



May 2020

F-35 JOINT STRIKE FIGHTER

Actions Needed to Address Manufacturing and Modernization Risks

GAO Highlights

Highlights of [GAO-20-339](#), a report to congressional committees

Why GAO Did This Study

The acquisition cost for the F-35 program increased substantially in 2019, partially due to the program's addition of estimated costs for modernization of hardware and software systems, referred to as its Block 4 efforts.

This is the fifth report under the provision that Congress included in statute for GAO to review the F-35 program annually until the program reaches full-rate production. This is also the first report under another provision in statute to review the program's production and Block 4 progress annually through 2024. Among other objectives, this report assesses (1) the program's production performance and (2) the program's modernization cost estimate and development progress. GAO reviewed Department of Defense (DOD) and contractor documentation and interviewed DOD officials and contractor representatives.

What GAO Recommends

Congress should consider extending DOD's reporting requirement for Block 4 modernization beyond 2023. GAO is also making five recommendations to DOD. While DOD did not concur with two of these recommendations—including to evaluate production risks and update its Block 4 cost estimate with a program-level plan, it identified actions that, if implemented, will meet the intent of these recommendations. DOD concurred with GAO's three other recommendations.

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What GAO Found

The F-35 program is at risk of missing its test schedule and not meeting manufacturing leading practices. In 2019, the F-35 program conducted much of its planned operational testing but extended the schedule by 9 months, which delays the program's full-rate production decision to between September 2020 and March 2021. Over that time, the program will continue to deliver aircraft.

In addition, while the F-35 program has increased the production rate and negotiated lower aircraft prices, it is not meeting manufacturing leading practices identified by GAO. Specifically, only about 3,000 of the over 10,000 airframe contractor's manufacturing key processes meet predefined design standards for ensuring product quality. Also, the fielded aircraft, over 500 so far, do not meet the program's reliability and maintainability goals. Although the contractor is changing manufacturing processes to address problems and improve efficiency, more remains to be done. Unless the program office evaluates the risks of not meeting these leading practices, the military services and international partners are at risk of not receiving the quality aircraft they purchased.

An F-35 in Flight over Edwards Air Force Base



Source: © Lockheed Martin. | GAO-20-339

In addition, the July 2019 suspension of Turkey from the F-35 program—due to security concerns after its acquisition of Russian defense equipment—is likely to compound production risks. The program has identified new sources for 1,005 parts produced by Turkish suppliers, but the program is assessing the effect of 15 key parts not currently being produced at the needed production rate.

In 2019, estimated development costs to modernize the F-35's hardware and software systems—known as Block 4—increased by over \$1.5 billion. The cost increase puts estimated Block 4 development costs at \$12.1 billion. However, the cost estimate did not fully adhere to leading practices, such as including all life cycle costs. In addition, while development will continue through 2026, reports on Block 4 that the program submits to Congress are slated to end in 2023. Without continued Block 4 reporting through the development phase, Congress will lack important oversight information.

Contents

Letter		1
	Background	3
	Operational Testing Delays Provide More Time to Address Deficiencies before Full-Rate Production Decision	11
	F-35 Aircraft Prices Decreased but Manufacturing and Supply Chain Risks Remain	18
	Block 4 Reporting Requirement Expires Before Completion Date, and Cost Estimate Does Not Fully Reflect Leading Practices	31
	Conclusions	38
	Matter for Congressional Consideration	40
	Recommendations for Executive Action	40
	Agency Comments and Our Evaluation	41
Appendix I	Prior GAO Reports on the F-35 Acquisition Program and DOD Actions	44
Appendix II	F-35 Block 4 Development Cost Estimate Analysis	48
Appendix III	Objectives, Scope, and Methodology	51
Appendix IV	The F-35's Reliability and Maintainability Metrics	54
Appendix V	Status of Selected F-35 Technical Risks	55
Appendix VI	Comments from the Department of Defense	57
Appendix VII	GAO Contact and Staff Acknowledgments	60

Related GAO Products

61

Tables

Table 1: F-35 Joint Strike Fighter Acquisition Program Cost Estimates, October 2001 to April 2019	8
Table 2: Assessment of the Extent to Which DOD's F-35 Modernization Development Cost Estimate Meets GAO's Leading Practices	35
Table 3: Select Prior GAO Reports on F-35 Joint Strike Fighter and Department of Defense (DOD) Responses	44
Table 4: Assessment of the F-35's Block 4 Development Cost Estimate Compared to Leading Practices	49
Table 5: The F-35 Reliability & Maintainability Metrics' Performance as of August 2019	54

Figures

Figure 1: An F-35B Exercising Its Short Takeoff and Vertical Landing Capability on the USS America	4
Figure 2: The Eight Elements of the F-35 Air System	5
Figure 3: F-35 2019 and 2020 Operational Test Schedules and Key Events through 2020	12
Figure 4: Total F-35 Open and Closed Category 1 and 2 Deficiencies, as of December 2019	16
Figure 5: An Inverted F-35C Aircraft Fires an AIM-9X Missile	17
Figure 6: The Reported F-35A Negotiated Price per Aircraft Continues to Decrease	19
Figure 7: The Contractor Delivered More Aircraft on Time in 2019 Compared to Prior Years	20
Figure 8: F-35 Aircraft Hours for Scrap, Rework, and Repair between 2016 and 2019	22
Figure 9: F-35 On-Time and Late Engine Deliveries Since 2016	23
Figure 10: F-35 Engine Quality Notifications Since 2016	24
Figure 11: F-35 Aircraft in Final Assembly	27

Abbreviations

ALIS	Autonomic Logistics Information System
C2D2	Continuous Capability Development and Delivery
DOD	Department of Defense
DOT&E	Director of Operational Test and Evaluation
NDA	National Defense Authorization Act
ODIN	Operational Data Integrated Network
OUSD (A&S)	Office of the Undersecretary of Defense for Acquisition and Sustainment
R&M	Reliability and Maintainability
WBS	work breakdown structure

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May 12, 2020

Congressional Committees

Also known as the Joint Strike Fighter, the F-35 Lightning II is the Department of Defense’s (DOD) most expensive weapon acquisition program in U.S. military history. DOD is now in its 19th year of developing this family of fifth-generation strike fighter aircraft for the United States Air Force, Marine Corps, and Navy, as well as seven international partners.¹ The F-35’s key capabilities include low-observable, or stealth, technology combined with advanced sensors and computer networking capabilities. The F-35’s acquisition cost increased by over \$22 billion in 2019, in part due to the addition of estimated costs for its modernization efforts, or Block 4. The total acquisition costs for the F-35 exceed \$428 billion and include the procurement of 2,470 U.S. aircraft through fiscal year 2044.

To date, the program has delivered almost 500 aircraft to the warfighter even though operational testing—which will determine if the aircraft is operationally effective and suitable—is ongoing. In October 2019, the program delayed its full-rate production decision, a review that authorizes entry into the production and deployment phase, to sometime between September 2020 and March 2021 so it could complete this testing. However, the program still faces risks ahead of that decision. We have reported on these and other program risks in the past and made recommendations for improvement. DOD has taken action to address some, but not all, of our recommendations. For a list of our recommendations to the F-35 acquisition program and a summary of DOD’s actions in response, see appendix I. In addition, a list of related GAO products is included at the end of the report.

This report fulfills two mandates. First, the National Defense Authorization Act (NDAA) for Fiscal Year 2015 included a provision for us to review the

¹The international partners are the United Kingdom, Italy, the Netherlands, Canada, Australia, Denmark, and Norway. These nations contributed funds for system development, and as of February 2020, all but Canada have signed agreements to procure aircraft. In addition, Belgium, Israel, Japan, Poland, and South Korea have signed on as foreign military sales customers, and Singapore plans to do so. Turkey was a partner in the development, but as verified by the F-35 program office, Turkey was suspended from the program in 2019. A growing number of allied nations are buying F-35s through foreign military sales in support of U.S. national security interests and interoperability.

F-35 program annually until the program reaches full-rate production.² This is our fifth report under that provision.³ Second, the NDAA for Fiscal Year 2020 included a provision for us to review the program's production and Block 4 progress annually through 2024.⁴ In this report, we (1) provide information on the program's progress toward completing operational testing and resolving deficiencies found in testing; (2) assess the program's production performance and manufacturing efficiency initiatives; and (3) assess the program's modernization cost estimate and progress with Block 4 development efforts.

For all objectives, we interviewed DOD officials and contractor representatives regarding the program's activities, progress, and plans.

- To provide information on what progress the program has made in operational testing and resolving deficiencies, we reviewed test event progress and schedules, program briefings, and internal DOD briefings. We analyzed program documentation and updates on resolved and newly identified deficiencies. We also interviewed DOD officials and contractor representatives regarding the deficiencies and resolution time frames.
- To assess the program's production performance and manufacturing efficiency initiatives, we collected and analyzed production performance data from the program office, the prime airframe contractor, and the prime engine contractor. We analyzed the extent to which the program has met GAO's manufacturing leading practices, which programs should follow prior to making a full-rate production

²The National Defense Authorization Act for 2015, Pub. L. No. 113-291, § 153(a) (2014).

³GAO, *F-35 Joint Strike Fighter: Action Needed to Improve Reliability and Prepare for Modernization Efforts*, [GAO-19-341](#) (Washington, D.C.: Apr. 29, 2019); *F-35 Joint Strike Fighter: Development Is Nearly Complete, but Deficiencies Found in Testing Need to Be Resolved*, [GAO-18-321](#) (Washington, D.C.: June 5, 2018); *F-35 Joint Strike Fighter: DOD Needs to Complete Developmental Testing Before Making Significant New Investments*, [GAO-17-351](#) (Washington, D.C.: Apr. 24, 2017); and *F-35 Joint Strike Fighter: Continued Oversight Needed as Program Plans to Begin Development of New Capabilities*, [GAO-16-390](#) (Washington, D.C.: Apr. 14, 2016).

⁴The National Defense Authorization Act for 2020, Pub. L. No. 116-92, § 166(b)(1)-(2) (2020).

decision.⁵ We also reviewed the Defense Contract Management Agency's reports on F-35 production.

- To assess the program's Block 4 cost estimate and development progress, we reviewed program office planning and implementation documents as well as documentation of the cost estimate, such as cost models and analyses. We assessed the cost estimating methodologies, assumptions, and results against leading practices for developing a comprehensive, accurate, well-documented, and credible cost estimate, identified in GAO's Cost Estimating and Assessment Guide.⁶ Appendix II contains more information about how we applied our cost estimating leading practices.

We determined that all the data we used were sufficiently reliable for the purposes of our reporting objectives. For example, we collected and analyzed the program's production data for all production lots and corroborated these metrics by interviewing contractor representatives and DOD officials in oversight offices such as the Defense Contract Management Agency. In addition, we reviewed official program documentation on the Block 4 efforts and corroborated it with officials across DOD involved in the effort, such as the F-35 Joint Program Office cost estimating team and DOD's Cost Assessment and Program Evaluation office, regarding Block 4. Appendix III contains a detailed description of our scope and methodology.

We conducted this performance audit from June 2019 to May 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

DOD started the F-35 program in 2001 to develop a fifth-generation fighter aircraft intended to replace a range of aging aircraft in the U.S. military services' inventories and to provide enhanced capabilities to warfighters that capitalized on technological innovations. Among other capabilities, the program designed the F-35 aircraft to be difficult to

⁵GAO, *Best Practices: DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed*, [GAO-10-439](#) (Washington, D.C.: Apr. 22, 2010).

⁶GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, [GAO-09-3SP](#) (Washington, D.C.: Mar. 2009).

observe using radar and include sensors that can provide insights into potential targets and other warfighting information. The program is producing and delivering three variants of the F-35 aircraft:

- the F-35A conventional takeoff and landing variant for the Air Force,
- the F-35B short takeoff and vertical landing variant for the Marine Corps, and
- the F-35C carrier-suitable variant for the Marine Corps and the Navy.

The characteristics of the services' variants are similar, but each variant also has unique operating requirements. For example, the Marine Corps requires that the F-35B be capable of operating from aircraft carriers, amphibious ships, and main and austere operating bases alike, requiring the capability to conduct short takeoffs and vertical landings. Figure 1 shows an F-35B exercising this capability.

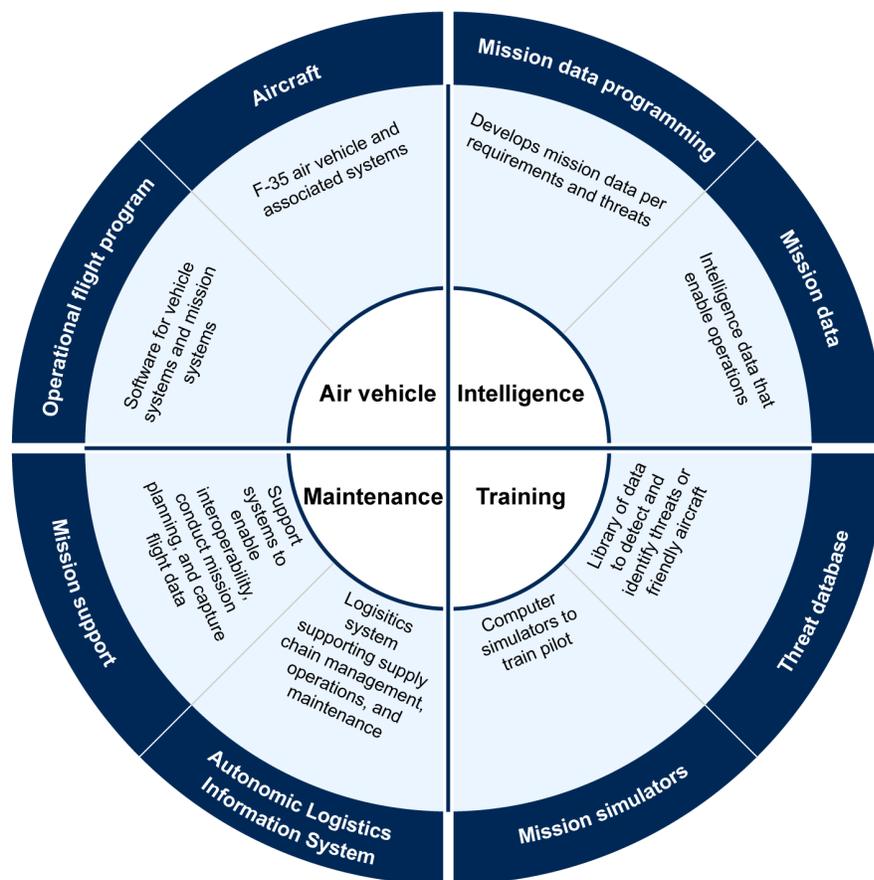
Figure 1: An F-35B Exercising Its Short Takeoff and Vertical Landing Capability on the USS America



Source: © Lockheed Martin. | GAO-20-339

While DOD plans to purchase 2,470 aircraft for the U.S. services, the F-35 program is acquiring more than just aircraft. The complete F-35 air system has eight elements, including training and maintenance systems. Figure 2 shows the eight elements that make up the entire F-35 Air System and how they each support the aircraft.

Figure 2: The Eight Elements of the F-35 Air System



Source: GAO interpretation of Department of Defense data. | GAO-20-339

For example, the program intends for the Automated Logistics Information System (ALIS) to provide the necessary logistics tools to F-35 program participants as they operate and sustain the F-35 aircraft. To do this, ALIS consists of multiple software applications designed to support different squadron activities, such as supply chain management, maintenance, training management, and mission planning. For the F-35 aircraft to have

full capability, each element of the air system has to be developed and fielded in sync with the aircraft. However, we found in March 2020 that problems with ALIS still pose significant challenges to day-to-day F-35 operations.⁷ According to DOD, it plans to replace ALIS with a new system named the Operational Data Integrated Network (ODIN). Furthermore, DOD reports that it is currently developing a strategy for ODIN, which will include key tasks, milestones and schedule, risks and opportunities, governance structure, and cost estimates. We concluded that, as DOD proceeds with replacing ALIS with ODIN, it will be important for the department to carefully consider and assess the key technical and programmatic uncertainties that we reported in March 2020. These include how much of ALIS will be incorporated in ODIN and the extent to which DOD has access to the data it needs to play a more active role in the management of the system.⁸ These issues are complex, and will require significant direction and leadership to resolve.

Further, we reported in March 2020 that the F-35 program office was not able to provide us with historic costs showing how much the department had spent on ALIS over the years. Also, because DOD had not answered key questions about the future of the system, such as the extent to which the re-design will incorporate current ALIS software, DOD has not been able to develop accurate cost estimates for the ALIS re-design. We recommended that DOD develop and implement a strategy for the re-design of ALIS.⁹ The strategy should be detailed enough to clearly identify and assess the goals, key risks or uncertainties, and costs of re-designing the system. DOD concurred with the recommendation.

Status of F-35 Program Development and Costs as of April 2019

DOD began development of the F-35 aircraft in 2001 without adequate knowledge of its critical technologies or a solid design, as we reported in March 2005.¹⁰ DOD's acquisition strategy also called for high levels of concurrency between development and production—building aircraft while continuing to refine the designs of key components—which runs counter to GAO's leading practices for major defense acquisition

⁷GAO, *Weapon System Sustainment: DOD Needs a Strategy for Re-Designing the F-35's Central Logistics System*, [GAO-20-316](#) (Washington, D.C.: Mar. 6, 2020).

⁸[GAO-20-316](#).

⁹[GAO-20-316](#).

¹⁰GAO, *Tactical Aircraft: Opportunity to Reduce Risks in the Joint Strike Fighter Program with Different Acquisition Strategy*, [GAO-05-271](#) (Washington, D.C.: Mar. 15, 2005).

programs.¹¹ In our prior work, we identified the F-35 program's lack of adequate knowledge and high levels of concurrency as the major drivers of the program's eventual significant cost and schedule growth, among other performance shortfalls.¹²

Since 2001, the program has been rebaselined with new cost and schedule estimates three times. DOD initiated the most recent restructuring in 2010 when the program's cost estimates for each aircraft exceeded critical thresholds established by statute—a condition known as a Nunn-McCurdy breach.¹³ DOD then established a new acquisition program baseline that increased the program's cost estimates by \$162.7 billion and extended delivery schedules 5-6 years into the future. This last revision is the current program baseline, reflecting the cost and schedule estimates to deliver the aircraft and systems and to meet the original program requirements.

From 2018 to 2019, the total cost estimate of the F-35 acquisition program increased by \$22 billion, from \$406 billion to over \$428 billion. This increase was partially due to the addition of the estimated Block 4 modernization costs. Block 4 includes efforts to enhance and add capabilities—beyond the F-35 baseline program—through hardware and software upgrades. In April 2019, the F-35 program estimated that Block 4 development and procurement costs would add \$13.9 billion to the program's total baseline cost.¹⁴ Beyond this Block 4 increase, the F-35

¹¹GAO, *Joint Strike Fighter: DOD Actions Needed to Further Enhance Restructuring and Address Affordability Risks*, [GAO-12-437](#) (Washington, D.C.: June 14, 2012).

¹²[GAO-05-271](#); [GAO-12-437](#).

¹³Section 2433 of title 10 of the United States Code, commonly referred to as Nunn-McCurdy, requires DOD to notify Congress whenever a major defense acquisition program's unit cost experiences cost growth that exceeds certain thresholds. Significant breaches occur when the program acquisition unit cost or procurement unit cost increases by at least 15 percent over the current baseline estimate or at least 30 percent over the original estimate. For critical breaches, when these unit costs increase at least 25 percent over the current baseline estimate or at least 50 percent over the original, DOD is required to take additional steps, including conducting an in-depth review of the program. Programs with critical breaches must be terminated unless the Secretary of Defense certifies to certain facts related to the programs and takes other actions, including restructuring the programs. 10 U.S.C. § 2433a.

¹⁴The \$13.9 billion for Block 4 development and procurement represents estimated costs in the December 2018 Selected Acquisition Report. Later in this report, we cite the F-35 program office's Block 4 development cost estimate, which was developed after the 2018 Selected Acquisition Report. In that portion of the report, we identified that the Block 4 development costs alone increased by \$1.5 billion to a total of \$12.1 billion.

program baseline costs also increased by \$8 billion over the program's 2018 estimate.

Table 1 outlines the program's baseline costs, the Block 4 modernization costs, and the sum total of the baseline and Block 4 cost estimates since 2001.

Table 1: F-35 Joint Strike Fighter Acquisition Program Cost Estimates, October 2001 to April 2019

	October 2001 baseline	March 2012 baseline	Difference from 2001 to 2012	April 2019 estimate	Difference from 2012 to 2019
F-35 baseline development program costs—does not include Block 4 costs (then-year dollars in billions)^a					
Development	34.4	55.2	20.8	57.3	2.1
Procurement	196.6	335.7	139.1	351.9	16.2
Military construction	2	4.8	2.8	5.2	0.4
Total program acquisition	233	395.7	162.7	414.4	18.7
F-35 Block 4 modernization costs (then-year dollars in billions)^b					
Development	NA	NA	NA	10.6	NA
Procurement	NA	NA	NA	3.4	NA
Military construction	NA	NA	NA	NA	NA
Total program acquisition	NA	NA	NA	13.9	13.9
Sum total of F-35 baseline and Block 4 costs	233	395.7	162.7	428.4	32.7

Source: GAO analysis of Department of Defense data. | GAO-20-339

^aAnnual projected cost estimates expressed in then-year dollars reflect inflation assumptions. We did not assess the reliability of the program office's F-35 baseline cost estimates. Amounts may not sum due to rounding.

^bWe assessed the F-35 program's Block 4 cost estimate; see our Block 4 finding.

In addition to the acquisition costs above, the program estimates that the sustainment costs to operate and maintain the F-35 fleet for its planned 66-year life cycle are \$1.2 trillion, bringing the total cost of the F-35 program to over \$1.6 trillion.

Status of Testing, Production, and Reliability and Maintainability as of December 2019

The F-35 program office, in coordination with the Director of Operational Test and Evaluation (DOT&E), received approval to conduct some preliminary operational testing in January 2018. This included weapons, cybersecurity, and cold weather testing, among other things. The program's formal operational testing (conducted by DOT&E) started in December 2018 and was ongoing in 2019. The purpose of operational testing is to assess the effectiveness, suitability, survivability, lethality, and mission capability of the F-35, including the information systems and the air vehicle, in an operationally representative environment.

Operational testing includes cybersecurity assessments, some of which the program has conducted. The program plans for the remaining testing to take place through at least September 2020, while the program continues to produce and deliver aircraft.

Through 2019, F-35 program test officials had identified over 3,200 deficiencies. Deficiencies represent specific instances where the weapon system either does not meet requirements or where the safety, suitability, or effectiveness of the weapon system could be affected.¹⁵ The test officials categorize deficiencies according to their potential impact on the aircraft's performance.

- Category 1 deficiencies are critical and could jeopardize safety, security, or another requirement.
- Category 2 deficiencies are those that could impede or constrain successful mission accomplishment.

In June 2018, we recommended that the program resolve all critical deficiencies before making a full-rate production decision, in part, to reduce the potential for additional concurrency costs stemming from continuing to produce aircraft while testing was ongoing.¹⁶ DOD concurred with our recommendation and stated that it would resolve critical deficiencies before full-rate production, currently planned to occur between September 2020 and March 2021.

Production of the aircraft began one year after testing started in 2007, while development was in its early stages. Due to the concurrency of testing and production, according to an F-35 program official, as many as 550 aircraft delivered through 2020 will need retrofits to fix deficiencies and design issues found during testing.¹⁷ The program refers to the cost of these fixes as its concurrency cost, which the program estimates at \$1.4 billion; this estimate did not change with the program's last update in 2019.¹⁸ Until operational testing is complete, there is a risk that the

¹⁵Developmental testing is intended to provide feedback on the progress of a system's design process and its combat capability as it advances toward initial production or deployment.

¹⁶[GAO-18-321](#).

¹⁷This total includes U.S., international partner, and foreign military sales aircraft.

¹⁸This estimate includes deficiencies that testers may still identify in operational testing.

program may identify additional deficiencies. As a result, as we have previously reported, the concurrency costs of retrofitting delivered aircraft could increase.¹⁹

In our June 2018 report, we found that the program was not on track to meet its reliability and maintainability (R&M) performance targets.²⁰ R&M targets indicate how much time the aircraft will be in maintenance rather than operations. We concluded that the program was missing a prime opportunity to infuse affordability into the aircraft's future with better R&M performance. As a result, we recommended that the F-35 program office identify what steps it needed to take to ensure the F-35 meets R&M requirements and update the R&M Improvement Program with these steps. DOD concurred with the recommendations, noting that the F-35 program office would update the R&M Improvement Program with the steps needed to ensure continued progress towards its goals. In April 2019, we found that F-35 R&M performance had shown some small improvements but that the program could take more actions to meet the R&M targets.²¹ We made additional recommendations to the Secretary of Defense, with which DOD concurred and has taken some actions to implement. Currently, the Office of the Under Secretary of Defense for Acquisition and Sustainment (OUSD (A&S)) is the acquisition decision authority for the F-35 program, and would direct the F-35 program office to take any further actions. In 2019, the program's R&M performance generally remained unchanged. However, measurable improvements in R&M can take time to manifest. For example, fielded aircraft must be modified and flown for many hours before the program can measure improvements. For details about the R&M performance, see appendix IV.

Block 4 Modernization's Development Approach

As we have previously reported, even though operational testing of the baseline program remains ongoing, the F-35 program office has turned its attention to Block 4 modernization activities using a different development approach.²² DOD refers to this approach as Continuous Capability Development and Delivery (C2D2). This method is loosely based on the Agile software development process. With this approach, the program plans to deliver capabilities to the warfighter faster than it did during the baseline development program. For example, rather than take years to

¹⁹[GAO-19-341](#).

²⁰[GAO-18-321](#).

²¹[GAO-19-341](#).

²²[GAO-19-341](#).

develop and deliver all the required capabilities to the warfighter, the program intends to incrementally develop, test, and deliver small groups of capabilities every 6 months. In January 2018, to transition from the baseline development program to its Block 4 activities, the F-35 program started using the C2D2 approach to develop and test software updates to address deficiencies identified during testing.

The planned \$13.9 billion Block 4 effort exceeds the statutory and regulatory thresholds for what constitutes a major defense acquisition program, and Block 4 is more expensive than many of the other major weapon acquisitions already in DOD's portfolio.²³ To provide better oversight into Block 4 activities, in 2016, we recommended that the Secretary of Defense hold a milestone B review—a critical point in an acquisition program leading to the engineering and manufacturing development phase—and manage it as a separate major defense acquisition program.²⁴ DOD did not concur with our recommendation, and it continues to manage Block 4 within the larger F-35 program. We maintain that DOD should manage the Block 4 activities as a separate program.

Operational Testing Delays Provide More Time to Address Deficiencies before Full-Rate Production Decision

Completion of Operational Testing Delayed by 9 Months

In 2019, the F-35 program conducted a majority of its planned operational testing but added 9 months to the schedule to complete the remaining tests. Specifically, as of February 2020, according to test officials, the program completed 156 flight tests. The program must still conduct four open-air flight tests, the remaining cybersecurity tests of the air vehicle

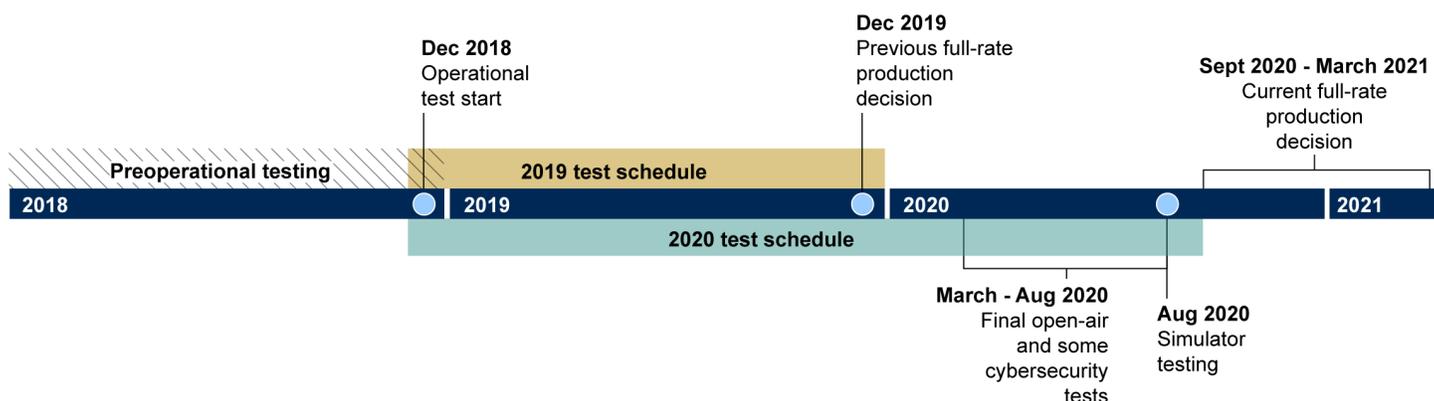
²³Major defense acquisition programs are those identified by DOD or that have a dollar value for all increments estimated to require eventual total expenditure for research, development, test, and evaluation of more than \$480 million, or for procurement of more than \$2.79 billion, in fiscal year 2014 constant dollars. See DOD Instruction 5000.02T, *Operation of the Defense Acquisition System* (Jan. 7, 2015) (incorporating change 6, Jan. 23, 2020). See also 10 U.S.C. § 2430.

²⁴[GAO-16-390](#).

and mission systems, and 64 simulated flight tests.²⁵ The 9-month delay needed to complete testing, however, also provides additional time for the program to address our June 2018 recommendation that it resolve critical deficiencies before making its full-rate production decision, currently planned to occur between September 2020 and March 2021.²⁶

Figure 3 shows the test schedule as of 2019, the delay to the schedule into 2020, and the remaining tests events planned.

Figure 3: F-35 2019 and 2020 Operational Test Schedules and Key Events through 2020



Source: GAO analysis of Department of Defense data. | GAO-20-339

The completion of operational testing hinges on three main tasks: (1) the final four open-air flight tests; (2) cybersecurity testing; and (3) the final development, integration, verification and validation of its simulator and 64 simulated flight tests.

First, the program expects to complete the four remaining open-air tests between March and April 2020. To conduct these tests, the program must finish moving the Radar Signal Emulators—test assets that simulate long-range threat radars—from the Nevada Test and Training Range to the Point Mugu Sea Range in California. According to test officials, there is some risk with this move, such as damage to the sensitive test

²⁵Besides the testing listed, the program also has several planned missile and bomb test events remaining to complete operational testing. According to test officials, these tests have been on hold awaiting deficiency fixes or test range availability. The program expects to complete these tests in 2020, before the end of operational testing. The remaining cybersecurity testing includes tests of ALIS.

²⁶GAO-18-321.

equipment. The test facilities will have to integrate the equipment into the testing infrastructure at Point Mugu.

Second, while the program has conducted cybersecurity testing on several aspects of the F-35 aircraft and support systems, three air vehicle subsystems tests and two enterprise-level ALIS tests remain. The program expects to complete these by August 2020. The tests completed to date have identified multiple cybersecurity vulnerabilities.²⁷ The F-35 program office has taken steps to address some identified vulnerabilities and is working to address the remainder. Test officials stated that some of the delays to cybersecurity testing of the aircraft are due to safety concerns and the risk of losing the use of a test aircraft before testing is complete.²⁸

According to DOD policy, cybersecurity testing should be conducted as early in the operational test cycle as possible.²⁹ Leaving this critical testing to the end of operational testing adds risk to the program because the program will not know the extent to which the aircraft may have cybersecurity vulnerabilities until near the expected decision to proceed to full-rate production.³⁰ If the program cannot finish these tests by September 2020, officials stated that DOT&E could require that the cybersecurity testing be completed in follow-on testing and not hold up the full-rate production decision. Any additional cybersecurity vulnerabilities may require more time to develop and implement plans to address vulnerabilities in aircraft that have already been produced and those slated for production.

Lastly, the program has not been able to complete the F-35 Joint Simulation Environment, which we refer to as the aircraft simulator, on time. The simulator runs the F-35's mission systems software along with

²⁷All cybersecurity test results and details are classified.

²⁸The F-35 program has 23 operational test aircraft because tests can require multiple aircraft for a single test. Program test officials stated that they do not want to lose any of these aircraft because the F-35 test aircraft have limited availability, in part, due to R&M issues and shortages of replacement parts.

²⁹Department of Defense, *Procedures for Operational Test and Evaluation of Cybersecurity in Acquisition Programs*. April 3, 2018.

³⁰We reported in October 2018 that, although DOD has begun taking steps to improve its overall weapon systems cybersecurity, it is also just beginning to grapple with its cybersecurity challenges. GAO, *Weapon Systems Cybersecurity: DOD Just Beginning to Grapple with Scale of Vulnerabilities*, [GAO-19-128](#) (Washington, D.C.: Oct. 9, 2018).

other software models (such as other weapons and modern threat systems) to provide complex test scenarios that the program cannot replicate in a real-world environment. We reported in April 2019 that the simulator's development was behind schedule and was a risk to operational testing.³¹ Since then, the program has struggled to develop the complex software and functionality needed to complete the simulator.

The difficulties stem, in part, from the program office's original plan to have the contractor, Lockheed Martin, develop the simulator. However, in August 2017, program office officials decided that the contractor's proposal was considered to be too expensive. To mitigate concerns over the cost of the proposal, the program decided to have the Navy complete the work. The program originally expected the Navy's simulator to be ready for testing in 2017, but it is now 3 years behind schedule. According to program office officials, the simulator's development effort has taken longer than expected to integrate F-35 aircraft and sensor data, in part because the contractor claimed the data as its own intellectual property. These issues were resolved by 2019 when the contractor provided the necessary data. Because of these delays, the program now expects that the simulator will be ready by August 2020, with the planned simulator testing expected to take about 3 weeks. According to test officials, there is increased risk that the completion of the simulator may face additional delays to correct deficiencies and add needed capabilities, but also stated that they can complete the tests by August 2020.

Due to these delays to completing operational testing, the program has delayed its full-rate production decision by at least an additional 9 months. Though the program is working toward September 2020, the program has acknowledged this decision could be made as late as March 2021.³² Any additional delays due to challenges with moving the emulators, completing the simulator, or cybersecurity testing could further delay the end of operational testing and the program's decision to enter

³¹[GAO-19-341](#).

³²The F-35 program originally planned for its full-rate production decision to occur in 2013.

into full-rate production. This delay, however, gives the program more time to complete two key steps consistent with statute and DOD policy.³³

- Complete operational testing, which is intended to demonstrate that the aircraft are operationally suitable.
- Resolve all deficiencies, which should be done prior to full-rate production, and is discussed below.

Even with these delays, the program plans to have produced and delivered over 550 aircraft before operational testing is complete, adding to the risk of finding more deficiencies that will require retrofits—at additional cost—for the delivered aircraft. Statute and DOD policy states that the preliminary low-rate production quantities will be set at the development request for proposal decision point. If, at that time, low-rate initial production quantities are determined to be above 10 percent of the total quantity planned, the Secretary of Defense must explain the reasons for the increase in a report to Congress. When a program reaches the planned low-rate initial production quantity, and requires to exceed the quantity, the program may seek approval to produce quantities above that amount.³⁴ The F-35 program will have delivered more than 10 percent of the total planned production quantities—due to the necessity to prevent a break in production—before operational testing and the full-rate production decision are complete. As noted above, this approach has contributed to the \$1.4 billion in concurrency costs already incurred by the program.

³³10 U.S.C. § 2399(b)((2)(A)-(B); DOD, *Operation of the Defense Acquisition System*. DODI 5000.02. (Washington, D.C.: Jan. 7, 2015). (incorporating change 4, August 2018). DoD reissued and updated DODI 5000.02 on January 23, 2020, and it is now entitled *Operation of the Adaptive Acquisition Framework*. See DODI 5000.02, *Operation of the Adaptive Acquisition Framework*. (Washington, D.C.: Jan. 23, 2020). DOD renumbered the 2015 DODI 5000.02 to DODI 5000.02T, and DODI 5000.02T will remain in effect with content removed as it is cancelled or transitions to a new issuance. For the purposes of this report, we used the prior iteration, as it was in place during our review.

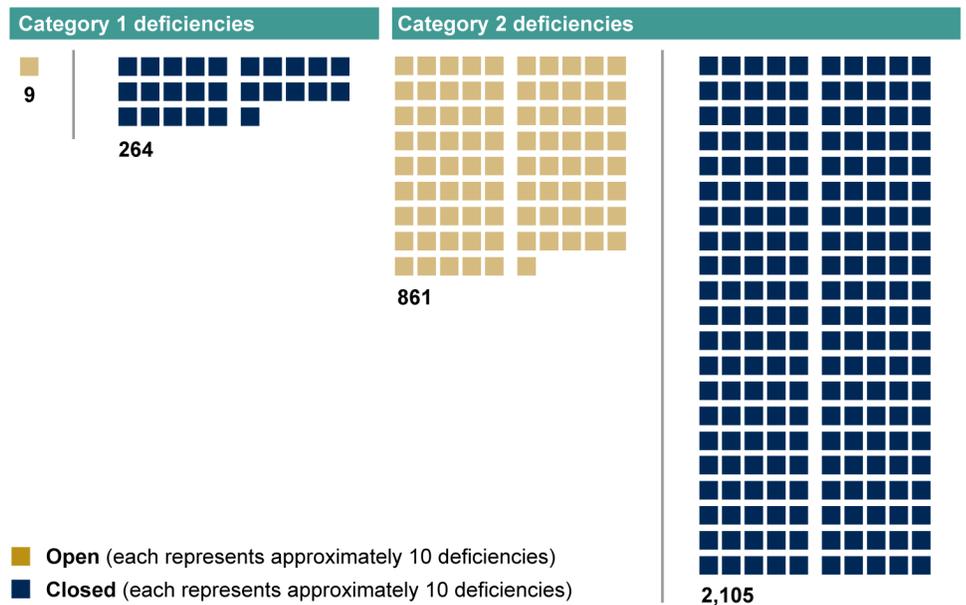
³⁴10 U.S.C. § 2400. ³⁵The program reports that none of the category 1 deficiencies is a safety of flight concern and all of them have operational workarounds. In 2019, the program split the category 1 deficiencies into two groups. Group A are deficiencies that may cause death, severe injury, severe occupational illness, or major loss or damage to equipment and has no workaround. The program has none of these deficiencies currently. Group B are deficiencies that may critically restrict the combat readiness capabilities or may result in adequate performance but not be able to accomplish the primary or alternate missions. All of the 9 category 1 deficiencies are in group B.

F-35 Program Made Progress Resolving Deficiencies during 2019, but Many Remain Unresolved

In 2019, the F-35 program resolved nearly 300 of the deficiencies it had identified in developmental and operational testing, but discovered even more over the same period. Specifically, 331 new deficiencies were identified in operational testing during 2019. As of December 2019, the F-35 program had 870 open deficiencies.

Of the 870 open deficiencies, the program characterizes nine as category 1 and 861 as category 2.³⁵ Figure 4 shows the total number of category 1 and 2 deficiencies the program has opened and closed since testing began in December 2006.

Figure 4: Total F-35 Open and Closed Category 1 and 2 Deficiencies, as of December 2019



Source: GAO analysis of Department of Defense data. | GAO-20-339

³⁵The program reports that none of the category 1 deficiencies is a safety of flight concern and all of them have operational workarounds. In 2019, the program split the category 1 deficiencies into two groups. Group A are deficiencies that may cause death, severe injury, severe occupational illness, or major loss or damage to equipment and has no workaround. The program has none of these deficiencies currently. Group B are deficiencies that may critically restrict the combat readiness capabilities or may result in adequate performance but not be able to accomplish the primary or alternate missions. All of the 9 category 1 deficiencies are in group B.

Note: Category 1 deficiencies are critical and could jeopardize safety, security, or another requirement. Category 2 deficiencies are those that could impede or constrain successful mission accomplishment.

Of the 9 open category 1 deficiencies, the program reports all have operational workarounds—procedures that avoid encountering the deficiency. This represents four fewer open category 1 deficiencies than we reported in April 2019, reflecting the resolution of previously identified deficiencies and the addition of new ones, some of which were resolved.³⁶ For example, the program fielded a software fix to a category 1 deficiency, which showed that the F-35’s cockpit display could falsely indicate its AIM-9X weapon—an air-to-air missile—selection status as “selected” though the weapon’s status is not selected. Figure 5 shows the F-35 firing an AIM-9X missile.

Figure 5: An Inverted F-35C Aircraft Fires an AIM-9X Missile



Source: © Lockheed Martin. | GAO-20-339

The program office plans to continue to address the open deficiencies, but officials report that some will not be fully resolved for several years. Further, some deficiencies may not be resolved ever and some may be resolved well after the program has completed testing, and after it expects to have made a full-rate production decision. According to DOT&E, there are many significant deficiencies the program should address to ensure the F-35 baseline aircraft configuration is stable prior to adding all of the new capabilities planned in Block 4.³⁷ As of December 2019, the program office and the contractor have resolved over 2,300

³⁶GAO-19-341.

³⁷Director, Operational Test & Evaluation, *Fiscal Year 2019 Annual Report* (December 2019).

F-35 Aircraft Prices Decreased but Manufacturing and Supply Chain Risks Remain

deficiencies and program office officials stated that they have a process in place to address the high priority ones.

In 2019, the program reported continuing to negotiate lower unit prices across all F-35 aircraft variants and delivered more aircraft on time. However, officials also reported that the airframe and engine contractors demonstrated some declines in production performance, such as the number of labor hours to produce each aircraft, as production rates increased. We also identified other risk indicators that could affect the contractors' future production performance. Specifically, the airframe contractor's manufacturing processes do not meet all manufacturing leading practices that programs should meet before full-rate production. Additionally, parts shortages increased significantly in 2019 and Turkey's suspension from the program will likely further complicate existing supply chain challenges.

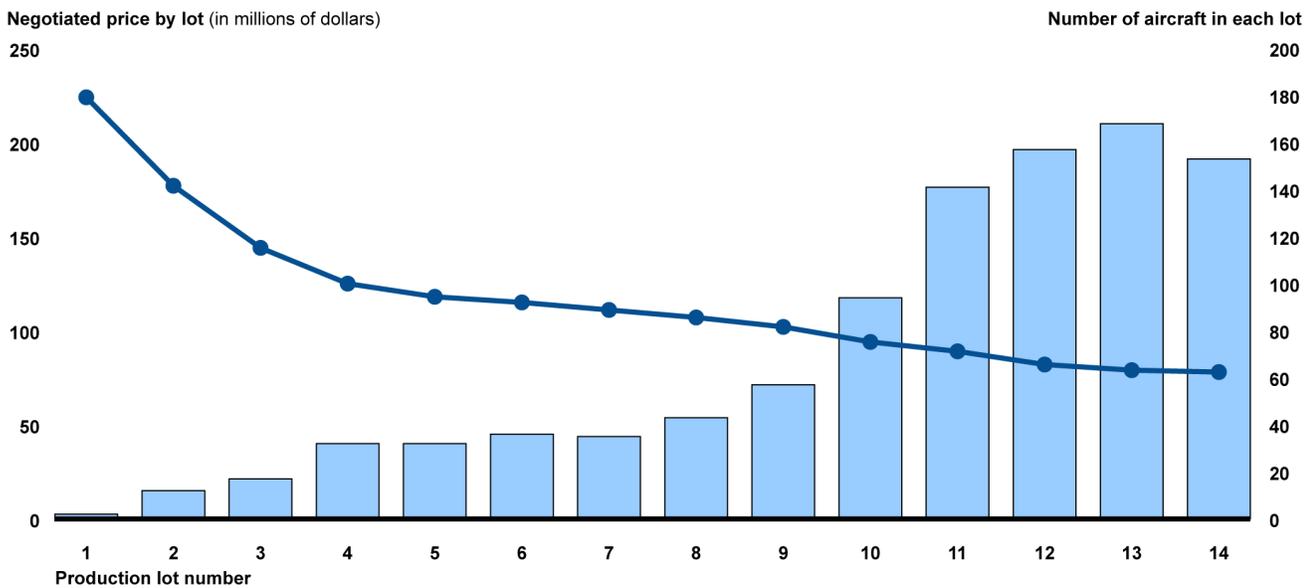
Aircraft Prices Decreased and More Aircraft Were Delivered on Time, but Other Measures of Production Performance Declined

According to the program office, the negotiated prices for all F-35 variants have generally been decreasing with each production lot and as more aircraft are being procured in each lot. In April 2019, we reported that the program set a goal of reducing the negotiated unit price of an F-35A to less than \$80 million by lot 13.³⁸ According to a program official, in October 2019, the program finalized the contract action for lots 12-14 that met this goal. Specifically, with the most recent contract, the program agreed to purchase 351 F-35As, with unit costs declining to \$73 million in lot 14.³⁹ Figure 6 shows how the negotiated price for an F-35A has decreased since production began, as reported by the program office.

³⁸[GAO-19-341](#).

³⁹The 351 includes F-35As for the U.S. Air Force, international partners, and foreign military sales.

Figure 6: The Reported F-35A Negotiated Price per Aircraft Continues to Decrease



Source: GAO analysis of Department of Defense data. | GAO-20-339

Note: These prices include the airframe contractor fee.

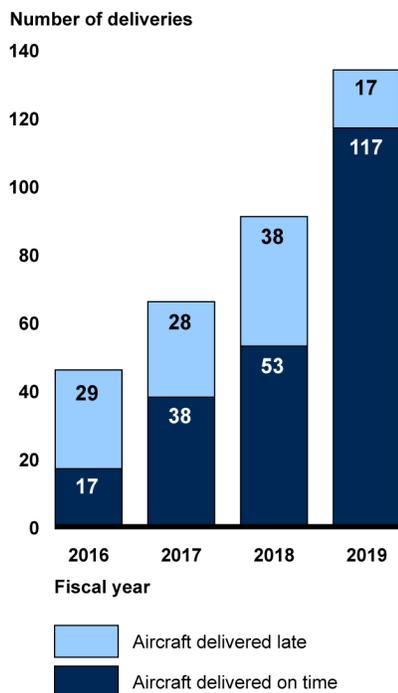
According to the program office, it negotiated lower unit prices by working with the airframe contractor to leverage economic order quantity purchases and invest in cost reduction initiatives. Economic order quantities involve the contractor making large purchases of components that it will use across multiple procurement lots of aircraft to reduce production costs by achieving economies of scale. The program office estimates that the economic order quantity purchases for lots 12-14 will save the program about \$225.5 million. In addition, the program office and prime contractors have continued to invest in various initiatives to lower production costs. Specifically, the program office spent \$320 million in efforts to improve manufacturing processes that it estimates could result in up to \$10.5 billion in savings over the life of the program. The airframe contractor told us that it has invested \$170 million as of January 2019 to further lower its production costs. The engine contractor also told us that it spent \$33 million to potentially realize over \$4 billion of cost savings.

Airframe Production Trends

The airframe contractor—Lockheed Martin—delivered 43 more aircraft in 2019 than in 2018, and as of October 2019, there were 229 aircraft in various stages of assembly worldwide. The contractor also delivered

more aircraft on time in 2019. According to contractor officials, the improved rates of on-time delivery are partially a result of the contractor's efforts to obtain a performance incentive fee that was added to the lot 11 production contract. The program intended the incentive fee to focus the contractor on improving its performance in the final assembly phase of production, which was expected to improve its on-time deliveries. To earn the incentive fee, contractor representatives told us they took several steps to improve production rates. For example, because the F-35Cs were taking longer to produce and all variants had to move through the same final assembly area, the contractor made a separate final assembly line for the F-35Cs so work could proceed without delaying the other variants. This step, according to program office officials, allowed the contractor to improve on-time deliveries for F-35As and F-35Bs. Figure 7 highlights progress in the contractor's aircraft deliveries since 2016.

Figure 7: The Contractor Delivered More Aircraft on Time in 2019 Compared to Prior Years



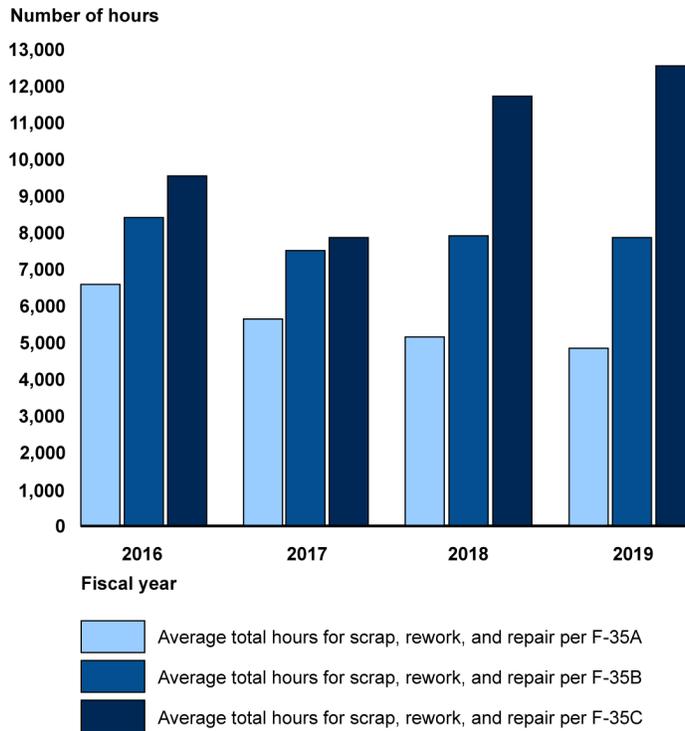
Source: GAO analysis of Lockheed Martin data. | GAO-20-339

Other production metrics associated with the airframe, however, demonstrated varied performance over the last two years as production increased. For example, the average number of hours needed to build an

aircraft decreased slightly for the F-35A but increased for the B and C variants. Defense Contract Management Agency officials told us the increase was partly attributable to new personnel. In particular, since January 2017, the contractor has hired and trained nearly 1,700 new personnel to accommodate increased production rates—nearly doubling its workforce. New personnel take time to train and gain experience on the production line. According to contractor representatives, as these new employees become more experienced and produce more aircraft, they expect the metric to improve.

The contractor's amount of rework needed was also mixed. During the course of production, the contractor may identify issues with a part or a process, which, in turn, may lead to scrap, rework, and repair to replace or fix the issue. Between 2016 and 2017, most F-35 variants realized improvements in the amount of scrap, rework, and repair needed. In 2018 and 2019, however, only the F-35A continued to show improvements. Figure 8 shows the average total hours for scrap, rework, and repair for each variant since 2016.

Figure 8: F-35 Aircraft Hours for Scrap, Rework, and Repair between 2016 and 2019



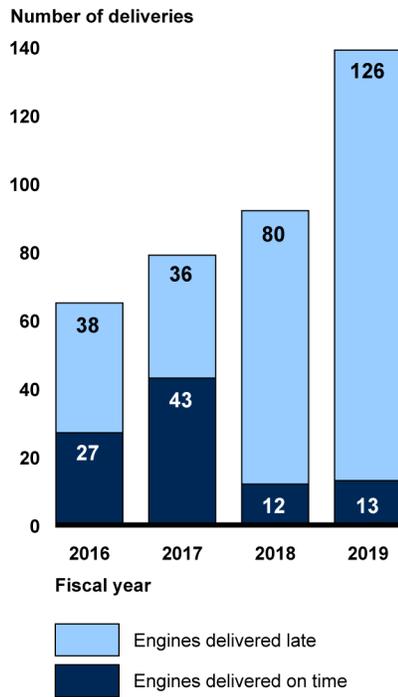
Source: GAO analysis of Department of Defense data. | GAO-20-339

According to the program office, the increased production rate posed a challenge, and because the contractor has not built as many F-35Cs, this has added to the increase in scrap, rework and repair. To improve performance in this regard, the contractor put teams in place to focus on addressing the main drivers of scrap, rework, and repair.

Engine Production Trends

Similarly, the engine contractor—Pratt & Whitney—increased its production rate by roughly 51 percent in 2019. However, engine on-time delivery performance has continued to decline which officials attribute to production quality issues and parts delays. Specifically, in 2019, 91 percent of engines delivered were late. In 2019, the airframe contractor was able to work around the late engine deliveries to deliver the entire aircraft on time. Figure 9 shows the engine contractor’s on-time and late deliveries since 2016.

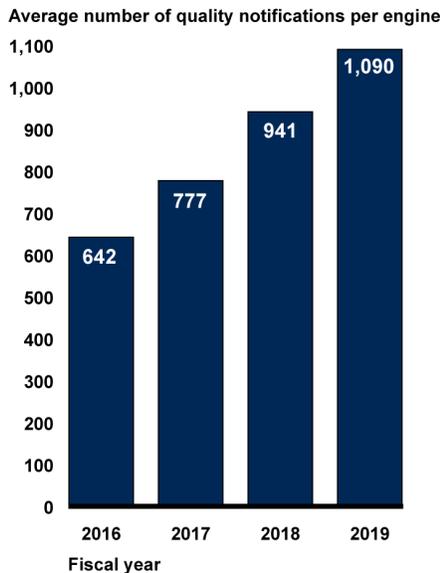
Figure 9: F-35 On-Time and Late Engine Deliveries Since 2016



Source: GAO analysis of Pratt & Whitney data. | GAO-20-339

In addition, the average number of quality notifications per engine—production defects indicating a quality issue—has increased by 16 percent in 2019. Figure 10 highlights the engine contractor’s quality notifications per engine over the last 4 years.

Figure 10: F-35 Engine Quality Notifications Since 2016



Source: GAO analysis of Pratt & Whitney data. | GAO-20-339

According to the Defense Contract Management Agency’s performance reports, engine test failures, among other quality issues, have affected engine deliveries. According to an official from this agency, there have been 18 engine test failures in 2019, which is eight more than in 2018, each requiring disassembly and rework. The engine contractor stopped deliveries due to the test failures, which has slowed engine acceptance and reduced on-time deliveries. These issues are affecting engines built at the engine contractor’s production facility in West Palm Beach, Florida, which opened in 2014. To address this issue, the engine contractor has developed new tooling for the assembly line and has established a team to identify characteristics leading to the test failures. Plans are also in place for additional training for employees.

F-35 Program Has Not Met All Manufacturing Leading Practices, Indicating Risk to Future Production

While F-35 aircraft have been in production since 2007 and have reached a high level of manufacturing readiness per DOD guidance, the program is not meeting two of eight manufacturing leading practices GAO has identified as indicators of a program’s readiness for full-rate production, or

milestone C review.⁴⁰ To date, the program is meeting or plans to meet six leading practices for this milestone:

- Demonstrating processes on a pilot production line.
- Building and testing production-representative prototypes to demonstrate product in intended environment.
- Collecting statistical process control data.
- Conducting an independent cost estimate.⁴¹
- Conducting an independent program assessment.
- Conducting major milestone decision review to begin production.

However, we also found that the production processes are not in control according to the Process Capability Index.⁴² This index is a tool to measure how closely the production steps result in a part or subsystem that meets predefined standards. According to the leading practices, meeting these standards provides greater confidence that the contractor can produce a high quality product consistently, to minimize variation which results in fewer defects or the need for rework. Additionally, the F-35 aircraft have not achieved their reliability goals through testing of production representative prototypes. These two leading practices focus on gathering sufficient knowledge to determine the relative ease of manufacturing and whether the product is of high quality and sufficiently mature to move forward into full-rate production.

Our analysis of contractor data shows that the airframe contractor's production processes are in flux. The contractor continues to change some of its production processes, and in other cases, is not following its own established processes well, which has led to several quality issues over the years. For example, in 2018, we reported that the contractor had halted deliveries of aircraft after the Air Force identified corrosion between

⁴⁰Department of Defense, *Manufacturing Readiness Level (MRL) Deskbook*. August 2015. GAO, *Weapon System Annual Assessment: Limited Use of Knowledge-Based Practices Continues to Undercut DOD's Investments*, [GAO-19-336SP](#) (Washington, D.C.: May 7, 2019); [GAO-10-439](#).

⁴¹The F-35 program is planning for the Office of the Secretary of Defense, Cost Assessment and Program Evaluation to complete an independent cost estimate for an interim program review scheduled for March 2020.

⁴²Process Capability Index determines if the process output is within design specifications, and it indicates how close the output is to the specification.

the aircraft's surface panels and the airframe because the contractor did not apply a primer when it attached the panels.⁴³ We reported in 2019 that the program office, the contractor, and the F-35 Program Executive Officer reached a mutual agreement on the cost to resolve this issue, the details of which they did not disclose publicly.⁴⁴ In November 2019, a mechanic identified titanium fasteners installed in an area of the aircraft where the design calls for a fastener stronger than titanium. According to the program office, the incorrect fasteners were installed on most already-fielded F-35 aircraft. That same month, the contractor started implementing its corrective action plan. As of March 2020, the F-35 program office had reviewed and approved the contractors' analysis as well as its durability and damage reports on the use of these fasteners. We describe other key F-35 technical risks in appendix V.

Over the years, the airframe contractor has continued to change and refine production processes, aiming to improve efficiency amidst concurrent development and production. For example, the airframe contractor identified a particular process that installs wiring harnesses into the aircraft wings as a driver of one of its production quality issues. To address this issue, the prime contractor developed a new tool that helps the installer route the wires more consistently.

While process changes like these can improve the quality of the product, they also indicate that the overall production process are not in control less than a year before the program's planned full-rate production decision, or milestone C review. In 2019, according to our analysis, the total number of key F-35 manufacturing processes identified in the final assembly phase increased 70 percent, to a total of over 10,000 critical processes. Furthermore, of these critical processes, only 30 percent are currently able to produce a product within predefined design standards. According to manufacturing leading practices, critical processes should be repeatable, sustainable, and consistent in producing parts within quality standards. Meeting these practices provides confidence that the contractor can produce the product within cost, schedule, and quality targets. Without processes in control, the program could face continued quality issues that will add to the overall cost of the program. Figure 11 shows the F-35 aircraft in the final assembly phase of production where some of these processes take place.

⁴³[GAO-18-321](#).

⁴⁴[GAO-19-341](#).

Figure 11: F-35 Aircraft in Final Assembly



Source: © Lockheed Martin. | GAO-20-339

Another leading practice that should be met before making a full-rate production, or milestone C decision, is to demonstrate that a production representative prototype can meet the program's R&M goals. The R&M goals lay out specific quantitative goals aimed at ensuring that an aircraft will be available for operations as opposed to out of service for maintenance. We reported in April 2019 that the F-35 aircraft in service around the world were still not meeting all of their R&M goals and recommended the program take actions to ensure that the aircraft would meet those goals.⁴⁵ Despite some improvement in 2019, the program is not meeting half of its R&M goals. Until the program does so, the warfighter will continue to accept aircraft for delivery that are less reliable and more costly to maintain than originally planned. For details on the F-35's R&M performance, see appendix IV.

The program has not met these two leading manufacturing practices, in part, due to the changes the airframe contractor made and continues to make to the production line and the program's concurrent approach to

⁴⁵[GAO-19-341](#).

acquisition. We have repeatedly found that DOD programs that moved into full-rate production carrying manufacturing risks experienced billions of dollars in cost growth in production, and nearly two-thirds reported increases in average procurement unit costs.⁴⁶ With the risks the F-35 program still faces, it may realize additional cost and schedule growth if these production risks are not evaluated. Despite these risks, the program has continued to push forward with increased production rates and has not taken actions to determine the potential impact of not meeting these leading practices may have on future production and overall life-cycle costs.

Furthermore, according to a program official, the F-35 program has not completed a comprehensive assessment of production risks and does not plan to ahead of its full-rate production decision. However, according to DOD officials, the F-35 program office and prime contractor convene a monthly Joint Risk Management Board, which identifies and manages overall program risk, and has completed an independent technical risk assessment to support the full-rate production decision, which identified production risks. Title 10 section 2366c of the U.S. Code requires the milestone decision authority for a major defense acquisition program to provide Congress with a report that includes, among other things, a summary of any manufacturing risks associated with the program; however, this summary is not required until 15 days after the authority grants approval for the program to enter the production and deployment phase.⁴⁷ The program currently plans to obtain this approval between September 2020 and March 2021. In this case, however, the F-35 program has not met all of the manufacturing leading practices that should be met before the full-rate production decision. Furthermore, the underlying risks, such as not meeting R&M goals, have persisted for years and the program has yet to take steps to fully address these risks. If an evaluation of these risks is not provided ahead of the full-rate production decision, Congress will not be fully aware of the risks the program is taking by committing to increased production rates.

⁴⁶[GAO-19-336SP](#); [GAO-10-439](#).

⁴⁷10 U.S.C. § 2366(c).

F-35 Supply Chain Challenges Continue and May Be Exacerbated by Turkey's Suspension from the Program

According to program officials, some suppliers for the F-35 struggled to meet increased production demands in 2019 and, as a result, the program witnessed increased rates of late deliveries or parts shortages. In particular, the number of parts delivered late to the airframe contractor, as well as parts shortages, have grown steadily over the past 2 years. According to the Defense Contract Management Agency:

- Between August 2017 and July 2019, the number of parts delivered late increased from under 2,000 to more than 10,000.
- Between July 2018 and July 2019, the parts shortages per month increased from 875 to over 8,000. According to contractor representatives, roughly 60 percent of parts shortages are attributable to 20 suppliers.

To mitigate late deliveries and parts shortages—and deliver more aircraft on time—the airframe contractor has utilized methods such as reconfiguring the assembly line and moving planned work between different stations along the assembly line. According to the program office, such steps can cause production to be less efficient, which, in turn, can increase the number of labor hours necessary to build each aircraft.

Airframe contractor representatives and a program office official cited measures they are taking to improve supplier performance in light of the upcoming full-rate production decision. For example, the contractor instituted action plans to help problematic suppliers, sent task teams to struggling suppliers to help resolve issues, and, in some cases, is seeking alternative sources. Additionally, the program office has established joint meetings with the prime contractor to monitor progress on a weekly basis and holds a semiannual review to achieve executive-level coordination. While prime contractor representatives told us that they have been actively managing underperforming suppliers for several years, some of their efforts are new and will need time before results materialize.

These supply chain risks may compound as the program continues to produce, deliver, operate, and maintain more aircraft each year. For example, in April 2019, we found that fielded, operational F-35 aircraft were not meeting warfighter requirements, largely due to spare parts shortages and difficulty in managing and moving parts around the world.⁴⁸

⁴⁸GAO, *F-35 Aircraft Sustainment: DOD Needs to Address Substantial Supply Chain Challenges*, [GAO-19-321](#) (Washington, D.C.: Apr. 25, 2019).

We recommended that the program assess what actions it should take to meet warfighter requirements, which could include adjusting the amount of spare parts acquired. DOD concurred and is working toward addressing the recommendation to identify warfighter gaps with regard to the supply chain. However, with the aircraft in production also facing significant shortages, this problem could get worse as the program prepares to further increase the production rate from 141 aircraft in 2019 to 169 in 2022.

We found that Turkey's recent suspension from the F-35 program is likely to compound these existing supply chain issues.⁴⁹ In July 2019, Turkey was suspended from the F-35 program. In particular, the Under Secretary of Defense for Acquisition and Sustainment directed that the F-35 program establish alternative sources and to stop placing orders from Turkish suppliers after March 2020. According to an official with that office, Turkish suppliers will provide parts through the end of lot 14 deliveries (scheduled to take place through 2022), in part, to avoid disruptions to aircraft deliveries and additional cost growth from standing up new suppliers. The F-35 program office identified that Turkish companies supplied 1,005 parts for the F-35 airframe and engine and some of these parts have been provided by only one supplier. As of December 2019, the program has identified new suppliers for all of these parts, but it still needs to bring roughly 15 parts currently produced in Turkey up to the current production rate.

During our review, the program reported that production through lot 14 should not be adversely affected if it continues to accept parts from Turkey until lot 14 aircraft are delivered, but risk remains with the transition to alternate sources. However, lots 12-14 still face some risk receiving parts from Turkey. According to program officials, some of these new parts suppliers will not be producing at the rate required until next year, as roughly 10 percent are new to the F-35 program. Airframe contractor representatives stated it would take over a year to stand up these new suppliers, with lead times dependent on several factors, such as part complexity, quantity, and the supplier's production maturity. In

⁴⁹In July 2019, Turkey was suspended from participating in the F-35 program due to Turkey's acquisition of a Russian air defense system. According to a senior program official, no delivered or yet-to-be delivered material, including aircraft, that Turkey has paid for is being physically transferred to Turkey. The Turkish aircraft that the contractor delivered are still in the United States. The F-35 program office is working to reallocate all of the Turkish materials. In regards to the aircraft the program already produced for Turkey, the program currently plans to store the aircraft until DOD can certify that they would be able to be integrated into the Air Force's fleet.

addition, these new suppliers are required to go through qualification and testing to ensure the design integrity for their parts. According to an official with the Under Secretary of Defense for Acquisition and Sustainment, by accepting parts from Turkish suppliers through lot 14, the program will have additional time to ensure new suppliers can meet demands for parts. Additionally, the program reported that it intends to utilize alternative sources for parts currently made in Turkey for aircraft delivered under lots 13 and 14 contracts. Furthermore, according to a program office official, it is also not clear how the prices for parts that will be obtained from new suppliers after Lot 14 will compare with the prices under the contracts with the suppliers from Turkey, but the official noted that alternative sources could be more costly.

Block 4 Reporting Requirement Expires Before Completion Date, and Cost Estimate Does Not Fully Reflect Leading Practices

In its May 2019 report to Congress, DOD outlined its plans for Block 4 with a development cost estimate of \$10.6 billion for activities through fiscal year 2024.⁵⁰ Since the 2019 report, we found the program office has increased its estimate by about 14 percent, to \$12.1 billion, primarily due to schedule delays. The program now expects to extend the delivery of Block 4 capabilities by 2 additional years, through 2026. In the meantime, DOD's Block 4 annual reporting requirement to Congress is scheduled to end in 2023, 3 years before development is complete. Additionally, most of the capabilities the F-35 program planned to deliver in 2019 were delayed. Furthermore, we found that the program's cost estimate used to support its report to Congress does not fully meet cost estimating leading practices.

Block 4 Modernization Will Not Be Completed before Reporting Requirements Expire, in Light of Schedule Delays

The Block 4 development cost and schedule have grown considerably since DOD's last report to Congress. In 2016, GAO recommended that DOD manage Block 4 as a major defense acquisition program with its own reporting requirements, separate from the original F-35 development program.⁵¹ DOD did not concur with our recommendation, citing the F-35 as DOD's most closely managed system and its existing F-35 program oversight. The NDAA for Fiscal Year 2017 required DOD to report annually on elements of a Block 4 baseline, such as development and retrofit cost estimates, beginning no later than one year after the award of the development contract for follow on modernization, until March 31,

⁵⁰This cost included funding for the U.S. services and international partners.

⁵¹[GAO-16-390](#).

2023.⁵² At that time, we reported that DOD had requested funding for the development and delivery of Block 4 through the end of 2022. However, over the last year, the program has revised its Block 4 schedule and now expects to field Block 4 capabilities into fiscal year 2026. As a result, there is no requirement for DOD to report on Block 4 progress for at least 3 years even though those efforts will be ongoing.

In its May 2019 Block 4 report to Congress, DOD reported that the total cost to develop 66 Block 4 capabilities—both hardware and software—would be \$10.6 billion for activities planned from fiscal years 2018 to 2024.⁵³ The report also included the F-35 program office estimate of an additional \$6.4 billion in fiscal year 2018 through 2024 funding to retrofit aircraft from the baseline F-35 configuration to a full Block 4 configuration. The F-35 program based the costs in this report on its Block 4 development cost estimate from July 2018. However, we found that reported Block 4 costs did not include all Block 4 costs. In particular, the report did not include Block 4 costs the program incurred prior to 2018 or costs that the effort will incur after 2024. Because the F-35 program office is not managing the Block 4 effort as a separate program, it has chosen to exclude the past and future costs in the Block 4 cost estimate it reported to Congress. Instead, the program reported on Block 4 costs for the future years defense program—which is DOD’s projected spending for the current budget year and the next four years. By excluding any costs prior to 2018 and those that would be incurred after 2024, the program did not report on the total costs of Block 4.

In May 2019, the program also updated its Block 4 development cost estimate, increasing both the time and cost to complete the work, but this updated estimate was not included in its May 2019 report to Congress.⁵⁴ The updated cost estimate reflects that the program office will be fielding Block 4 capabilities into fiscal year 2026. This new schedule adds 2 years

⁵²National Defense Authorization Act for Fiscal Year 2017, Pub. L. No. 114-328, § 224(d), (2016). In the NDAA for Fiscal Year 2020, Congress required that DOD’s future reports also include an integrated master schedule and past performance assessments for each planned phase of Block 4 and the C2D2 approach. The National Defense Authorization Act of Fiscal Year 2020, Pub. L. No. 116-92, § 166.

⁵³DOD provided its first report to Congress on Block 4 in January 2018. This report included Block 4 development costs through fiscal year 2022 and some development costs not funded through the F-35 program.

⁵⁴The May 2019 report to Congress was based on a Block 4 cost estimate developed in July 2018.

to the costs DOD reported to Congress in May 2019. Additionally, our analysis of DOD's updated cost estimate indicates the total cost of Block 4 development grew by \$1.5 billion to a total of \$12.1 billion for activities in fiscal years 2018 through 2026.⁵⁵ Furthermore, in addition to the Block 4 development costs, the program also estimates it will need another \$2.9 billion to develop other capabilities, such as upgrades to ALIS. Program officials attributed this schedule and cost growth to having better insight into the scope of work to develop and test Block 4 capabilities and noted that they would continue to refine and update these costs annually as modernization efforts progress further into development.

Once the existing statutory reporting requirement expires in 2023, DOD will no longer be required to provide Congress key information that would be useful in making informed decisions regarding the Block 4 effort—which now extends until 2026. Furthermore, without a complete cost estimate for Block 4, inclusive of costs already incurred and those not yet incurred but estimated through completion, Congress is left without a complete picture of what DOD intends to spend on the total Block 4 effort. Without a complete picture of these costs, the Congress's ability to assess the program's cost and schedule performance in the future will be hindered.

Program Office Delayed Delivery of Most 2019 Block 4 Capabilities to the 2020s

The airframe contractor did not deliver the Block 4 capabilities it planned to deliver in 2019. Specifically, according to the plan outlined in its May 2019 report to Congress, the F-35 program was going to deliver eight Block 4 capabilities in 2019. However, the program delivered only one—a software capability called the auto ground-collision avoidance system. This capability enables the aircraft to perform an automatic recovery when it predicts that the aircraft will strike the ground. This was ahead of schedule as the program had originally planned to deliver this capability after 2019. According to program officials, the development of the other capabilities is taking longer than planned and, as a result, the program pushed their delivery schedule into 2020.

Development and delivery of the capabilities within the Block 4 effort are complex, and the program does not consider development complete until

⁵⁵The \$12.1 billion for Block 4 development does not include \$3.4 billion in estimated procurement costs reported in the F-35 program's December 2018 Selected Acquisition Report.

the products for all elements of the F-35 air system are ready.⁵⁶ In particular, full capability delivery occurs when the contractor delivers all of the software and hardware needed for all of the F-35 air system elements to support the planned capability. Program officials stated they are still working to put the processes in place to synchronize the delivery of the late capabilities for all of the F-35 air system elements. For example, the airframe contractor had planned to deliver a capability called the interim full motion video for the Marine Corps in 2019. The contractor developed the software needed, but it is late in developing the hardware needed for the software to operate and, as a result, the contractor did not deliver the capability in 2019 as planned.

DOD test officials we met with at Edwards Air Force Base stated that in 2019, using the C2D2 approach, the contractor delivered other, partial Block 4 capabilities to be tested. However, test officials told us those capabilities were delivered later than expected. Since the program could not fully test those capabilities on the aircraft, the program office deferred them to the next incremental update scheduled for 2020. Changes such as these have contributed to the Block 4 cost and schedule growth.

The program is also discovering issues during Block 4 testing, causing the testing to take longer than anticipated. According to a DOT&E official, Block 4 software changes caused issues with functionality of F-35 baseline aircraft capabilities that worked before the program installed new Block 4 software onto the aircraft. The program discovered issues with each new software version during flight testing and has been working to fix these issues in subsequent software updates. Testing and DOD officials stated that the contractor had not performed adequate testing of the software before delivering it to the test fleet as the reason for these issues. Contractor representatives acknowledged these issues and stated that they will conduct additional lab testing for future software releases to avoid such problems going forward.

⁵⁶The eight elements of the F-35 air system are the air vehicle, operational flight program, mission data file, reprogramming enterprise, mission simulators, threat database, ALIS, and mission support.

Block 4 Development Cost Estimate Does Not Fully Meet Leading Practices, Which Limits Congress' Understanding of Costs

We found that the F-35 program office's Block 4 cost estimate did not fully meet the four key characteristics of GAO's cost estimating leading practices when projecting Block 4 development costs.⁵⁷ Table 2 presents key points from our assessment, and appendix II provides additional detail on our rationale.

Table 2: Assessment of the Extent to Which DOD's F-35 Modernization Development Cost Estimate Meets GAO's Leading Practices

Characteristic	Assessment	Rationale for assessment
Comprehensive	Partially met	<p>The cost estimate includes both government and contractor costs, but it does not include incurred or sustainment costs in the estimate. Officials assumed sustainment costs are not affected by Block 4 costs as reflected in the current sustainment annual cost estimate; however, they did not conduct an analysis to support this assertion. The program office stated that cost impacts due to Block 4 have been evaluated by the program office and that the Block 4 cost estimate was intended to inform development and not life-cycle costs. Officials reported that the program office will continue to validate or revise the sustainment cost assertion as necessary and as Block 4 continues to mature.</p> <p>Further, part of the estimate relies on a work breakdown structure (WBS) developed by the contractor, but the overall estimate does not. A WBS broadly represents the program's plan to complete the project, in this case Block 4. A WBS should define in detail the work necessary to accomplish a program's objectives and provide a basis for identifying resources and activities necessary to produce deliverables. The F-35 program office is relying on the contractor's WBS rather than creating its own. If the F-35 program office had its own WBS, it could determine if it has identified all of the resources and tasks needed to accomplish Block 4, including those beyond the contractor's scope of work.</p> <p>In addition, the estimate defines ground rules and assumptions, but it does not assess the impact of those assumptions changing. For example, program officials stated the current estimate is based on the assumption that most Block 4 capabilities are based on mature technologies. However, the program has not completed a technology readiness assessment to determine the maturity of Block 4 capabilities.^a Therefore, the estimate does not assess the impact if capabilities are immature and may take longer than planned to develop. Costs can be expected to increase if a capability takes longer than planned to design, integrate, or test.</p>
Well-documented	Substantially met	<p>The documentation describes the methods used to arrive at the estimate and describes step-by-step how the estimate was developed. The estimate also relies on technical baseline descriptions, but these are not contained within a single document. The objective of the technical baseline is to provide, in a single document, a common definition of the program—including a detailed technical, program, and schedule description of the system—on which all program and independent cost estimates are based. The F-35 program office uses multiple documents at varying levels of detail to document the Block 4 technical baseline.</p>
Accurate	Partially met	<p>The estimate relied on historical data to estimate costs. According to program officials, the estimate was peer-reviewed to check its accuracy. Further, the estimate has been updated to reflect changes in the program.</p>

⁵⁷[GAO-09-3SP](#).

However, while the program adjusted the estimate for inflation and updated it annually to incorporate contract costs, we found inconsistencies between inflation factors applied in the estimate and the sources cited. Applying inflation 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.

Additionally, the program did not consider variance between planned and actual costs. Without a documented comparison between the current estimate (updated with actual costs) and the old estimate, the cost estimator cannot determine the level of variance between the two estimates. That is, the estimators cannot see how well they are estimating and how the program is changing over time. Program officials stated that, going forward, they are taking steps to include actual costs in the estimate and consider the variance between planned and actual costs.

Characteristic	Assessment	Rationale for assessment
Credible	Minimally met	<p>Although the program office and the contractor regularly meet to discuss risk, the program did not conduct a cost risk analysis. A cost risk analysis considers the likelihood that an unfavorable event will occur and considers the consequences. An uncertainty analysis would show how costs can change if variables in the estimate change. An estimate without risk and uncertainty analyses is unrealistic because it does not assess the variability in the cost estimate from such effects as schedules slipping, missions changing, and proposed solutions not meeting users' needs. Without risk and uncertainty analyses, management cannot determine the funding needed for unexpected design complexity, incomplete requirements, technology uncertainty, and other uncertainties.</p> <p>Additionally, the estimate does not include any sensitivity analysis. A sensitivity analysis examines how changing a single variable changes the cost estimate. Without a sensitivity analysis that reveals how the cost estimate is affected by a change in a single assumption, the cost estimator will not fully understand which variable most affects the cost estimate.</p> <p>One way to reinforce the credibility of the cost estimate is to determine if applying a different method produces similar results. While program office officials stated that they compared some cost elements to the contractor's cost elements to determine if results are similar when using different methods, there was no evidence of this in the estimate.</p> <p>Finally, there has been no independent cost estimate on Block 4 to date, although the program was planning for one to support an upcoming interim program review in March 2020. Without the independent cost estimate, decision makers will lack insight into a program's potential costs because independent cost estimates frequently use different methods and are less burdened with organizational bias.</p>

Source: GAO analysis of DOD information. | GAO-20-339

^aA technology readiness assessment is a systematic, evidence-based process that evaluates the maturity of hardware and software technologies critical to the performance of a larger system or the fulfillment of the key objectives of an acquisition program.

As reflected in table 2, our assessment of the F-35 Block 4 development cost estimate identified a number of missing elements. Specifically, the estimate does not rely on a product-oriented work breakdown structure (WBS), it does not address cost risk and uncertainty, it does not take into account risk related to technology maturity, and it does not have an independent cost estimate, as leading practices reflect. While the program office updates its cost estimate regularly, officials told us that they do not intend to address some of these missing elements in future updates.

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- **Work breakdown structure.** According to cost estimating leading practices, the program should base its cost estimate on a program-level, product-oriented WBS that allows a program to track cost and schedule by defined deliverables, such as hardware or software components. The WBS ensures that the program does not leave out any portions of the work and makes it easier to compare it to similar systems and programs. According to program officials, the Block 4 cost estimate does not rely on a single WBS; rather, multiple, contractor-derived WBSs exist for the program. Without its own, program-office-level WBS, the program lacks a framework to develop a schedule and cost plan that it can use to track progress and accomplishments.
 - **Risk and uncertainty analyses.** The program did not perform cost risk and uncertainty analyses. Program officials said they do not plan to conduct a formal risk analysis. The program office works jointly with the contractor to identify and manage risks for the F-35 program. For example, there are monthly Joint Risk Management Boards attended by both program office and contractor leadership. However, overall program risk management is different from quantitative cost risk and uncertainty analyses in that program risk management is not specific to costs and it is not used to assess the cost variance of the cost estimate itself. When planning for funding decisions for a program of this scale, analyzing program-level risks alone is inadequate. Without a risk analysis, the cost estimate will not be fully accurate or credible because it will not account for the effects of potential schedule slips or other risks that the program could realize.
 - **Technology maturity.** A program office official stated that in developing the cost estimate they did not consider that technologies would not be mature, but rather assumed that most technologies needed to deliver each Block 4 capability would be mature before the program begins development for that capability. The official stated that the complexity of design, development, and testing based on the baseline program experience was reflected in the estimate, but the cost estimate did not identify if there were specific costs associated with maturing these technologies. The official further noted that Block 4 costs would increase if a capability takes longer than planned to design, integrate, and test due to its immaturity. In 2019, we recommended that the Secretary of Defense ensure that the F-35 program office completes an independent technology readiness assessment, as part of its business case for the initial Block 4

capabilities, before initiating additional development work.⁵⁸ DOD did not concur with our recommendation. According to a program official, as of December 2019, the program office had not completed any technology readiness assessments even though the contractor has started development of over half of the capabilities within Block 4. Going forward, the program is considering holding incremental technology readiness assessments as it plans for and develops a new set of capabilities, in accordance with the C2D2 schedule. Program officials told us that, going forward, as they update the Block 4 cost estimate, they will consider the results of future technology readiness assessments. Until the program office does so, management cannot determine a reasonable level of additional resources that might be necessary to cover increased costs resulting from unexpected design complexity, incomplete requirements, technology uncertainty, and other uncertainties.

- **Independent cost estimate.** In 2019, we also recommended the F-35 program office include an independent cost estimate as part of its business case for Block 4.⁵⁹ As noted in table 2, the Block 4 effort still lacks an independent cost estimate. The program is planning for the Office of the Secretary of Defense, Cost Assessment and Program Evaluation to have a draft independent cost estimate for an interim program review scheduled for March 2020 and to have a complete independent cost estimate in June 2020. This estimate will evaluate the entire F-35 program, including Block 4.

With these pieces currently missing, the Block 4 development cost estimate does not present a full picture of Block 4's cost. Ultimately, without a complete understanding of Block 4 costs, the program could face additional cost growth, which will be hard to track without a complete cost baseline. The lack of a complete cost baseline hinders insight and oversight into the program's costs, plans, and progress to date and going forward. Moreover, if a cost estimate does not fully or substantially meet all four characteristics of cost estimating leading practices, it cannot be considered reliable.

Conclusions

DOD plans for the F-35 to be central to the warfighter prevailing in future conflicts. However, the program has been behind schedule and over cost almost since its inception.

⁵⁸[GAO-19-341](#).

⁵⁹[GAO-19-341](#).

DOD is slated to move into full-rate production despite several key challenges in the production of aircraft. We acknowledge that the current F-35 program's production rates are more commonly associated with programs already in full-rate production. However, the F-35 aircraft in the field have not met standards for reliability and maintainability, indicating that the program is not delivering aircraft at the level of quality expected. Additionally, the program's concurrent approach and the contractor's continual changes to the production line indicate that the production line processes are not in control. Leading practices indicate that mature production lines—production lines ready for full-rate production—should meet metrics for consistency. Furthermore, to minimize production risk and potential cost growth, suppliers should routinely meet quality and delivery schedules, although this is not yet true of the F-35 program. Not meeting these leading practices poses risks that DOD and the international partners will not routinely receive the F-35's they specified and need. The long-standing challenges with receiving parts on time and efforts underway to replace Turkish suppliers of parts for the F-35 compound these production challenges and may raise additional risks. Unless the program office assesses and reports on these manufacturing risks ahead of the milestone C review, Congress may not have key insights into the risks that remain with the program and to the overall effort to deliver F-35s to the warfighter.

Since the F-35 program is not managing the Block 4 effort as a separate program with traditional oversight tools, we are particularly concerned as Block 4 efforts proceed through development and testing. Specifically, because of the delays to the program, after 2023, DOD will not be required to provide Congress information on Block 4's development efforts as the current reporting requirements will end. Furthermore, the program's cost estimate, as presented in its report to Congress, does not fully present all incurred and future costs for Block 4. Without this information, Congress may not have the insight it needs to assess Block 4 cost and schedule progress as well as to make informed oversight and budgeting decisions.

In addition, the Block 4 development cost estimate does not fully meet leading practices, lacking a full reflection of all costs. Specifically, the cost estimate does not have a program office level work breakdown structure, a risk and uncertainty analysis, and consideration of technology readiness. Without a comprehensive and credible cost estimate, DOD and Congress lack a sound basis for informed investment decision making, realistic budget formulation, meaningful progress measurement,

proactive course correction when warranted, and program and contractor accountability for results.

Matter for Congressional Consideration

Congress should consider revising Section 224(d) of the National Defense Authorization Act for Fiscal Year 2017, Pub. L. No. 114-328, to extend DOD's Block 4 reporting requirement until all Block 4 capabilities are fielded to ensure that Congress is aware of cost and schedule growth beyond 2023. (Matter for Consideration 1)

Recommendations for Executive Action

We are making the following five recommendations to the Secretary of Defense to direct the Undersecretary of Defense for Acquisition and Sustainment (OUSD (A&S)).

The OUSD (A&S) should direct the F-35 program office to provide information that is similar to that which is statutorily required after the milestone C review to Congress ahead of the milestone C review (full-rate production decision). This submission should include an evaluation of the production risks associated with critical production processes that are not in control, reliability and maintainability (R&M) targets that are not met, and supplier readiness—particularly for those replacing Turkish suppliers, along with the steps it is taking to address those risks. (Recommendation 1)

The OUSD (A&S) should direct the F-35 program office to establish a Block 4 cost estimate baseline that includes all Block 4 costs, including incurred costs and future costs in its reports to Congress as required by the NDAA for Fiscal Year 2017, so that Congress has a complete understanding of all Block 4 costs and can compare this baseline to future cost estimates and performance. (Recommendation 2)

The OUSD (A&S) should direct the F-35 program office to complete a program office level, product-oriented work breakdown structure for the next update to its Block 4 cost estimate to ensure that the estimate meets the comprehensive leading practices. (Recommendation 3)

The OUSD (A&S) should direct the F-35 program office to conduct risk and uncertainty analyses for the next update to its Block 4 cost estimate to ensure that the estimate meets the credible leading practices. (Recommendation 4)

The OUSD (A&S) should direct the F-35 program office to consider the results of its future technology readiness assessment of all Block 4 technologies and incorporate the cost and schedule risks of developing

those technologies in the next update to its Block 4 cost estimate to ensure that the estimate meets the comprehensive leading practices. (Recommendation 5)

Agency Comments and Our Evaluation

We provided a draft of this report to DOD for review and comment. DOD provided written comments, which we have reproduced in appendix VI. DOD concurred with three of the recommendations related to the Block 4 modernization effort (recommendations 2, 4, and 5 above). While DOD did not concur with the other two recommendations, it outlined planned actions that we believe, if implemented, would meet the intent of our recommendations. DOD also provided technical comments, which we incorporated as appropriate. We will continue to monitor the program and evaluate implementation of these recommendations.

DOD officials did not concur with the first recommendation, which, in the draft report, was to evaluate production risks and provide a statutorily required report to Congress ahead of the program's full-rate production decision. While DOD did not concur with the draft recommendation, it agreed to keep the Congress apprised of these matters in its quarterly briefings to the defense committees. To clarify the actions we intended DOD to take to address our findings, we revised the recommendation to indicate that DOD should provide information to Congress on the production risks we identified in our report, ahead of the milestone C review. If the DOD provides a substantive assessment highlighting these production risks, as well as the steps it will take to mitigate them, during its quarterly briefing to Congress ahead of the milestone C review, it would address the intent of our recommendation.

DOD also did not concur with our third recommendation for the F-35 program office to complete a program-level, product-oriented work breakdown structure (WBS) for the next update to its Block 4 cost estimate. DOD noted that its next scheduled update was due in April 2020, after we provided our report for comment. While DOD noted it would be unable to complete a program-level WBS by the April 2020 update, it agreed to evaluate moving to a program-level, product-oriented WBS in 2021. If the F-35 program office utilizes a program-level, product-oriented WBS for this cost estimate update, it would meet the intent of our recommendation.

We are sending copies of this report to the appropriate congressional committees; the Secretary of Defense; and the Under Secretary of Defense for Acquisition and Sustainment, the Secretary of the Air Force, the Acting Secretary of the Navy, and the Commandant of the Marine

Corps. In addition, the report is available at no charge on the GAO website at <http://www.gao.gov>.

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



Jon Ludwigson
Director, Contracting and National Security Acquisitions

List of Committees

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

The Honorable Richard C. Shelby
Chairman
The Honorable Dick Durbin
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Adam Smith
Chairman
The Honorable Mac Thornberry
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Pete Visclosky
Chairman
The Honorable Ken Calvert
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: Prior GAO Reports on the F-35 Acquisition Program and DOD Actions

Table 3: Select Prior GAO Reports on F-35 Joint Strike Fighter and Department of Defense (DOD) Responses

Year, GAO report	Estimated F-35 development costs, development length, and aircraft unit cost ^a	Key program event	Primary GAO conclusions and recommendations	DOD response and actions
2001 GAO-02-39	\$34.4 billion 10 years \$69 million	Start of system development and demonstration approved.	Critical technologies needed for key aircraft performance elements are not mature. We recommended that the program delay start of system development until critical technologies are matured to acceptable levels.	DOD did not concur with our recommendation. DOD did not delay the start of system development and demonstration stating technologies were at acceptable maturity levels and that it will manage risks in development.
2006 GAO-06-356	\$45.7 billion 12 years \$86 million	Program sets in motion plan to enter production in 2007 shortly after first flight of the non-production representative aircraft.	The program was entering production with less than 1 percent of testing complete. We recommended that the program delay investing in production until flight testing shows that the Joint Strike Fighter performs as expected.	DOD partially concurred but did not delay start of production because it believed the risk level was appropriate.
2010 GAO-10-382	\$49.3 billion 15 years \$112 million	The program was restructured to reflect findings from a recent independent cost team and independent manufacturing review team. As a result, development funds increased, test aircraft were added, the schedule was extended, and the early production rate decreased.	Costs and schedule delays inhibited the program's ability to meet needs on time. We recommended that the program complete a comprehensive cost estimate and assess warfighter and initial operational capability requirements. We suggested that Congress require DOD to tie annual procurement requests to demonstrated progress.	DOD continued restructuring, increasing test resources, and lowering the production rate. Independent review teams evaluated aircraft and engine manufacturing processes. Cost increases later resulted in a Nunn-McCurdy breach. Military services completed the review of capability requirements, as we recommended.
2014 GAO-14-322	\$55.2 billion 18 years \$135 million	The services established initial operational capabilities dates in 2013. The Marine Corps and Air Force planned to field initial operational capabilities in 2015 and 2016, respectively, and the Navy planned to field its initial capability in 2018.	Delays in developmental flight testing of the F-35's critical software may hinder delivery of the warfighting capabilities to the military services. We recommended that DOD conduct an assessment of the specific capabilities that can be delivered and those that will not likely be delivered to each of the services by their established initial operational capability dates.	DOD concurred with our recommendation. On June 22, 2015, the Under Secretary of Defense for Acquisition, Technology, and Logistics issued a Joint Strike Fighter software development report, which met the intent of GAO's recommendation.

Year, GAO report	Estimated F-35 development costs, development length, and aircraft unit cost ^a	Key program event	Primary GAO conclusions and recommendations	DOD response and actions
2016 GAO-16-390	\$55.1 billion 18 years \$130.6 million	DOD planned to begin what it refers to as a block buy contracting approach that was anticipated to provide cost savings. In addition, DOD planned to manage the follow-on modernization program under the current F-35 program baseline and not as its own separate major defense acquisition program.	The terms and conditions of the planned block buy and managing follow-on modernization under the current baseline could present oversight challenges for Congress. We recommended that the Secretary of Defense hold a milestone B review and manage follow-on modernization as a separate major defense acquisition program.	DOD did not concur with our recommendation. DOD viewed modernization as a continuation of the existing program and the existing oversight mechanisms, including regularly scheduled high-level acquisition reviews, would be used to manage the effort.
2017 GAO-17-351	\$55.1 billion 18 years \$130.6 million	The DOD F-35 program office was considering contracts for economic order quantity of 2 years' worth of aircraft parts followed by a separate annual contract for procurement of lot-12 aircraft with annual options for lot-13 and lot-14 aircraft. However, as of January 2017, contractors stated they were still negotiating the terms of this contract; therefore, the specific costs and benefits remained uncertain.	Program officials projected that the program would only need \$576.2 million in fiscal year 2018 to complete baseline development. At the same time, program officials expected that more than \$1.2 billion could be needed to commit to Block 4 and economic order quantity in fiscal year 2018. GAO recommended DOD use historical data to reassess the cost of completing development of Block 3F, complete Block 3F testing before soliciting contractor proposals for Block 4 development, and identify for Congress the cost and benefits associated with procuring economic order quantities of parts.	DOD did not concur with the first two recommendations and partially concurred with the third while stating that it had finalized the details of DOD and contractor investments associated with an economic order quantity purchase and would brief Congress on the details, including costs and benefits of the finalized economic order quantity approach.

Year, GAO report	Estimated F-35 development costs, development length, and aircraft unit cost ^a	Key program event	Primary GAO conclusions and recommendations	DOD response and actions
2018 GAO-18-321	\$55.5 billion 18 years \$140.6 million	The program office determined that it could not resolve all open deficiencies found in developmental testing within the development program, and they would need to be resolved through post-development contract actions. DOD provided a report to Congress outlining preliminary plans to modernize the F-35. It stated it planned to develop a full acquisition program baseline for the modernization effort in 2018 and provide a report to Congress by March 2019.	The program office plans to resolve a number of critical deficiencies after full-rate production. We recommended that the F-35 program office resolve all critical deficiencies before making a full-rate production decision and identify steps needed to ensure the F-35 meets reliability and maintainability requirements before each variant reaches maturity. We also suggested that Congress consider providing in future appropriations that no funds shall be available for obligation for F-35 Block 4 until DOD provides a report setting forth its complete acquisition program baseline for the Block 4 effort to the congressional defense committees.	DOD concurred with both recommendations and identified actions that it would take in response. The National Defense Authorization Act for fiscal year 2019 included a provision limiting DOD from obligating or expending more than 75 percent of the appropriations authorized under the Act for the F-35 continuous capability development and delivery program until 15 days after the Secretary of Defense submits to the congressional defense committees a detailed cost estimate and baseline schedule. DOD submitted its F-35 Block 4 report to Congress in May 2019, which contained cost and schedule information responding to this provision.

Year, GAO report	Estimated F-35 development costs, development length, and aircraft unit cost ^a	Key program event	Primary GAO conclusions and recommendations	DOD response and actions
2019 GAO-19-341	\$55.5 billion 18 years \$140.6 million	For as long as the program has tracked reliability and maintainability performance, only minimal, annual improvement has been realized. Half of these metrics are failing and unlikely to meet targets outlined in the Operational Requirements Document by full aircraft maturity. As of December 2018, not all reliability and maintainability metrics within the Operational Requirements Document have been met, nor reevaluated to determine more realistic reliability and maintainability performance metrics.	We recommended that the Secretary of Defense should ensure that the F-35 program office assess the feasibility of its required reliability and maintainability targets, identify specific and measurable reliability and maintainability objectives in its improvement plan guidance, document projects that will achieve these objectives, and prioritize funding for these improvements. We also recommended that the Secretary of Defense should ensure that the F-35 program office completes its business case for the initial Block 4 capabilities under development before initiating additional development work.	DOD concurred with our four recommendations on reliability and maintainability and identified actions it would take in response. While DOD has taken some action, these recommendations are still open. DOD did not concur with our recommendation on Block 4 modernization. DOD stated that the F-35 program has adequate cost, schedule, and technical maturity knowledge to begin the development of initial Block 4 capabilities.

Source: GAO | GAO-20-339

^aThe aircraft unit cost is the program's average procurement unit cost estimate, which is calculated by dividing the procurement amount by the procurement aircraft quantities. This is different than the negotiated price for F-35 aircraft, also reported above.

Appendix II: F-35 Block 4 Development Cost Estimate Analysis

To assess the reliability of the F-35 Block 4 development cost estimate, we obtained and reviewed cost estimate documentation such as the Joint Program Office briefing on its May 2019 estimate, the Air System Procurement Playbook—a planning document for Block 4—and its cost estimate models. Additionally, we met with relevant staff in the F-35 program office and the Department of Defense’s Office of Cost Assessment and Program Evaluation. We analyzed this information and determined the extent to which the program office’s practices for developing the F-35 Block 4 development cost estimate were consistent with the leading practices identified in the GAO Cost Estimating and Assessment Guide.¹ These practices have been found to be the basis for reliable cost estimates. We assessed each practice as being one of the following:

- Met—the agency provided data and documentation that satisfies the entire leading practice criterion.
- Substantially met—the agency provided data and documentation that satisfies a large portion of the leading practice criterion.
- Partially met—the agency provided data and documentation that satisfies about half of the leading practice criterion.
- Minimally met—the agency provided data and documentation that satisfies a small portion of the leading practice criterion.
- Not met—the agency provided data and documentation that does not satisfy any portion of the leading practice criterion.

For our reporting needs, we collapsed GAO’s 18 leading practices into four general characteristics: comprehensive, well-documented, accurate, and credible. The assessment of each characteristic was based on an average of the F-35 program office’s scores for the leading practices included in that category. A second analyst verified the assessment and management reviewed the results. We determined the overall assessment rating by assigning each individual rating a number:

- Not met = 1,
- Minimally met = 2,
- Partially met = 3,

¹GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, [GAO-09-3SP](#) (Washington, D.C.: Mar. 2009).

- Substantially met = 4, and
- Met = 5.

Then, we took the average of the individual assessment ratings to determine the overall rating for each of the four characteristics. The resulting average becomes the Overall Assessment as follows:

- Not met = 1.0 to 1.4,
- Minimally met = 1.5 to 2.4,
- Partially met = 2.5 to 3.4,
- Substantially met = 3.5 to 4.4, and
- Met = 4.5 to 5.0.

A cost estimate is considered reliable if the overall assessment ratings for each of the four characteristics are substantially or fully met. If any of the characteristics are not met, minimally met, or partially met, then the cost estimate does not fully reflect the characteristics of a high-quality estimate and cannot be considered reliable. See table 4 for a high level summary of each leading practice and the reasons for the overall scoring.

Table 4: Assessment of the F-35's Block 4 Development Cost Estimate Compared to Leading Practices

Characteristic	Overall assessment	Leading practice	Individual assessment
Comprehensive	Partially Met	The cost estimate includes all life-cycle costs, from inception of the program through design, development, deployment, and operation and maintenance to retirement of the program.	Partially met
		The cost estimate completely defines the program, reflects the current schedule, and is technically reasonable.	Partially met
		The cost estimate work breakdown structure (WBS) is product-oriented, traceable to the statement of work/objective, and at an appropriate level of detail to ensure that cost elements are neither omitted nor double-counted. A WBS is essentially the program's plan to complete the project. A WBS should define in detail the work necessary to accomplish a program's objectives and provide a basis for identifying resources and activities necessary to produce deliverables.	Partially met
		The estimate documents all cost-influencing ground rules and assumptions.	Partially met
Well documented	Substantially met	The documentation should capture the source data used, the reliability of the data, and how the data were normalized.	Substantially met
		The documentation describes in sufficient detail the calculations performed and the estimating methodology used to derive each element's cost.	Substantially met

Characteristic	Overall assessment	Leading practice	Individual assessment
		The documentation describes step by step how the estimate was developed so that a cost analyst unfamiliar with the program could understand what was done and replicate it.	Substantially met
		The documentation discusses the technical baseline description and the data in the baseline is consistent with the estimate. The objective of the technical baseline is to provide in a single document a common definition of the program—including a detailed technical, program, and schedule description of the system—on which all program and independent cost estimates are based.	Partially met
		The documentation provides evidence that the cost estimate was reviewed and accepted by management.	Partially met
Accurate	Partially met	The cost estimate results are unbiased, not overly conservative or optimistic and based on an assessment of most likely costs.	Not met
		The estimate has been adjusted properly for inflation.	Partially met
		The estimate contains few, if any, minor mistakes.	Substantially met
		The cost estimate is regularly updated to reflect significant changes in the program so that it always reflects current status.	Met
		Variances between planned and actual costs are documented, explained, and reviewed.	Minimally met
		The estimate is based on a historical record of cost estimating and actual experiences from other comparable programs.	Substantially met
Credible	Minimally met	The cost estimate includes a sensitivity analysis that identifies a range of possible costs based on varying major assumptions, parameters, and data inputs. A sensitivity analysis examines how changing a single variable changes the cost estimate.	Not met
		A risk and uncertainty analysis was conducted that quantified the imperfectly understood risks and identified the effects of changing key cost driver assumptions and factors. A risk analysis considers the likelihood that an unfavorable event will occur and considers the consequences. An uncertainty analysis assesses how costs can change if variables in the estimate change.	Minimally met
		Major cost elements were cross-checked to see whether results were similar.	Minimally met
		An independent cost estimate was conducted by a group outside the acquiring organization to determine whether other estimating methods produce similar results.	Minimally met

Source: GAO analysis of DOD data. | GAO-20-339

Appendix III: Objectives, Scope, and Methodology

This report fulfills two mandates. First, the National Defense Authorization Act for fiscal year 2015 included a provision for GAO to review the F-35 acquisition program annually until the program reaches full-rate production. This is the fifth report under that provision. Second, the National Defense Authorization Act for Fiscal Year 2020 includes a provision for GAO to review the program's production and Block 4 progress annually through 2025. In this report, we (1) provide information on the program's progress toward completing operational testing and resolving deficiencies found in testing; (2) assess the program's production performance and manufacturing efficiency initiatives; and (3) assess the program's modernization cost estimate and progress with Block 4 development efforts.

To provide information on the program's progress in operational testing and the resolution of deficiencies, we first reviewed the baseline program's costs, schedule, and performance plans and compared the actual progress in each area with the goals established in its 2012 baseline to identify any significant trends. We reviewed progress on test events completed versus those that remain, test schedules, program briefings, and DOD briefings. We traveled to Edwards Air Force base to interview DOD test authorities and met with officials from the program office, DOD test authorities, and the contractor Lockheed Martin (the prime aircraft contractor), to discuss key aspects of F-35 development progress, including flight testing, future test plans, and recent findings from test events. Specifically, we obtained updates on key events that are required to complete testing according to the program office's current schedule. We also interviewed the Director, Operational Test and Evaluation office and F-35 program developmental and operational test pilots. To provide information on the program's progress resolving deficiencies, we interviewed the same officials mentioned above and discussed how the number of open and closed deficiencies changed in 2019. We reviewed program and contractor information on deficiency reports, mitigations, resolutions, and the deficiency resolution process.

To assess the program's production performance and manufacturing efficiency initiatives, we obtained and analyzed the production metrics from Lockheed Martin and Pratt & Whitney (the prime engine contractor) and their aircraft and engine delivery rates from 2012 through 2019. We reviewed metrics and briefings provided by the program office, Lockheed Martin, Pratt & Whitney, and the Defense Contract Management Agency to identify progress in improving manufacturing processes. We analyzed delivery dates for lot 11 aircraft delivered in 2019. We traveled to the production facility in Fort Worth, Texas to discuss reasons for any delivery

delays and plans for improvements with officials from Lockheed Martin. We obtained cost investment and savings estimates and discussed cost and manufacturing efficiency initiatives, such as the economic order quantity purchases, with the contractors and program office officials to understand potential cost savings and plans. We collected and analyzed the extent to which the program has met leading practices identified by GAO for full-rate production. We also obtained and analyzed metrics on parts and aircraft quality through December 2019 and discussed steps taken to improve quality and deliveries with Lockheed Martin and Pratt & Whitney officials. We interviewed officials from Lockheed Martin, Pratt & Whitney, and Northrop Grumman (a key subcontractor) regarding the administration's decision to suspend Turkey from the program and the implications of the suspension for the contractors. We determined that the contractors' production metrics and delivery dates were sufficiently reliable for our purposes of determining production efficiency and deliveries. We collected and analyzed production and supply chain performance data from the program office, Lockheed Martin, and Pratt & Whitney.

To assess the reliability of the May 2019 Block 4 development cost estimate, we evaluated documentation supporting the estimate, such as the cost estimating models, the F-35's Air System Procurement Playbook, its updated acquisition strategy, the Decision Memorandum requirements document, and briefings provided to the DOD decision authority. We assessed the cost estimating methodologies, assumptions, and results against leading practices for developing a comprehensive, accurate, well-documented, and credible cost estimate, identified in GAO's Cost Estimating and Assessment Guide.¹ We also interviewed program officials responsible for developing and reviewing the cost estimate to understand their methodology, data, and approach for developing the estimate. We found that the cost estimate was not reliable. To assess progress with Block 4 development efforts, we interviewed DOD and program office officials, and contractor representatives regarding the program's Block 4 planning, development, testing, and production activities to date. We reviewed other program documentation, such as the F-35's fiscal year 2020 budget request, to identify costs associated with the Block 4 effort. We compared the program's accomplishments in 2019 to its plans and identified what capabilities the program office delivered to

¹[GAO-09-3SP](#).

the fleet. We reviewed the program office's plans to develop and deliver additional Block 4 capabilities from 2020 through 2025.

We conducted this performance audit from June 2019 to May 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 IV: The F-35's Reliability and Maintainability Metrics

The Joint Strike Fighter Operational Requirements Document, which outlines the requirements Department of Defense and the military services agreed the F-35 should meet, defines all eight reliability and maintainability (R&M) metrics. Table 5 shows each F-35 variants' performance against these metrics' targets, as of August 2019.

Table 5: The F-35 Reliability & Maintainability Metrics' Performance as of August 2019

	Contractually required	F-35A	F-35B	F-35C
Mission reliability^a —measures the probability of successfully completing a mission of average duration	✓	○	●	—
Mean flight hours between failure (design controlled) —measures time between failures that are directly attributable to the design of the aircraft and are considered fixable with design changes	✓	●	●	●
Mean time to repair —measures the amount of time it takes a maintainer to repair a failed component or device	✓	○	○	●
Maintenance man hours per flight hour —measures the average amount of time spent on scheduled and unscheduled maintenance per flight hour ^b	✓	●	◐	●
Mean flight hours between maintenance events —also referred to as the logistics reliability metric, measures time between maintenance, unscheduled inspections, and servicing actions, including consumables ^{b, c}	—	○	◐	◐
Mean flight hours between removals —measures the time between part removals from the aircraft for replacement from the supply chain ^b	—	○	○	○
Mean flight hours between critical failure —measures the time between failures that result in the loss of a capability to perform a mission-critical capability ^b	—	○	○	○
Mean corrective maintenance time for critical failure —measures the amount of time it takes to correct critical failure events ^b	—	○	○	○

Legend:

- : Metric is at or above current targets
- ◐: Metric is near current targets
- : Metric is below current targets
- ✓: Metric is contractually required
- : not available

Source: GAO analysis of contractor data. | GAO-20-339

Note: Each metric is measured using a 3-month average and reported on a monthly basis; this table summarizes the Joint Reliability and Maintainability Evaluation Team's review of reliability growth and maintainability improvement data from November 2009, and for some metrics, through August 2019.

^aMission Reliability is a key performance parameter. Mission reliability, as well as performance against the targets related to all of these metrics, will be evaluated during initial operational test and evaluation.

^bThis metric's data is mature as of September 2018.

^cConsumable parts are nonrepairable items or repair parts that can be discarded more economically than they can be repaired or that are consumed in use (such as oil filters, screws, nuts, and bolts).

Appendix V: Status of Selected F-35 Technical Risks

The F-35 program continues to address technical risks identified in the field. Since our 2019 report, the program identified new risks with the F-35B thrust, nose landing gear, and the three bearing swivel modules.¹ The program also incorporated design changes to mitigate technical risks we previously highlighted. The status of the Department of Defense's (DOD) efforts to address these issues is as follows:

Newly Identified Technical Risks

F-35B Thrust Cutback: An F-35B aircraft can experience an unanticipated cutback in thrust during vertical landings (hover). The contractor put hover weight restrictions in place to mitigate the effect and has identified the root cause. The contractor is developing software and hardware fixes.

F-35C Nose Landing Gear: During shipboard landings, the F-35C can experience bending stress, which causes cracking of the coating on a part in the nose landing gear. In the short term, this part will be inspected for damage every 400 flying hours. The contractor is also redesigning the part that is cracking and expects to test it between early 2020 to June 2021.

F-35B Three Bearing Swivel Module: The module is mounted at the back of the aircraft and allows the thrust from the engine to be vectored from straight aft for conventional flight to straight down for short takeoff and vertical landing operations. In June 2019, an F-35B experienced a warning indicator in its short takeoff mode due to a hardware component. However, according to the contractor, this component should not cause a warning indicator or loss of functionality for the aircraft. The contractor has identified the root cause of the hardware issue and a gap in the software's logic that led to the warning. As a result, the contractor is making manufacturing changes to the hardware and implementing software changes to address the issue.

Technical Risks Identified in Our Previous Reports

Canopy Coating Delaminations: The F-35 fleet has experienced over 50 incidents of the canopy transparencies delaminating after less than 100 flight hours since August 2017. This is over 30 more than we reported in 2019.² The contractor tested solutions for the delaminations in 2019 and implemented a solution of adding a vent to the canopy's frame.

¹[GAO-19-341](#).

²[GAO-19-341](#).

Since October 2019, the contractor has added a vent to 146 canopies with one subsequent delamination.

Helmet Mounted Display: During low-light flights, the Helmet Mounted Display's technology cannot display pure black images, instead presenting a green glow on the screen, which makes it difficult to see the full resolution of the night vision video feed. The contractor developed a new display to avoid this effect. According to F-35 program officials, they placed an initial order of 62 displays with 35 delivered by December 2019 to support U.S. Marine Corps and Navy F-35C fleet operations. Three F-35C pilots completed initial day and night testing using the new display in July 2019 on a carrier. The contractor expects to have a fully qualified redesign by August 2021 and will incorporate it into the production of lot 12 aircraft.

Appendix VI: Comments from the Department of Defense



ACQUISITION

ASSISTANT SECRETARY OF DEFENSE
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WASHINGTON, DC 20301-3600

Mr. Jon Ludwigson
Director, Contracting and National Security Acquisitions
U.S. Government Accountability Office
441 G Street, N.W.
Washington, DC 20548

Dear Mr. Ludwigson:

This is the Department of Defense response to the Government Accountability Office (GAO) Draft Report, GAO-20-339, "F-35 JOINT STRIKE FIGHTER: Actions Needed to Address Manufacturing and Modernization Risks," dated April 2020 (GAO Code 103588). Detailed comments on the report recommendations are enclosed.

The Department finds that the GAO-20-339 Report is UNCLASSIFIED and cleared for open publication and recommends removal of all FOR OFFICIAL USE ONLY markings. This approval is pending, as amended, based on the GAO addressing one sensitivity mitigation on page 36, paragraph two, line four that the Department staff has communicated with the GAO staff along with two additional wording modifications. Enclosed is a copy of the Department's official security review.

Sincerely,

FAHEY, KEVIN, Digitally signed by
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Enclosures:
As stated

GAO DRAFT REPORT DATED APRIL 2020
GAO-20-339 (GAO CODE 103588)

“F-35 JOINTSTRIKE FIGHTER: ACTIONS NEEDED TO ADDRESS
MANUFACTURING AND MODERNIZATION RISKS”

DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The OUSD(A&S) should direct the F-35 program office to provide its statutorily required submission to Congress ahead of the milestone C review (full-rate production decision). This submission should include an evaluation of the production risks associated with critical production processes that are not in control, R&M targets that are not met, and supplier readiness-particularly for those replacing Turkish suppliers, along with the steps it is taking to address those risks.

DoD RESPONSE: Non-concur. The F-35 Program has provided updates to the Defense Acquisition Executive (DAE) via an Interim Program Review Defense Acquisition Board (IPR DAB) on March 27, 2020, and another planned in September 2020. These reviews continue to assess readiness for Milestone C/Full Rate Production Decision (MS C/FRPD), projected for early CY 2021. The March 2020 IPR DAB included an update on the February 2020 Lockheed Martin Production Readiness Review and Reliability & Maintainability metrics. Additionally, the F-35 Joint Program Office closely tracks supplier readiness for those companies that are replacing Turkish suppliers and routinely updates Department senior leaders, including the DAE, on this progress. The Department will keep the Congress apprised of these matters in our quarterly updates to the defense committees.

RECOMMENDATION 2: The OUSD(A&S) should direct the F-35 program office to establish a Block 4 cost estimate baseline that includes all Block 4 costs, including incurred costs and future costs in its reports to Congress as required by the NDAA for fiscal year 2017, so that Congress has a complete understanding of all Block 4 costs and can compare this baseline to future cost estimates and performance.

DoD RESPONSE: Concur. Development/Block 4 cost estimates and briefings historically have been focused on the U.S. Future Years Defense Program (FYDP). Prior and future costs are available and future communications will include this past and future cost outside of the FYDP information. Additionally, DoD Cost Assessment and Program Evaluation (CAPE) is in the final stages of completing an Independent Cost Estimate which will be shared with Congress once completed.

RECOMMENDATION 3: The OUSD(A&S) should direct the F-35 program office to complete a program office level, product-oriented work breakdown structure for the next update to its Block 4 cost estimate to ensure that the estimate meets the comprehensive leading practices

DoD RESPONSE: Non-concur. Due to the number of on-going contracts that have different Work Breakdown Structures (WBS), the F-35 program does not currently have a single WBS and the program office would be unable to complete this request prior to the next update to its Block 4 Cost Estimate, which is currently in the review and approval process. In the coming months, the program will evaluate moving to a single Program Office WBS. The program office does consider that the estimate developed by the program meets comprehensive standard estimating process requirements.

RECOMMENDATION 4: The OUSD(A&S) should direct the F-35 program office to conduct risk and uncertainty analyses for the next update to its Block 4 cost estimate to ensure that the estimate meets the credible leading practices.

DoD RESPONSE: Concur. The F-35 Program Office estimate is aligned with the DoD CAPE approach and methodology for performing Development Cost Estimates.

RECOMMENDATION 5: The OUSD(A&S) should direct the F-35 program office to consider the results of its future technology readiness assessment of all Block 4 technologies and incorporate the cost and schedule risks of developing those technologies in the next update to its Block 4 cost estimate to ensure that the estimate meets the comprehensive leading practices.

DoD RESPONSE: Concur. The F-35 Program continues to evaluate Technology Readiness Levels (TRLs) for Block 4 hardware and capabilities and incorporate that information into the estimate as appropriate. While the JPO does not believe there are any low TRL hardware or capabilities, these are more difficult to estimate and the program typically bases its estimate on an analogy with an existing, proven technology, in accordance with standard cost estimating procedures. In 2020, the Office of the Under Secretary of Defense for Research and Engineering plans to accomplish an Independent Technical Risk Assessment of the Block 4 program.

Appendix VII: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the contact named above, the following staff members made key contributions to this report: Justin Jaynes and Alissa Czyz (Assistant Directors); Diana Maurer, Desirée E. Cunningham (Analyst-in-Charge), Jillena Roberts, Tim Moss, Rose Brister, Juaná Collymore, Emile Ettedgui, Jennifer Leotta, and Jeff Hubbard, Other staff who contributed include Leslie Ashton, Priyanka Sethi Bansal, Vinayak Balasubramanian, Julia DiPonio, Christine Pecora, Ralph Roffo, Roxanna Sun, Jessica Waselkow, and Alyssa Weir.

Related GAO Products

Weapon System Sustainment: DOD Needs a Strategy for Re-Designing the F-35's Central Logistics System. [GAO-20-316](#). Washington, D.C.: March 6, 2020.

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