prototyping pathway, in December 2018, MPF awarded two FAR-based, firm-fixed-price development contracts, each valued at over $300 million, with fixed-price incentive options for low-rate initial production. The contractors will have a 5-year time frame for rapid prototyping imposed by the middle-tier acquisition pathway. The Army plans to transition MPF to the major capability acquisition pathway in June 2022 for initial production.

Optionally Manned Fighting Vehicle. The Optionally Manned Fighting Vehicle (OMFV) program had planned to use the middle-tier rapid prototyping pathway and award two FAR-based, firm-fixed-price development contracts for the rapid prototyping effort in March 2020, but

[16]A fixed-price incentive contract is comprised of a target cost, target profit, ceiling price, and profit adjustment formula. It provides for adjusting profit and establishing final contract price by application of a formula, known as a share line, based on the relationship of total final negotiated cost to total target cost. The share line establishes how the government and contractor share responsibility for cost increases or decreases compared to the agreed upon target cost. When the final cost is less than the target cost, the contractor's profit will be greater than if the final costs were more than the target cost.

Optionally Manned Fighting Vehicle

The Optionally Manned Fighting Vehicle program is intended to replace the Bradley Fighting Vehicle as the Army solution for maneuvering soldiers on the battlefield.



Source: Combat Capabilities Development Command Ground Vehicle Systems Center. | GAO-20-579

the solicitation has been halted. In September 2018, the program initiated system development using the middle-tier acquisition pathway for rapid prototyping to prioritize timely delivery of capability to the field. Under this approach, a March 2019 request for proposals included flexibility in requirements to achieve the program's goals within the 5-year middle-tier acquisition time frame. Under this approach, the Army planned to hold a second full and open competition prior to transitioning OMFV to the major capability acquisition pathway at Milestone C for initial production.

In January 2020, the Army canceled the request for proposals. According to the Army's press release announcing cancellation of the solicitation, "a combination of requirements and schedule overwhelmed industry's ability to respond within the Army's timeline." In addition, program officials told us they canceled the solicitation because proposing vendors faced difficulty meeting the aggressive OMFV schedule, and the program office and requirements developers may have misjudged the contractors' ability to integrate the desired technology within 5 years. The Army subsequently conducted additional market research to develop an updated plan for the program and released a preliminary revised acquisition approach to industry in April 2020. This preliminary approach proposes a five-phase acquisition under the middle-tier rapid prototyping pathway, but many details have yet to be finalized.

Robotic Combat Vehicle

The Robotic Combat Vehicle effort is developing a set of autonomous and semiautonomous vehicle platforms to provide a range of capabilities on the battlefield.

Source: Combat Capabilities Development Command Ground Vehicle Systems Center. | GAO-20-579

Robotic Combat Vehicle. The Robotic Combat Vehicle (RCV) effort, according to Army officials, is currently employing other transaction agreements to conduct experiments to determine the availability and maturity of technologies and the validity of operating concepts. The outcome of these experiments will be used to determine whether an acquisition program is feasible, with plans for three vehicle variants—a light, a medium, and a heavy variant. As RCV is not yet a program of record, no acquisition approach has been selected. According to technology development officials, the Army is conducting RCV technology demonstration activities under two competitively-awarded consortium-based other transaction agreements, awarded in August 2018 and February 2019 and worth roughly $1 million, rather than a FAR-based

contracting strategy because of the flexibility this approach offers.[17] Army officials stated that by conducting technology demonstrations now, rather than waiting until they initiate a formal program of record, they can gain knowledge about the feasibility of RCV and "fail fast" or succeed and proceed into a formal acquisition program with more mature concepts. According to Army officials, in March 2020, the Army competitively awarded two contractors additional consortium-based other transaction agreements. One contractor received an award to build four prototypes of the light RCV variant and one contractor received a similar award for the medium variant. Army officials stated that clauses within these other transaction agreements preclude them from proceeding directly into production without further competition.

Application of Additional Leading Practices by the Army While Using Middle-Tier Acquisition Pathway Could Improve Insight into Program Risks

The Army's use of the flexibilities of the middle-tier acquisition pathway for MPF and OMFV may facilitate rapid development, but could be improved by application of additional leading practices. Officials for these recently initiated programs created schedule and cost estimates with more detail than Army and OSD guidance requires for middle-tier programs. For example, the programs identified some risks in both their schedule and cost estimates, but the cost estimates do not fully reflect program uncertainty in key areas. Similarly, program officials took some steps to mitigate technical risk, but delayed systems engineering reviews in ways that increase risk to the programs.

MPF and OMFV Developed Schedules That Exceeded Requirements under Middle-Tier Acquisition Pathway

The Army created schedules for MPF and OMFV that exceeded requirements for the middle-tier pathway. MPF, which began with the expectation that it would follow a major capability acquisition pathway, prepared a detailed schedule and supplementing documents that included items like key decision points, when the system is expected to be available to soldiers in the field, and risks to the schedule as is generally required for such programs. In contrast, OMFV began with the expectation that it would follow the middle-tier acquisition pathway and prepared an acquisition plan that contains a high-level schedule that captured some, but not all, of these same events and associated risks.

[17]Consortiums may be comprised of non-traditional companies, traditional defense contractors, and others such as non-profit research institutions. These consortiums may be administratively managed by a single firm. Consortium management firms in general provide administrative support to consortium members, such as distributing requests for proposals, holding proposal writing workshops, negotiating the general terms and conditions of prototype projects with consortium members, and making payments to consortium members.

OSD guidance on middle-tier rapid prototyping provides for the creation of an acquisition strategy that includes an assessment of schedule risks. Army guidance provides that programs using the middle-tier acquisition pathway describe schedule objectives and include risk management in their acquisition plan. The Army guidance also provides for the development of schedule metrics to inform decision makers on the program's progress on the planned schedule. This guidance, however, does not specify that programs should prepare a detailed schedule as part of their acquisition approach and allows programs to tailor their schedule documentation to expedite the start of prototyping. As a result, the amount of detail in middle-tier program schedule documentation can vary. We found that while the high-level schedules for MPF and OMFV met the criteria in the OSD guidance for middle-tier acquisitions, the level of detail provided limited our ability to fully apply the criteria in GAO's Schedule Assessment Guide.[18] While we could not fully assess the schedules, we were able to generally compare the high-level schedules to the broad principles of the leading practices described in the guide.

Specifically, both the MPF and OMFV programs established high-level schedules in their acquisition plans that we were able to examine. These schedules provided some insight into the program, such as that they generally capture the work to be done and identify the duration of ordered activities, both of which are principles captured in the leading practices in GAO's Schedule Assessment Guide. To track the progress of the programs, the Army inserted decision points into the MPF and OMFV prototyping efforts. At these decision points, if the 5-year schedule cannot be met, program officials can work with Army leadership to identify alternative approaches, such as modifying program requirements to support the schedule or obtaining a waiver. These decision points occur throughout the program and include, among other things, reviews for proposal release, design maturity, and prototype decisions. In addition, our review of these schedules found that the MPF and OMFV programs are taking steps to address known risks by planning to incorporate mature technologies, addressing supplier issues to facilitate delivery of needed materials, and mapping out integrated testing plans of components, consistent with the principles of the leading practices in GAO's Schedule Assessment Guide. For example, the MPF acquisition plan leverages existing vehicle powertrain systems and electronics to meet program requirements within the prototyping phase. The original OMFV acquisition plan identified the ordering of long-lead items as a risk to the program

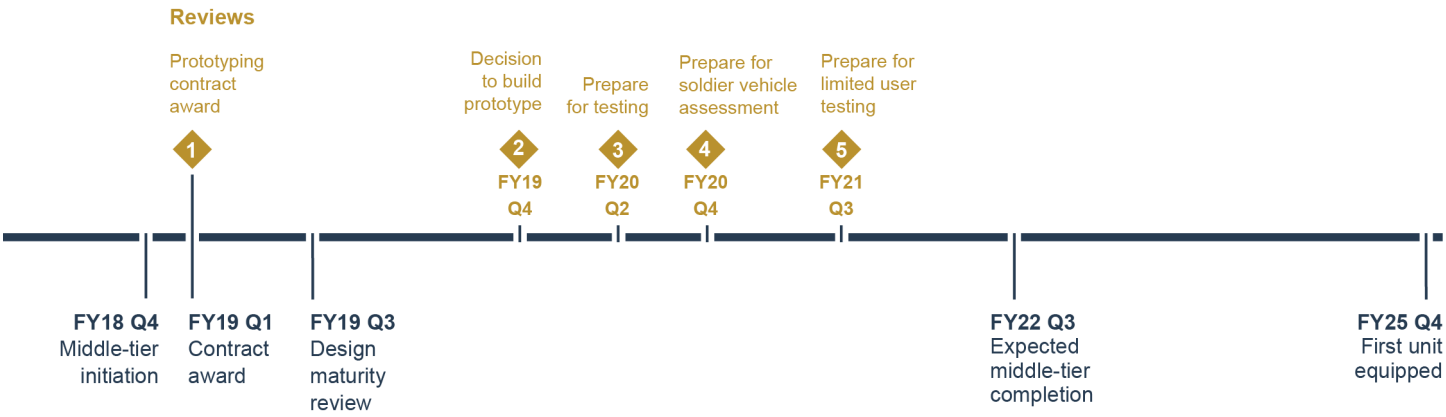
[18]GAO-16-89G.

schedule. OMFV's new acquisition approach also acknowledges the risk of long-lead items and states that the Army plans to order subsystems for contractors to meet the proposed schedule for production of prototypes.

The Army planned the MPF program as a major capability acquisition. We found that MPF program managers developed detailed schedule documentation that included more of the principles inherent in our leading practices for schedule estimates. For example, MPF created a test and evaluation master plan that provides a more detailed description of schedule objectives and schedule risk than those outlined in the acquisition plan provisions in middle-tier guidance. This helps to address our leading practice for capturing all activities in the schedule. In addition, program officials produced plans to identify and update systems engineering risks that could affect the planned schedule. MPF program officials also produced a detailed schedule following the fiscal year 2019 contract award. The schedule includes plans for updating it with risks to the critical path. Updating schedule documentation is another way MPF is taking measures to demonstrate the broad principles in our leading practices for schedule assessments.

The MPF program is more than a year into its 5-year period for developing an operational prototype. After awarding two prototyping contracts in December 2018, the program held a design maturity review in June 2019, to determine whether the program was successfully meeting its design goals. A program official told us that the program is approaching prototype testing in July 2020, which will provide performance data on the vehicle's lethality and cybersecurity, among other issues. The Army is planning to equip its first unit with MPF late in fiscal year 2025. Figure 4 shows the schedule for MPF.

Figure 4: Planned Timeline for Mobile Protected Firepower Rapid Prototyping and Production



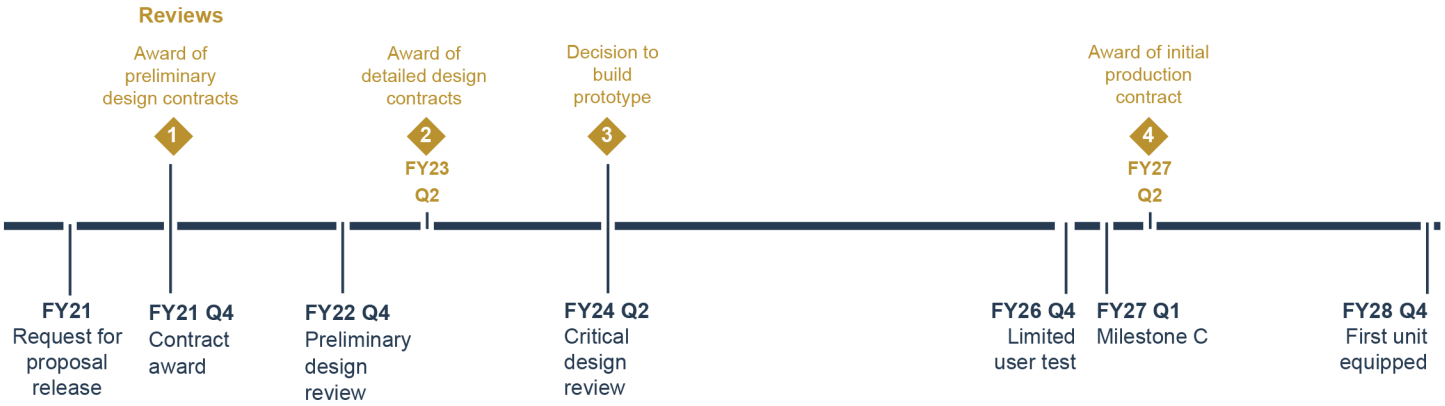
FY Fiscal year
Q Quarter
Source: GAO analysis of Army documentation. | GAO-20-579

Unlike MPF, OMFV began as a middle-tier program in 2018 with the expectation of having the first unit equipped in 2025, and was not required to develop detailed schedule documentation. Instead, the Army created a high-level acquisition plan and schedule to support decision-making. According to Army officials, they canceled the initial OMFV solicitation in January 2020, in part because the vendor(s) that submitted proposals could not meet program requirements or integrate the technology within the desired schedule. This outcome echoes concerns raised by OSD officials in 2018, who expressed concerns that meeting the 5-year schedule was risky. Army contracting officials told us they acknowledged these schedule concerns, but planned the prototyping milestones within the given schedule constraints directed by Army leadership.

In April 2020, as part of program changes following the January 2020 cancellation of the original OMFV solicitation, the Army proposed a new acquisition approach for OMFV that may also align with the broad principles of our leading practices for schedule assessments. As opposed to the original solicitation, the updated OMFV schedule will provide opportunities up to the preliminary design review for contractors to provide candid feedback on the OMFV acquisition approach and on their ability to meet the characteristics based on the schedule and funding proposed. OMFV program officials also plan to update the schedule after the first contract award, a key activity in our leading practices for schedule

assessments. For example, OMFV officials reported that a draft test plan and schedule will be created during development prior to the preliminary design review and that program officials will develop multiple iterations of the test plan as OMFV characteristics are further developed. Figure 5 shows the proposed OMFV schedule.

Figure 5: Planned Timeline for Revised Optionally Manned Fighting Vehicle Rapid Prototyping and Production



FY Fiscal year
Q Quarter

Source: GAO analysis of Army documentation. | GAO-20-579

In addition, the revised OMFV schedule proposes dates for the program up to equipping the first unit with the new capability. According to the Army's preliminary plans for this new contract solicitation, the Army plans to release a new request for proposals in fiscal year 2021 and award contracts in the 4th quarter of the same year. This will be followed by a subsequent full and open competition for detailed design contracts followed by an award to build a prototype(s). The revised schedule also provides additional time between the first design review and the production decision. As reflected in figure 5, the new schedule estimates delivery of the first prototype vehicles in the 1st quarter of fiscal year 2027, and the first delivery of first unit equipped in the 4th quarter of fiscal year 2028.

MPF and OMFV Developed Life-Cycle Cost Estimates That Could Better Reflect Uncertainties in Program Cost

Although not required under the middle-tier guidance for rapid prototyping, MPF and OMFV program officials completed full life-cycle cost estimates that demonstrated elements of our leading practices for cost estimation. These estimates could provide further insight to decision makers by better reflecting the uncertainty surrounding program costs. The estimates included costs from research and development through disposal, including the prototyping efforts, acquisition operations and support, military construction, and operations and sustainment costs. Both the MPF and OMFV cost estimates were developed prior to contract award, when the Army knew less about potential vehicle designs and vendor solutions. The MPF cost estimate was completed during the source selection period when the cost estimators would have had access to the proposed design providing more information on which to base costs. In contrast, the OMFV cost estimate was created to support the release of a contract solicitation, before designs were received. Both programs plan to update their cost estimate with actual costs throughout the program's life-cycle, an example of activity that demonstrates leading practices.

Based on their initial acquisition plans, the total estimated life-cycle cost of MPF is approximately $16 billion and the cost of OMFV is approximately $46 billion (in fiscal year 2019 dollars). The estimated costs for OMFV are greater than MPF, in part, because the Army plans to procure more OMFV than MPF. In both estimates, we found that the middle-tier rapid prototyping effort accounts for the majority of the research and development costs.

We found that the life-cycle cost estimates for MPF and OMFV generally followed our leading practices for such estimates, but did not appropriately reflect uncertainty. We assessed the program life-cycle cost estimates against the four characteristics of reliable cost estimates identified in GAO's Cost Estimating and Assessment Guide; comprehensive, well-documented, accurate, and credible.[19] See table 3 in appendix I for more detail on the four characteristics.

> **Comprehensive.** We found that the MPF and OMFV cost estimates included total life-cycle costs and were not limited to just the costs for rapid prototyping. These estimates included the costs for research and development as well as test and evaluation both within and outside the middle-tier rapid prototyping effort,

[19]GAO-09-3SP.

procurement, operations and support, and disposal, which is consistent with our characteristic of comprehensive life-cycle cost estimates. Our leading practices state that a cost estimate should provide an exhaustive and structured accounting of all resources and associated cost elements—such as hardware, software, and personnel—required to deploy and sustain a program. By creating a comprehensive cost estimate, Army leaders have information needed for program planning and decision-making from program inception through maintenance and retirement of the program.

Well-Documented. We found that the MPF and OMFV cost estimates included key documentation to understand the drivers of the systems' costs, such as analogies to other similar combat vehicle systems used to create the cost estimate. This is consistent with our characteristic of well-documented cost estimates. A well-documented cost estimate, which is written justification of the how the cost estimate was developed, is important because it can present a convincing argument of an estimate's validity and help answer decision maker questions about the program.

Accurate. Both cost estimates were largely consistent with the elements of the accurate characteristic, although the OMFV cost estimate contained minor errors. We found that both MPF and OMFV based their cost estimates on historical data from comparable programs, which is critical in creating an accurate cost estimate. MPF program officials documented their work based on actual costs and plan to update their cost estimates during the rapid prototyping phase to take into consideration actual costs incurred for the design, production, delivery, and testing of MPF prototype vehicles. However, one of the minor errors we found was that the OMFV estimate relied on an inflation index that had not yet been updated for the fiscal year. During the course of our work, program officials noted that it would have delayed the cost estimate to wait on an updated inflation index and plan to update the cost estimate in the future. Applying inflation correctly is an important step in cost estimating because in the development of an estimate, cost data must be expressed in like terms. If a mistake is made or the inflation amount is not correct, cost overruns can result. The accuracy of a cost estimate is critical to ensuring a reliable and well-founded life cycle cost estimate. This is because this estimate serves as the basis to

request program funding and provide insight into the overall affordability of the acquisition program.

Credible. Our review of the MPF and OMFV cost estimates found that the programs included only a limited sensitivity analysis to help quantify the effect of unknown variables on the estimated cost, which could impact the credibility of the estimate. Our past work has found that to determine an estimate's credibility, cost estimators should test, among other things, the sensitivity of key variables that could affect cost and conduct analyses to identify areas of uncertainty. Since uncertainty cannot be avoided, it is necessary to identify the cost elements that represent the most risk and, if possible, quantify the risk for decision makers. Specifically, a sensitivity analysis can provide helpful information for the system designer and decision makers because it highlights the elements that have the most effect on cost, such as the number of troops to be carried by a vehicle. MPF and OMFV cost estimators developed some sensitivity analyses as part of their efforts to estimate program costs, but the final cost estimates did not clearly reflect this uncertainty to support informed decision-making. When an agency fails to conduct sensitivity analysis to identify the effect of uncertainties associated with different assumptions, this increases the chance that decisions will be made without a clear understanding of these impacts on costs.

During the course of our review of the MPF and OMFV cost estimates, we also found that the Army program offices identified areas of uncertainty as part of their analyses, an activity that would support cost estimate credibility. The program offices, however, did not reflect this uncertainty in the point estimates communicated to Army decision makers. In the analyses done for the estimates, MPF program officials took into account uncertainties such as crew size and vehicle weight. For example, at the time the program developed the MPF cost estimate, Army leadership had not determined whether the MPF vehicle design would include machinery to automatically load ammunition or require a soldier to do the same job, which would determine the number of personnel needed. The number of crew in the vehicle can affect the vehicle design, such as the need to add or remove vehicle subsystems to accommodate a larger or smaller crew. These decisions can in turn affect the cost of building and operating the vehicle. Another example is that the MPF program documentation specifies that two vehicles must fit on a C-17 cargo

aircraft for transport, which influences the maximum size and weight of the vehicle. The weight of the vehicle affects its fuel needs and its operations and sustainment costs because the heavier the vehicle, the higher its fuel costs will be.

OMFV officials also identified cost uncertainties and assessed how these uncertainties might affect overall cost for development, production, operations and maintenance. For example, they considered how factors that could affect the rate of production would affect overall production cost. The Army recognized more uncertainty about the design in the OMFV cost estimate than in the MPF cost estimate, due to the nature of the programs. For example, as an optionally manned vehicle, OMFV will need to operate both with a crew and autonomously, which adds complexity and unknowns to the design as no vehicle like this currently exists in the Army's ground vehicle fleet, but the uncertainty surrounding this complex design is not reflected in the point estimate. Because these uncertainties were not included in the point estimate, decision makers are left making choices without a clear understanding of the impact on costs and may not be able to accurately budget for the program.

Further, the point estimates the Army developed for the MPF and OMFV programs present a single estimated cost rather than a range of costs. Our past work has determined that a point estimate alone is insufficient for managers to make informed decisions about the cost of a program. For informed decisions, the cost estimate must reflect a degree of uncertainty, typically achieved through an uncertainty analysis, so that a level of confidence can be given about the estimate. OMFV officials stated that the inclusion of risk around an estimate could overstate confidence in the estimate, because of uncertainty around unknown issues of program design. We acknowledge that information about how well technology will perform or how external events may affect the program is imperfect early in a project development, as is the case for the MPF and OMFV programs. A point estimate by itself, however, provides no information about the underlying uncertainty. According to program officials, the point estimate was chosen from several calculated costs as the most representative cost. In contrast, if the programs had conducted an uncertainty analysis, it would provide the estimate with a confidence interval that reflects a range of possible costs and gives decision makers a more realistic picture

of what costs could be for the program. Neither MPF nor OMFV officials used uncertainty analyses to determine the confidence level surrounding the point estimate. Relying solely on a point estimate, rather than establishing a confidence level around it, limits insight for decision makers as they determine future program budgets, which could lead to cost overruns.

Army Mitigated Some Technical Risk, but Could Further Mitigate Risk by Demonstrating Additional Leading Practices

The Army's development approach mitigates some technical risks to MPF and OMFV by incorporating elements of leading practices for acquisition, but could further mitigate risk by implementing other practices. Specifically, by constraining development to 6 years or less and incrementally developing system capabilities the programs align with DOD's budget planning process and limit the amount of technology development required during system design. In contrast, the Army does not plan to fully mature technologies and plans to begin system development prior to conducting a preliminary design review, practices our prior work has found can result in cost growth, schedule delays, and failure to deliver the capabilities needed by the end-user. Completing the latter steps in conjunction with constrained and incremental development is critical to building the knowledge required to successfully initiate a program.

Constrained development period. The Army approach for these programs constrains system development and demonstration to less than 6 years by using the 5-year middle-tier acquisition approach, consistent with our leading practices for knowledge-based acquisitions. Our prior work on knowledge-based acquisitions states that constraining the development phase of a program to less than 6 years aligns it with DOD's budget planning process and fosters the negotiation of trade-offs in requirements and technologies. MPF plans to have a 3-year, 7-month period of performance for rapid prototyping, including system design and demonstration. OMFV planned to have a 3-year, 3-month period of performance that included system design and demonstration before the Army canceled its solicitation. Under the new plan, OMFV expects to complete system development and prototype demonstration in close to 5 years.

Incremental development. The Army is taking an incremental development approach to deliver increased capability over time, consistent with our leading practices for knowledge-based acquisition. This approach—as opposed to achieving all requirements in a single step—provides program managers with more achievable requirements, which, in turn, facilitates more rapid development. Prior to cancellation of

the solicitation, the OMFV program strategy allowed for incremental prototyping to upgrade system capability. For example, the Army planned to evaluate the timing and scope of a potential second increment for OMFV after demonstrations of the initial prototypes. Under the proposed approach for the new solicitation, a five-phase effort will allow the Army to reassess the prototyping process at decision points throughout the development. In addition, OMFV plans to incorporate a modular open systems architecture to allow for incremental upgrades of capability. We have previously reported that developing systems under a modular open systems architecture approach can provide benefits to DOD acquisitions that are consistent with principles in our leading practices for acquisition.

The Army's Combat Capabilities Development Command Ground Vehicle Systems Center (the Systems Center) is key to implementing the incremental approach and we found that its processes for assessing technologies generally met leading practices. Army officials said the Systems Center is the lead agency for NGCV science and technology activities and is responsible for maturing and demonstrating selected technologies before transitioning them to the Next Generation Combat Vehicles portfolio. At the time of our review, neither MPF nor OMFV had identified critical technologies that could be assessed against our leading practices. More generally, however, the Systems Center process for conducting readiness assessments for science and technology development—a fundamental means for evaluating the technology maturity and its readiness to perform as part of a larger system—fully or substantially meets seven of the eight leading practices we assessed, as shown in table 2.

Table 2: Selected Leading Practices Applied to Army's Ground Vehicle Systems Center Process for Conducting Technology Readiness Assessments (TRA)

Leading practice	GAO assessment[a]
Assigns Technology Readiness Level (TRL) ratings based on credible and verified evidence	Fully met
TRA report identifies the recipient or recipients of the report	Fully met
TRA report is used for its stated purpose, such as to inform decision makers about whether a prescribed TRL goal has been met, or identify potential areas of concern or risk, among other purposes	Fully met
Is conducted by an independent and objective TRA team.	Substantially met
Is based on a level of detail that is consistent with the level of detail (evidence) available	Substantially met
Has adequate time and resources to conduct the assessment	Substantially met
TRA report identifies the actions to take for critical technologies assessed as immature, such as considering an alternate or backup technology, developing a technology maturation plan, updating the cost and schedule risk assessments	Substantially met
The TRA identifies and has the expertise needed to conduct the assessment	Partially met

Source: GAO analysis of Army documents and interviews with Army officials. | GAO-20-579

[a]We assigned individual ratings for each leading practice as: Not met, Minimally met, Partially met, Substantially met, or Fully met.

The Systems Center partially met the leading practice of identifying expertise needed to conduct the assessments as they do not document how they staff their assessment teams or what the team composition should be. Systems Center staff told us, however, that technology assessment teams are composed of seasoned and less experienced engineers, and they have an extensive cadre of experienced staff to choose from.

Technology maturation. The Army approach to rapid prototyping under the middle-tier acquisition approach relies on technologies that have not been demonstrated in an operational environment, to meet requirements due to the aggressive schedules for these programs.

- The Army evaluated the maturity of technologies included in proposed designs for MPF through an independent technology readiness assessment by the Office of the Deputy Assistant Secretary of the Army for Research and Technology. This assessment found that the proposed designs for MPF included technologies that were demonstrated in at least a relevant environment. Additionally, in January 2020 the Office of the Under Secretary of Defense for Acquisition and Sustainment reported to Congress that the least mature technology for MPF was demonstrated in a relevant environment. According to program officials, the selected designs for the MPF program rely on these technologies in order to build and

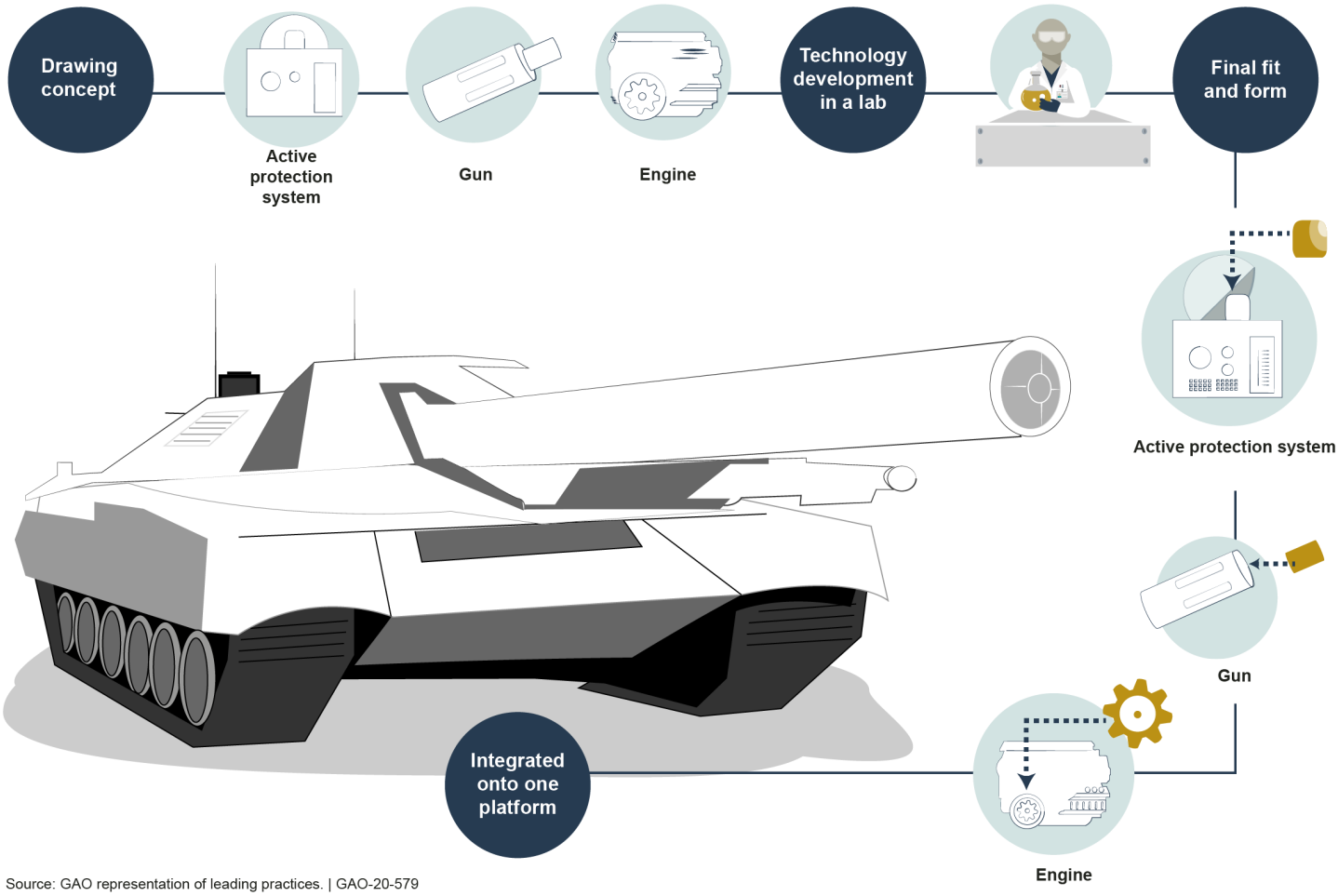
deliver the first prototypes 15 months after contract award. Additionally, the MPF program plans to conduct iterative technology tests throughout the prototyping phase to mitigate risk.

- Prior to the cancellation of the initial solicitation, OMFV planned to use a mix of existing and new technologies to meet requirements. Unlike MPF, OMFV did not plan to complete an independent technology readiness assessment until the program was approaching a production decision. In its report to Congress on middle-tier acquisition programs, the Office of the Under Secretary for Defense for Acquisition and Sustainment stated that the least mature technology for OMFV had only been demonstrated at the component level in a laboratory environment. Such a level of maturity would need significant additional development before it can be incorporated into a weapon system. The program balanced the risk of incorporating new, immature technologies—such as a system for autonomous control of the vehicle—through flexible requirements that allowed the incorporation of a threshold (minimum acceptable) capability—such as the use of a modular open systems architecture to establish interfaces for later upgrades—with the ability to develop the objective (maximum desired) capability in a later increment. While the Army only required potential contractors to meet threshold requirements, the request for proposals included incentives to develop technological solutions to meet the objective requirements as well. Army officials said that they considered the threshold requirements to be highly achievable within the 5-year middle-tier acquisition time frame and acknowledged in its acquisition plan that not all of the objective requirements might be achievable.
- Networking is an important capability for the Next Generation Combat Vehicles portfolio not only for secure communications and sharing of information, but also control of autonomous or semi-autonomous vehicles that may eventually be incorporated into operational ground forces, such as OMFV and RCV. Past modernization efforts failed, in part, due to challenges maturing networking capabilities. According to program officials, networked communication is key to connecting the vehicles, and collecting and processing sensor data. At the time of our review, however, a mature technology enabling this functionality had not yet been identified. The Network cross-functional team leads Army networking modernization efforts. Network cross-functional team staff said they are developing technologies to link OMFV and RCV due to the lack of commercially available technologies. OMFV program staff said that they have been in regular contact with the Network cross-functional team, but do not have control over the choices that team makes. OMFV program staff said they have taken steps to mitigate

potential risk by communicating their requirements to the Network cross-functional team and pursuing a modular open systems network architecture that can integrate different types of networking solutions.

The Army is maturing, or has plans to mature, individual technologies to a level lower than the threshold recommended by leading practices before beginning system development. This creates a danger of limited insight into key technology risks. Leading practices for knowledge-based acquisitions state that each of the critical technologies should be demonstrated in an operational or realistic environment—not simply in a relevant environment—prior to their incorporation into a system design to ensure that they work as intended for the end-user. Demonstrating that each technology operates as intended in an operational environment demonstrates their individual technological maturity and limits risks associated with integrating them into weapons systems. Our past work indicates that by demonstrating each technology in only in a relevant rather than an operational environment, the Army increases the risk that new capabilities will not perform as intended and require further technological maturation while in system development. This could raise MPF and OMFV costs and extend timelines for delivery of equipment to the field. A notional depiction of leading practices for maturing technologies through the development process is shown in figure 6.

Figure 6: Notional Depiction of Leading Practices on Technology Maturation before Integration



Source: GAO representation of leading practices. | GAO-20-579

The Army's choice to start development of MPF and OMFV at lower levels of technology maturity raises concerns that are consistent with those we have raised over the past 2 decades. For example, in a 1999 report, we recommended demonstrating technologies in an operational environment prior to system development and DOD concurred with that recommendation.[20] In addition, we reiterated this leading practice in 2020 in GAO's Technology Readiness Assessment Guide.[21] We have also

[20]GAO, *Best Practices: Better Management of Technology Development Can Improve System Outcomes,* GAO/NSIAD-99-162 (Washington, D.C.: July 1999).

[21]GAO-20-48G.

reported on the importance of achieving this level of maturity on an annual basis since 2003, most recently in 2019, in our assessment of DOD's major weapon system acquisition programs.[22] We reiterated this point specifically for the Army's current modernization efforts in 2019 and recommended that the Army demonstrate the technologies it is developing for modernization in an operational environment prior to starting system development.[23] The Army concurred with this recommendation and we continue to monitor the Army's progress. Army officials acknowledged the importance of demonstrating technology in an operational environment prior to starting system development and stated that they have taken steps to assist in the identification and removal of infeasible or immature technologies.[24]

Systems engineering reviews. Neither MPF nor OMFV held a systems engineering design review before beginning system development due to the prioritization of rapid development. This situation limits insight into potential technology risks. While OSD and Army policies on the middle-tier acquisition pathway do not explicitly call for systems engineering reviews, MPF held a design maturity review 6 months after awarding development contracts, in June 2019. The original plan for OMFV likewise included a systems engineering review subsequent to the award of system development contracts. The Army canceled the OMFV solicitation instead of pursuing development, in part due to the conclusion that contractors could not complete a system design that met requirements within the given schedule. Army documents show that initial plans for the revised OMFV solicitation include a new phase for vendors to develop preliminary designs, and for the program to verify through systems engineering that preliminary designs are operationally suitable and technically achievable. Vendors also are to pass a preliminary design review before beginning detailed design and building prototypes.

Our previous work has found that conducting detailed systems engineering analysis before starting product development contributes to

[22]GAO, *Weapon Systems Annual Assessment: Limited Use of Knowledge-Based Practices Continues to Undercut DOD's Investments*, GAO-19-336SP (Washington, D.C.: May 2019).

[23]GAO-19-132.

[24]DOD policy implements statutory requirements and states that programs following the major capability pathway should, at a minimum, demonstrate technologies in a relevant environment before system development. This does not preclude program officials from pursuing a higher level of maturity. 10 U.S.C. § 2366b.

understanding whether requirements are achievable, and identifying and mitigating associated risks.[25] Once risks are identified, the program can resolve the risks through trade-offs and additional investments, thereby ensuring that the risks are clearly understood and adequately resourced. Further, we have found that programs that held a design review prior to starting development generally experience better cost and schedule outcomes. For example, our May 2019 analysis of major DOD acquisitions programs found that programs that held a preliminary design review prior to beginning system development had an average cost savings of 0.5 percent and a 33.5 percent increase in schedule. In comparison, programs that did not hold a systems engineering design review before system development experienced an average 65.6 percent cost increase and an 80.5 percent schedule increase.[26]

Foregoing a systems engineering design review before beginning system development may save time at the outset but risks design rework that may ultimately result in cost increases, schedule delays, and failure to deliver capabilities to the end-user. Our prior work has found that other Army programs that began system development before fully considering systems engineering and requirements resulted in a mismatch of available technologies with program requirements, and ultimately schedule delays.[27] For example, the Army's decision to begin AMPV system development was not informed by sufficient requirements analysis because the program had not completed any systems engineering reviews. Instead, a design review was held 6 months into systems development and program office engineers found that the preliminary design would not meet survivability and force protection requirements. As a result, the Army reduced its requirements to match the capabilities AMPV was likely to provide.

The Army's decision to cancel the OMFV solicitation further illustrates the risks of beginning system development without conducting a systems engineering design review, but presents an opportunity to learn key lessons and apply them. Program officials said that the vendors who submitted proposals could not meet program requirements under the 5-year prototyping time frame. Further, program officials told us that the program office and requirements developers may have misjudged the

[25]GAO/NSIAD-99-162.

[26]GAO-19-336SP.

[27]GAO, *Army Weapon Systems Requirements: Need to Address Workforce Shortfalls to Make Necessary Improvements*, GAO-17-568 (Washington, D.C.: June 2017).

ability of contractors to integrate the desired technology within the given schedule. As the Army finalizes the new acquisition approach proposed for OMFV, it should consider the lessons learned from the cancelled solicitation and conduct detailed systems engineering reviews to gain insight on the maturity of its design. If the Army incorporates these lessons into its proposed approach, the program would be more likely to deliver desired capabilities to the warfighter on time and at or near expected costs.

NGCV Officials Communicated with Additional Army and DOD Stakeholders to Mitigate Risks

The Army has taken actions to enhance communication, both within the Army and with other DOD stakeholders, to mitigate risks.

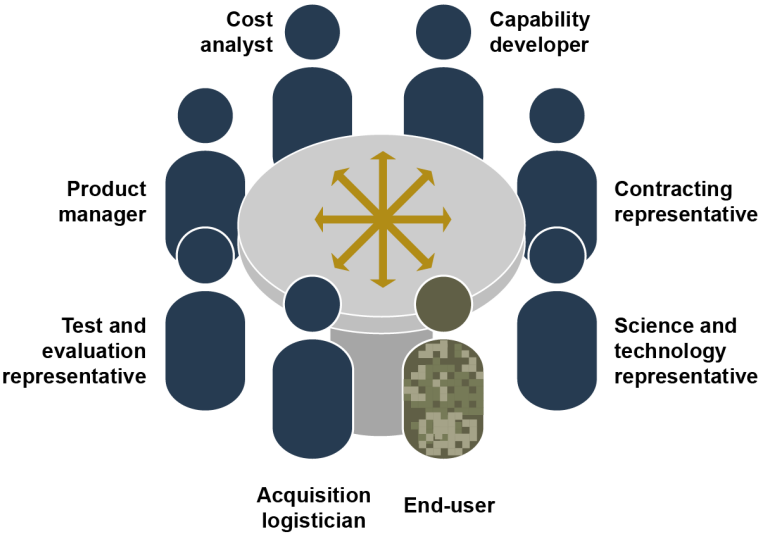
Cross-functional team model. The Army enhanced communications to mitigate risk to the NGCV portfolio through its use of the cross-functional team model. This model is designed to facilitate communication among diverse experts early in development to improve the efficiency of the requirements development and defense acquisition processes. In January 2019, we reported that the Army cross-functional team structure demonstrated leading practices for acquisitions by promoting communication between end-users and requirements developers.[28]

For NGCV, the Army relocated cross-functional team staff from Ft. Benning, Georgia to Warren, Michigan, which co-located them with program and other acquisition, contracting, and technology development staff. Army officials said that the cross-functional team model enhanced communication and facilitated stakeholder input into key documents. Army contracting staff said that there was historically a divide between requirements development and contracting strategy, and that the cross-functional team model has helped bridge that divide. For example, they credited the cross-functional team model and co-location for their increased involvement in developing the MPF and OMFV strategies. Similarly, Army technology development staff said that co-location has helped to increase the amount of communication and build relationships that facilitate difficult discussions. Army technology development staff told us that, as a result, the cross-functional team has a greater incentive to consider the realism of a proposed requirement and listen to their stakeholders than under prior structures. See figure 7 for a comparison of the requirements development process under a cross-functional team to the prior Army requirements process.

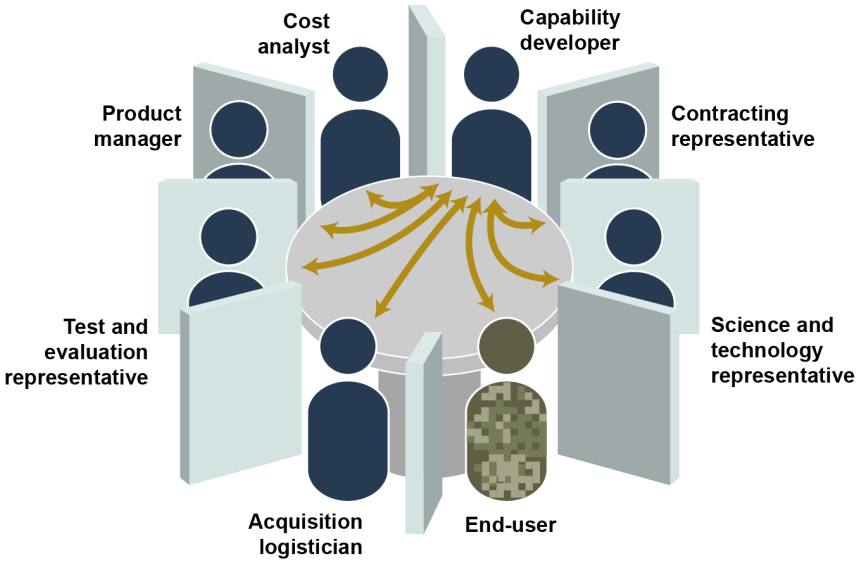
[28]GAO-19-132.

Figure 7: Comparison of Army Requirements Development Processes

Cross-functional team requirements development process



Traditional Army requirements development process



Source: GAO interpretation of Army information. | GAO-20-579

Other Army stakeholders. The NGCV programs have also communicated with other Army stakeholders to mitigate risks. The OMFV program manager said that the program is regularly communicating with the program executive office, Army acquisition staff, Army technology development staff, and cost estimation staff. For example, OMFV program officials said they chose to coordinate early with the Army Test and Evaluation Command, and other test and evaluation officials, to develop testing plans to make sure that Army stakeholders were satisfied with the programs' testing approach and timing. Similarly, Army G-8 budget officials said that the improvements to communication through the co-located team have also been beneficial for offices outside Warren, Michigan, noting that disagreements were more quickly identified and resolved prior to forwarding material for review.

Department of Defense. MPF and OMFV program officials chose to communicate with some DOD offices to mitigate risk for future decision-making. The shift of authority for decision-making for most defense acquisition programs from OSD to the military services limited the potential oversight of acquisition programs by OSD, including coordination with external stakeholders in DOD.[29] Some external DOD stakeholders said they had unclear or informal roles under the middle-tier acquisition pathway prior to the issuance of recent guidance. For example, Under Secretary of Defense for Research and Engineering officials said they were figuring out their oversight role for technology development at middle-tier programs across DOD at the time MPF and OMFV program officials were consulting with stakeholders outside the Army. These comments align with our previous reporting on the implementation on the middle-tier acquisition approach.[30] Nonetheless, program staff consulted with external stakeholders in DOD to develop documentation such as a cost estimate and testing and evaluation plans. While these documents are not required for middle-tier acquisition programs, they would be required when MPF and OMFV transition to a major capability acquisition pathway. For example, DOD cost estimation staff said program officials consulted them informally to solicit feedback on MPF and OMFV cost documents. Additionally, MPF and OMFV staff said their communication approach with the DOD office of Operational

[29]These external stakeholders are a number of Office of the Secretary of Defense offices that played roles in the oversight of acquisition programs prior to the shift of authority, including Acquisitions and Sustainment, Research and Engineering, and Cost Assessment and Program Evaluation.

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

Test and Evaluation did not differ from the approach under the major capability acquisition pathway. For example, both programs chose to develop a coordinated testing and evaluation approach to reduce program risk prior to the start of production.

Conclusions

Past, unsuccessful, efforts to update the Army's ground combat vehicles add urgency to the current efforts to provide new equipment to the warfighter but more could be done to reduce risks for current efforts. Acquisition flexibilities like the use of middle-tier acquisition pathways have the potential to enable programs to develop and field weapon systems more rapidly, but can also introduce uncertainty and risk. While the Army has incorporated a number of our leading practices incorporation of additional leading practices for cost estimation and systems engineering would help the programs mitigate risk and provide insights to leadership to support planning and budgeting.

For MPF and OMFV, program documentation does not clearly communicate the uncertainty associated with projected costs and limits the programs' ability to gather the knowledge to effectively mitigate risks associated with system design maturity. In the early stages of program development, uncertainty about technical specifications and system design translates into uncertainty about projected costs. Rather than acknowledge that uncertainty with a range of potential costs, both MPF and OMFV documentation present expected costs as a single value. This approach limits the ability of DOD to effectively plan for and make investment decisions and limits congressional oversight for these programs. Additionally, the schedule-driven decision to begin OMFV at system development led to choices to accelerate or cut out parts of development, including not holding a systems engineering review in advance of program initiation, which is inconsistent with leading practices to mitigate the risk of an immature design. Efforts to apply additional leading acquisition practices, especially in areas designed to provide the Army insight into uncertainty and risk in cost and systems engineering, would help ensure the success of these programs and avoid canceled acquisitions, slipped schedules, and cost overruns.

Recommendations for Executive Action

We are making three recommendations to the Army:

- The Secretary of the Army should direct the MPF program to update its cost estimate to include analyses to support the development of a range of possible cost outcomes for decision makers in a manner consistent with GAO's Cost Estimation Guide. (Recommendation 1)

- The Secretary of the Army should direct the OMFV program to update its cost estimate to include analyses to support the development of a range of possible cost outcomes for decision makers in a manner consistent with GAO's Cost Estimation Guide. (Recommendation 2)
- The Secretary of the Army should direct the OMFV program to inform requirements by conducting systems engineering reviews at key decision points consistent with our leading practices for acquisition, as the program office finalizes its acquisition approach. (Recommendation 3)

Agency Comments

We provided a draft of this product to the Army for comment. In its comments, reproduced in appendix II, the Army concurred with all of our recommendations. The Army also provided technical comments, which we incorporated as appropriate.

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

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

Jon Ludwigson
Director
Contracting and National Security Acquisitions

Appendix I: Objectives, Scope and Methodology

This report examines (1) the acquisition approaches and contracting strategies the Army is considering for the Next Generation Combat Vehicles (NGCV) portfolio, (2) the extent to which the Army's efforts to balance schedule, cost, and technology reduce acquisition risks for the NGCV portfolio, and (3) how the Army is communicating internally and externally to reduce acquisition risks for the NGCV portfolio.

To identify the acquisition approaches and contracting strategies the Army is considering for the NGCV portfolio, we reviewed acquisition and contract documentation, where available, for each of the four programs. We also spoke with officials from the cross-functional team, program offices, and the Ground Vehicle Systems Center to discuss the planning and decision-making that went into developing these documents. To understand how the acquisition approach and contracting strategy might change following the cancellation of the Optionally Manned Fighting Vehicle (OMFV) solicitation, we reviewed new documentation and followed up with program officials.

To assess the extent to which Mobile Protected Firepower (MPF) and OMFV schedules reduce program risk, we reviewed existing Office of the Secretary of Defense (OSD) and Army guidance for schedule documentation required to be completed by the programs. We then requested, obtained and reviewed available MPF and OMFV schedule documentation and compared them to the key scheduling leading practices identified in GAO's Schedule Assessment Guide.[1] We identified schedule documentation the programs completed that were identified in the Schedule Assessment Guide. To determine the delay in the OMFV schedule, we reviewed existing programmatic schedules for review dates and project milestones and compared them against prior schedules. Because detailed schedule documentation that lends itself to a full schedule analysis through GAO's Schedule Assessment Guide is not yet available, we cannot definitively determine if the 5-year schedules for prototyping for MPF and OMFV are realistic and reliable.

To evaluate the extent to which MPF and OMFV cost estimates reduce risk, we obtained and analyzed the MPF and OMFV life-cycle cost estimates and documentation supporting the Army's cost estimating practices. This documentation included an independent cost estimate, budget data, and management briefings and reports. We assessed MPF

[1]GAO-16-89G.

and OMFV cost estimates by comparing the estimates and supporting documentation to the leading practices discussed in GAO's Cost Estimating and Assessment Guide.[2] These practices have been found to be the basis for reliable cost estimates. Specifically, we reviewed each cost estimate against leading practices to support four characteristics—comprehensive, well-documented, accurate, and credible which are described in table 3.

Table 3: Four Characteristics of a Reliable Cost Estimate and Summary of Leading Practices

Characteristic	Summary of leading practices
Comprehensive	The cost estimate should include both government and contractor costs of the investment over its full life-cycle, from inception through design, development, deployment, and operation and maintenance, to retirement of the investment. It should also completely define the investment, reflect the current schedule, and be technically reasonable. Comprehensive cost estimates should be structured in sufficient detail (at least three levels of cost elements) to ensure that costs are neither omitted nor double counted. Specifically, the cost estimate should be based on a product-oriented work breakdown structure that allows an investment to track cost and schedule by defined deliverables, such as hardware or software components. Finally, where information is limited and judgments must be made, the cost estimate should document all cost-influencing ground rules and assumptions.
Well documented	A good cost estimate—while taking the form of a single number—is supported by detailed documentation that describes how it was derived and how the expected funding will be spent in order to achieve a given objective. Therefore, the documentation should capture in writing such things as the source data used, the calculations performed and their results, and the estimating methodology used to derive each work breakdown structure element's cost. Moreover, the cost estimate information should be captured in such a way that the data used to derive the estimate can be traced back to and verified against their sources so that the estimate can be easily replicated and updated. The documentation should also discuss the technical baseline description and how the data were normalized. Lastly, the final cost estimate should be reviewed and accepted by management on the basis of confidence in the estimating process and the estimate produced by the process.
Accurate	The cost estimate should provide results that are unbiased, and it should not be overly conservative or optimistic. An estimate is accurate when it is based on an assessment of most likely costs, adjusted properly for inflation, and contains few, if any, minor mistakes. A cost estimate should be updated regularly to reflect material changes in the investment, such as when schedules or other assumptions change, and actual costs, so that it is always reflecting current status. The estimate should be grounded in a historical record of cost estimating and actual experiences on other comparable investments.
Credible	The cost estimates should discuss any limitations of the analysis because of uncertainty or biases surrounding data or assumptions. Major assumptions should be varied, and other outcomes recomputed to determine how sensitive they are to changes in the assumptions (i.e., sensitivity analysis). A risk and uncertainty analysis should be performed to determine the level of risk associated with the estimate. For management to make good decisions, the investment's estimate must reflect the degree of uncertainty, so that a level of confidence can be given about the estimate. Having a range of costs around a point estimate is more useful to decision makers because it conveys the level of confidence in achieving the most likely cost and also informs them on cost, schedule, and technical risks. The estimate's results should be cross-checked and an independent cost estimate conducted by a group outside the acquiring organization should be developed to determine whether other estimating methods produce similar results.

Source: GAO-20-579

[2]GAO-09-3SP.

We supplemented our analysis with interviews of cognizant Army officials. These officials included program and other officials responsible for developing the MPF and OMFV cost estimates as well as Deputy Assistant Secretary of the Army for Cost and Economics, and the Army G-8. From these officials, we sought additional information on each program's approach to developing cost estimates and the steps taken, if any, to establish department cost estimation guidance specific to middle-tier acquisitions.

To assess the extent to which the Army technology efforts reduce acquisition risks for the NGCV portfolio, we obtained and reviewed Army and DOD documentation on MPF and OMFV including but not limited to acquisition plans, acquisition strategy documents, technology readiness assessment briefings, and reports to Congress. We also interviewed Army officials to learn about technology development activities they had conducted or planned to conduct. We then compared Army documentation and cross-functional team officials' statements against leading practices for weapons systems acquisitions identified in our prior work, specifically leading practices at the start of system development.[3] We also assessed relevant data from Army documentation and statements from Army officials regarding the Ground Vehicle System Center process for conducting technology readiness assessments in a record of analysis. We applied a selected subset of leading practices outlined in GAO's Technology Readiness Assessment Guide as criteria for this analysis.[4] The full breadth of leading practices were not applied because neither MPF nor OMFV identified critical technologies that could be assessed at the time of our review.

To assess how the Army is communicating internally and externally to reduce acquisition risks for the NGCV portfolio, we interviewed officials from various Army offices about Army's cross-functional team model and their efforts to communicate with stakeholders. Army offices that we interviewed include the Next Generation Combat Vehicles cross-functional team; Armored Multi-Purpose Vehicle program office; Mobile Protected Firepower program office; Optionally Manned Fighting Vehicle program office; Program Executive Officer Ground Combat Systems; Army Contracting Command; Army Ground Vehicle Systems Center; Network cross-functional team; Assistant Secretary of the Army for Acquisition, Logistics, and Technology; Deputy Assistant Secretary of the

[3]GAO-19-336SP.

[4]GAO-20-48G.

Army for Cost and Economics, and Research and Technology. We also interviewed various offices in the Department of Defense about Army's communication with them, including the Office of the Under Secretary of Defense, Acquisition and Sustainment; the Office of the Under Secretary of Defense, Research and Engineering, and the Office of Cost Assessment and Program Evaluation.

We conducted this performance audit from May 2019 to August 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.

Appendix II: Comments from the Department of the Army

DEPARTMENT OF THE ARMY
UNITED STATES ARMY FUTURES COMMAND
210 W. 7TH STREET
AUSTIN, TEXAS 78701-2903

FCDC

MEMORANDUM FOR John Ludwigson, Director, Defense Capabilities and Management, U.S. Government Accountability Office, 441 G Street, NW, Washington, DC 20548

SUBJECT: Army Response to GAO Draft Report, GAO-20-579, "NEXT GENERATION COMBAT VEHICLES: As Army Prioritizes Rapid Development, More Attention Needed to Provide Insight on Cost Estimates and Systems Engineering Risks" dated June 9, 2020 (GAO Code 103516)

1. This is the Army response to the Government Accountability Office (GAO) Draft Report, GAO-20-579, "NEXT GENERATION COMBAT VEHICLES: As Army Prioritizes Rapid Development, More Attention Needed to Provide Insight on Cost Estimates and Systems Engineering Risks," dated 9 June 2020.

2. GAO made three recommendations to the Secretary of the Army. The Army concurs with the recommendations. The enclosed document describes planned corrective actions to address each recommendation.

3. The point of contact for this action is Mike Porter; Headquarters, Army Futures Command Internal Review at 512.960.5970 or mychal.l.porter.civ@mail.mil.

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SUSAN J. GOODYEAR
Executive Deputy to the
Commanding General

JAMES M. RICHARDSON
Lieutenant General, USA
Deputy Commanding General

GAO DRAFT REPORT DATED JUNE 9, 2020
GAO-20-579 (GAO CODE 103516)

"NEXT GENERATION COMBAT VEHICLES: AS ARMY PRIORITIZE RAPID DEVELOPMENTS, MORE ATTENTION NEEDED TO PROVIDE INSIGHT ON COST ESTIMATES AND SYSTEMS ENGINEERING RISKS"

DEPARTMENT OF THE ARMY (DA) COMMENTS

RECOMMENDATION 1: The GAO recommends that the Secretary of the Army should direct the Mobile Protected Firepower (MPF) program to update its cost estimates to include analyses to support the development of a range of possible cost outcomes for decision makers in a manner consistent with GAO's Cost Estimation Guide. (Recommendation 1)

DA RESPONSE: The Army concurs with the recommendation.

In September 2018, the Army completed formulation of a well-documented, comprehensive MPF Army Cost Position (ACP) to inform the decision to utilize Middle Tier Acquisition (MTA) authorities to execute MPF rapid prototyping. Through the employment of competition and firm fixed price (FFP) rapid prototyping contracts, the MPF program significantly minimized cost risk during the rapid prototyping phase. Furthermore, the MPF rapid prototyping solicitation prioritized system requirements and provided design trade space to improve the ability of contractors to meet the system's key performance Parameters (KPPs) and execute within the program's schedule and cost constraints. Given these efforts to mitigate cost risk, the Army determined the cost sensitivity analyses performed during the development of the MPF ACP sufficiently assessed cost risk to inform the MTA decision.

In support of all future MPF program milestone decisions, the Army will focus on uncertainty analysis when formulating cost estimates, both quantitatively and qualitatively, to provide decision makers with a range of possible cost outcomes. The Army will analyze uncertainty in a manner consistent with applicable DoD guidance, and will focus its analysis on key variables and drivers of cost risk. Uncertainty analysis will be applied in the development of cost estimates for all programs beginning in the 3rd Quarter of FY 21.

RECOMMENDATION 2: The GAO recommends that the Secretary of the Army should direct the Optionally Manned Fighting Vehicle (OMFV) program to update its cost estimate to include analyses to support the development of a range of possible cost outcomes for decision makers in a manner consistent with GAOs Cost Estimation Guide. (Recommendation 2)

DA RESPONSE: The Army concurs with the recommendation.

Prior to the issuance of specific policy regarding Middle Tier Acquisition – Rapid Prototyping (MTA-RP) programs, the Army conducted a well-documented and comprehensive OMFV life-cycle cost estimate to support the release of the OMFV Request for Proposals (RFP). As the

resultant OMFV Draft Army Cost Position (Draft ACP) was completed prior to RFP release in March 2019, specific solutions were unknown.

The OMFV RFP employed a Firm-Fixed Price (FFP) strategy with annual funding limits as a means of controlling near-term cost risk prior to awarding contracts. Additionally, the Army planned to update the OMFV Draft ACP to support an MTA-RP contract award decision and future milestone decisions. Therefore, the Army deemed the Draft ACP, combined with discussions of cost risk and sensitivity analysis conducted at various echelons of leadership, were sufficient to support the release of the OMFV RFP.

The Army, in support of all future OMFV program milestone decisions, will focus on uncertainty analysis when formulating cost estimates, both quantitatively and qualitatively, to provide decision makers with a range of possible cost outcomes. The Army will analyze uncertainty in a manner consistent with applicable DoD guidance, and will focus its analysis on key variables and drivers of cost risk. Uncertainty analysis will be applied in the development of cost estimates for all programs beginning in the 3rd Quarter of FY 21.

RECOMMENDATION 3: The GAO recommends that the Secretary of the Army should direct the OMFV program to inform requirements by conducting system engineering reviews at key decision points consistent with our leading practices for acquisitions, as the program office finalizes its acquisition approach. (Recommendation 3)

DA RESPONSE: The Army concurs with the recommendation.

Project Manager—Maneuver Combat Systems (PM MCS) is executing system requirements reviews at the start of work meeting for the OMFV digital design phase. The program will also execute a system functional review and a preliminary design review during the digital design phase. The Next Generation Combat Vehicles Cross Functional Team will use these system engineering reviews, along with trade-space exploration tools, Soldier Touchpoints, test and evaluation of digital designs, and physical prototypes to refine the Army's desired OFMV characteristics into final requirements in support of the Army's Middle Tier Acquisition – Rapid Prototyping approach. This innovative approach will maximize industry partners' ability to develop creative, innovative solutions, and the iterative reviews will ensure these cutting-edge solutions are ultimately feasible for the OMFV's production.

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Jon Ludwigson, (202) 512-4841 or ludwigsonj@gao.gov

Staff Acknowledgments

In addition to the contact named above, J. Kristopher Keener (Assistant Director), Scott Purdy (Analyst-in-Charge), Jessica Berkholtz, Joy Kim, Hunter Stephan, Sarah Cantatore, Stephanie Gustafson, Robin Wilson, Brian Bothwell, Jennifer Leotta, Emile Ettedgui, John Ortiz, Hai Tran, Mary Weiland, Marie Ahearn, and Alyssa Weir made significant contributions to this review.

Related GAO Products

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