United States Government Accountability Office

Report to Congressional Committees

April 2022

F-35 JOINT STRIKE FIGHTER

Cost Growth and Schedule Delays Continue

Accessible Version

GAO-22-105128

GAO Highlight

Highlights of GAO-22-105128, a report to congressional committees

April 2022

F-35 JOINT STRIKE FIGHTER

Cost Growth and Schedule Delays Continue

Why GAO Did This Study

The F-35 Lightning II Joint Strike Fighter program remains DOD's most expensive weapon system program. It is estimated to cost over $1.7 trillion to buy, operate, and sustain. DOD is 4 years into a development effort to modernize the F-35 aircraft's capabilities. An important element to operating and maintaining the F-35 is a complex logistics system called ALIS. In 2020, DOD began an effort to improve ALIS after years of concerns regarding its performance. Congress included provisions in two statutes for GAO to review the F-35 program.

This report (1) identifies the F-35's progress towards full-rate production, (2) addresses the program's progress and improvements towards developing, testing, and delivering modernization capabilities, and (3) describes DOD's plan for improving its logistics system. To assess progress for the F-35 and its modernization program, GAO compared the cost and schedule targets in the original development program documentation to the most recent data available. GAO also reviewed DOD and contractor documentation and interviewed DOD officials and contractor representatives.

What GAO Recommends

Since 2001, GAO has made a number of recommendations to DOD to improve aspects of the acquisition of F-35 aircraft. In 2020, GAO recommended DOD develop a strategy for its logistics system redesign. In 2021, GAO made 3 recommendations aimed at improving Block 4. DOD concurred with these recommendations and has addressed or is taking steps to address them.

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What GAO Found

The Department of Defense (DOD) has not yet authorized the F-35 program to begin full-rate production. Full-rate production generally is the point when a program has demonstrated an acceptable level of performance and reliability; and in the case of the F-35, is ready for higher manufacturing rates. The delay in reaching this milestone stems largely from problems and delays developing the F-35 simulator, needed for crucial testing. The program is projected to finalize its schedule in spring 2022. As a result, the date for the full-rate production decision remains undetermined at this time. Despite this delayed decision, DOD is planning on acquiring up to 152 aircraft per year. At that rate, DOD would purchase about one-third of all planned F-35 aircraft before achieving this production milestone, which increases risk. For example, it means that more aircraft will need to be fixed later if more performance issues are identified, which will cost more than if those issues were resolved before those aircraft were produced. At the same time that DOD is purchasing aircraft at these high rates, those that are already in the fleet are not performing as well as expected.

DOD is also 4 years into development of its modernization effort, known as Block 4, which is continuing to experience cost growth and schedule delays. Block 4 costs continued to rise during 2021 due to higher costs associated with upgrading crucial hardware and testing upgrades, among other things. The program office extended Block 4 development and delivery into fiscal year 2029—which is now 3 years beyond the original plan (see figure). To avoid further delays, the program office is taking steps to improve the timeliness and quality of software deliveries, but it is too soon to tell whether these actions will result in improved outcomes for Block 4.

F-35 Block 4 Modernization Schedule Changes since 2018 Plan

Source: GAO analysis of Department of Defense data. | GAO-22-105128

The F-35 program office has changed plans from replacing its logistics system and is now taking incremental steps to improve and modernize it. The Autonomic Logistics Information System (ALIS) has faced long-standing challenges, including technical complexity, poor usability, and inaccurate or missing data. Initially, the F-35 program intended to develop a new system to replace ALIS. However, the program office now plans to make gradual improvements to ALIS and eventually rename it. These planned improvements include smaller hardware and improved program data access. The program has yet to identify a date for when it will consider this transition complete but has mapped out the improvements it intends to make over the next 3 years.

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Abbreviations

ALIS	Autonomic Logistics Information System
DOD	Department of Defense
DOT&E	Director of Operational Test and Evaluation
NDAA	National Defense Authorization Act
ODIN	Operational Data Integrated Network
TR-2	Technology Refresh 2
TR-3	Technology Refresh 3

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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April 25, 2022

Congressional Committees

The F-35 Lightning II Joint Strike Fighter is a family of fifth-generation strike fighter aircraft that integrates low-observable (stealth) technology with advanced sensors and computer networking capabilities. Specifically designed versions of the F-35 are expected to be used by the United States Air Force, Marine Corps, and Navy and seven international partners, as well as by approved buyers in allied countries. The Department of Defense (DOD) aims to procure 2,470 F-35s to replace several other aircraft used by the Air Force, Navy, and Marine Corps to perform a wide range of missions. The program has overseen delivery of over 700 aircraft to the U.S. services, allied partners, and foreign military sales customers, but it continues to identify new issues with the aircraft and has yet to achieve all requirements.

DOD is also now in the fourth year of a $15 billion modernization effort—known as Block 4—to upgrade the hardware and software systems of the F-35. DOD intends for Block 4 to help the aircraft address new threats that have emerged since the aircraft's original requirements were established in 2000. DOD's approach for incrementally delivering these capabilities is loosely based on Agile software development processes.[1]

The program wrapped up development of the F-35's original capabilities in 2018 and is undergoing operational testing to verify that the aircraft adequately provide those original development capabilities. GAO has reported that there have been delays to a full-rate production decision, which would formally authorize DOD's transition from development to full production. As the program moves toward completing this testing and evaluating the results, it faces risks ahead of the full-rate production decision. The program office has also faced a number of challenges with the Autonomic Logistics Information System (ALIS), the primary logistics tool to support F-35 operations, mission planning, and sustainment. In March 2020, we reported that inaccurate and missing data in ALIS have at times resulted in the system's signaling that an F-35 aircraft should not

[1]Agile is a framework for incremental development, which has been adopted by many federal agencies. Agile emphasizes development of software in iterations that are continuously evaluated on their functionality, quality, and customer satisfaction.

be flown—even though the aircraft had no issues that required it to be grounded, and it was ready for flight.[2] We 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 comprehensive list of our recommendations 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 GAO to review the F-35 program annually until the program reaches full-rate production. This is our seventh report under that provision.[3] Second, the NDAA for Fiscal Year 2020 includes a provision for us to submit a report on the F-35 program's production and Block 4 progress within 30 days of the President's budget submission for Fiscal Years 2021 through 2025. This is our third report under that provision.[4]

In this report, we (1) describe remaining risks with completing the original development program as it progresses towards full-rate production; (2) assess DOD's progress and improvements in developing, testing, and delivering modernization capabilities; and (3) describe DOD's plan for improving the program's logistics system.

To do this work, we reviewed cost, schedule, and performance documents for the original development program, Block 4 modernization, and the logistics system to determine progress DOD has made in achieving its costs, schedule, and performance goals since we reported last year. To identify risks with completing the original development

[2]GAO, *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).

[3]GAO, *F-35 Joint Strike Fighter: DOD Needs to Update Modernization Schedule and Improve Data on Software Development*, GAO-21-226 (Washington, D.C.: Mar. 18, 2021); *F-35 Joint Strike Fighter: Actions Needed to Address Manufacturing and Modernization Risks,* GAO-20-339 (Washington, D.C.: May 12, 2020); *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).

[4]GAO-21-226 and GAO-20-339.

program, we collected and analyzed production data such as on-time deliveries and number of deficiencies, among others. We interviewed officials and representatives from the F-35 program office; Office of the Director of Operational Test and Evaluation; Lockheed Martin (airframe contractor); Pratt & Whitney (engine contractor); and the Defense Contract Management Agency located at each of the contractors, among others, about any production and testing risks, the status of the modernization program, and plans for the new logistics system.

To determine that the data we used were sufficiently reliable for the purposes of responding to our reporting objectives, we corroborated data collected from contractor representatives and program officials with other data sources or knowledgeable officials, such as the Director of Operational Test and Evaluation. See appendix II for a detailed description of our scope and methodology.

We conducted this performance audit from March 2021 to April 2022 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

F-35 Program

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, DOD intended the F-35 aircraft to be difficult to detect using radar and included sensors that can provide insights into potential targets and other warfighting information. Lockheed Martin is the prime contractor for the F-35 aircraft and is responsible for integrating the engine into the

airframe. Pratt & Whitney is the contractor for the engine, also known as the F135.[5]

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 amphibious ships, and main and austere operating bases. Meeting these requirements meant designing the variant to be capable of short-distance takeoffs and vertical landing. Figure 1 shows an F-35B preparing for landing.

Figure 1: F-35B Exercising Its Vertical Landing Capability

Source: Lockheed Martin Corporation (All rights reserved). | GAO-22-105128

[5]The engines are purchased by the government directly from Pratt & Whitney and delivered as government-furnished equipment to Lockheed Martin for integration into the airframes during production.

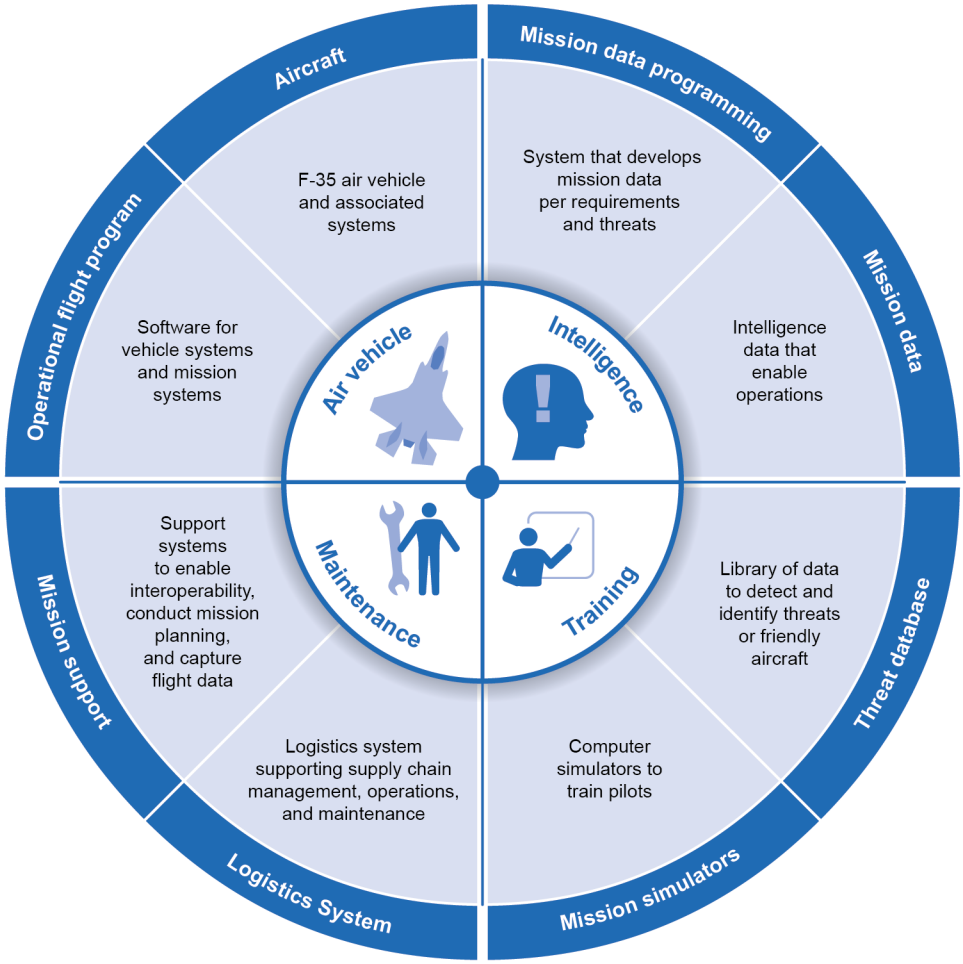
DOD leads the F-35 program, but it also involves several allied partner countries in its development.[6] Companies in these countries also support aircraft production by producing certain parts of the airframe or engine and provide software for ALIS, according to program office officials. In July 2019, DOD removed Turkey from the development program due to its government's decision to procure Russian-made radar systems. Consequently, the F-35 program office and the prime contractors have identified and are contracting with alternative suppliers to produce the 1,005 parts that were made in Turkey. In March 2021, we reported that the program estimates it will cost $108 million to establish alternative suppliers. However, the program has not negotiated these costs with them; therefore, it does not yet know what the cost implications will be for the parts suppliers being replaced.[7]

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. For the F-35 aircraft to be fully operational, capabilities associated with each element of the air system have to be developed and fielded in sync with the aircraft. Figure 2 shows the eight elements that make up the entire F-35 air system and how they support the aircraft.

[6]Seven partner nations—United Kingdom, Italy, Netherlands, Canada, Australia, Denmark, and Norway—contribute to F-35 development, production, and sustainment. In addition, the program currently has six foreign military sales customers: Israel, Korea, Japan, Belgium, Poland, and Singapore. According to program officials, multiple other countries are at various stages of foreign military sales consideration.

[7]GAO-21-226.

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



Source: GAO interpretation of Department of Defense data. | GAO-22-105128

Historical Cost Drivers and Program Acquisition Costs as of December 2019

As we previously reported in March 2005, DOD began development of the F-35 aircraft in 2001 without adequate knowledge of its critical technologies or a solid design.[8] Later, we reported DOD's acquisition

[8]GAO, *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).

strategy called for high levels of concurrency between development and production—building aircraft while continuing to refine and test the designs of key components—which runs counter to leading practices for major defense acquisition programs that we have identified.[9] In our prior work, we reported on the F-35 program's lack of adequate knowledge and high levels of concurrency as major drivers of the program's eventual significant cost and schedule growth, among other performance shortfalls.[10]

Since 2001, DOD has significantly revised the cost and schedule goals for the program several times. For example, DOD revised these goals in March 2012 after the cost of each aircraft grew by an amount that exceeded critical thresholds established by statute—a condition known as a Nunn-McCurdy breach.[11] This 2012 revised baseline increased the program's cost estimate by $162.7 billion and extended delivery schedules 5 to 6 years into the future. Since 2012, the program has revised its baseline schedule three more times due to delays in development, among other things. However, the program's cost estimate for development and procurement has remained relatively stable. As of DOD's most recent cost estimate in December 2019, total acquisition costs are $397.8 billion.

[9]GAO, *Joint Strike Fighter: DOD Actions Needed to Further Enhance Restructuring and Address Affordability Risks*, GAO-12-437 (Washington, D.C.: June 14, 2012); and *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes,* GAO-02-701 (Washington, D.C.: July 15, 2002).

[10]GAO-05-271 and GAO-12-437.

[11]DOD is required to notify Congress whenever a major acquisition program's unit cost experiences cost growth that exceeds certain thresholds, commonly referred to as a Nunn-McCurdy breach. 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. The text of this statute was previously codified at 10 U.S.C. § 2433a until it was transferred on January 1. The NDAA for Fiscal Year 2022 changed and renumbered acquisition and acquisition related sections within Title 10. The new section, which is pending formal publication, is 10 U.S.C. § 4371a. National Defense Authorization Act for Fiscal Year 2022, Pub. L. No. 117-81, § 805(a) (2021).

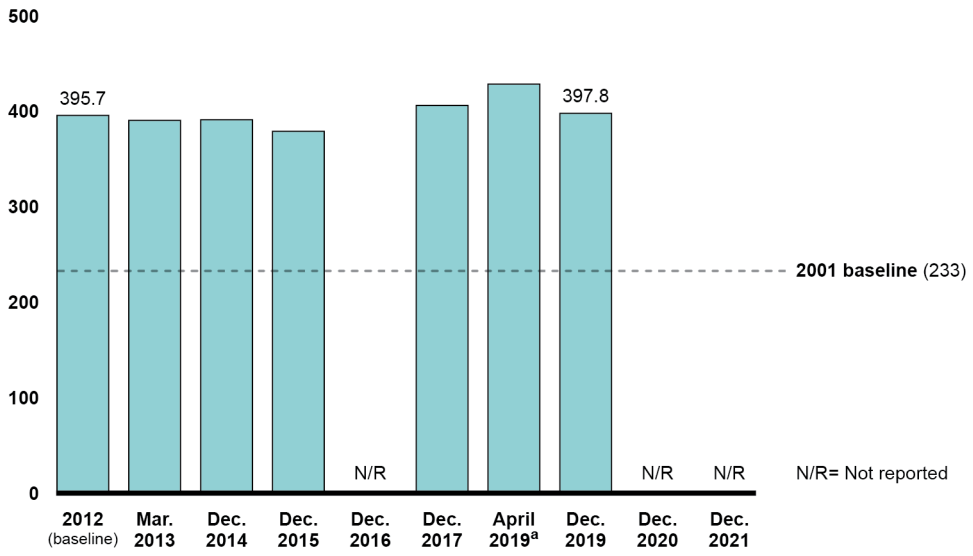
In addition to the acquisition costs, in July 2021 we reported that the program office estimates that the costs to operate and sustain the F-35 fleet for its planned 66-year life cycle is about $1.3 trillion, bringing the total cost of the F-35 program to over $1.7 trillion.[12]

We were unable to determine the extent to which F-35 program costs changed since 2019 or evaluate total program cost growth in comparison to the program's current 2012 acquisition program baseline estimate. The F-35 program office did not provide an update on total program cost more recently than as of December 2019 because it has not updated its Selected Acquisition Report since that time.[13] According to program officials, the program office will not update its total program cost and schedule estimate until the spring of 2022, when a revised acquisition program baseline is finalized. Figure 3 shows total program cost since 2012 for years when those data were available.

[12]GAO, *F-35 Sustainment: DOD Needs to Cut Billions in Estimated Costs to Achieve Affordability*, GAO-21-439 (Washington, D.C.: July 7, 2021).

[13]The Selected Acquisition Report includes a program update on development, production, sustainment, and total program costs, among other things. The program office did not complete a Selected Acquisition Report in fiscal year 2021. In 2019, Congress terminated the requirement for DOD to submit Selected Acquisition Reports after the final submission of reporting covering fiscal year 2021. Pub. L. No. 116-92, § 830(a)(2) (2019). However, the NDAA for Fiscal Year 2022 subsequently extended the requirement for 2 years, through fiscal year 2023. Pub. L. No. 117-81, § 805(a) (2021). The text of this statute was previously codified at title 10, section 2432(j) of the U.S. Code until it was transferred on January 1 to 10 U.S.C. § 4351.

Figure 3: Reported F-35 Total Program Acquisition Costs since 2012



Source: GAO analysis of Department of Defense (DOD) data. | GAO-22-105128

Accessible Data Table for Figure 3

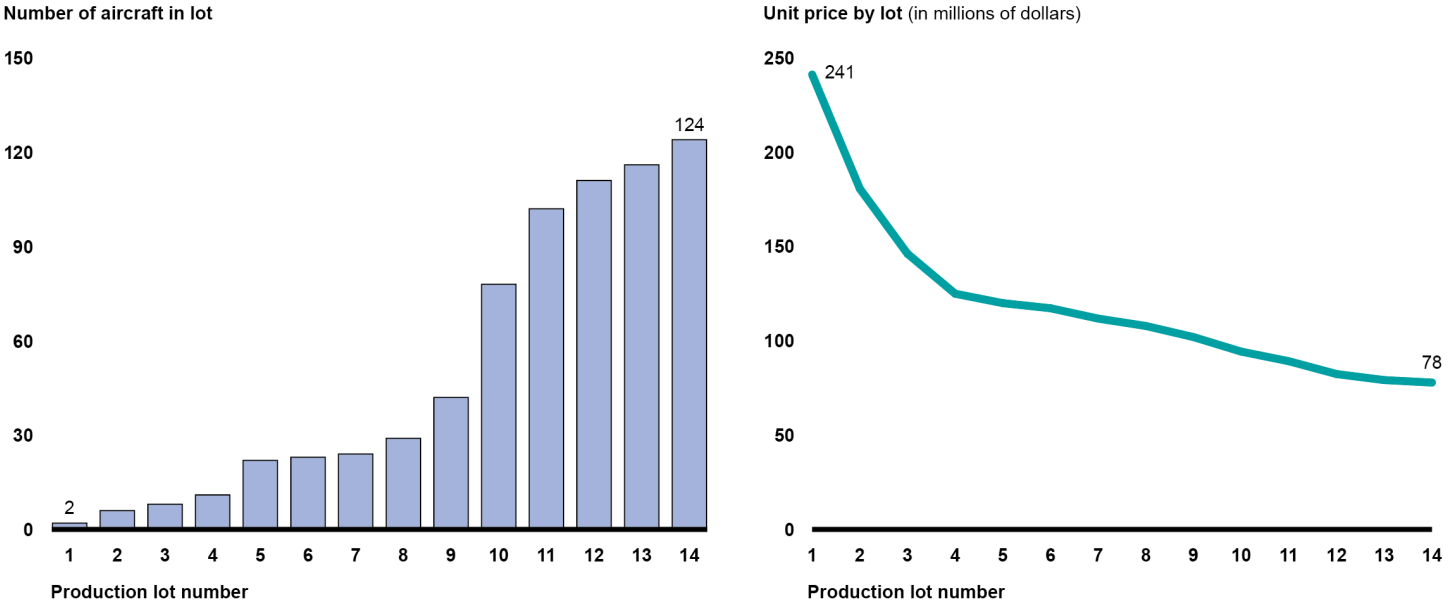
	Total acquisition cost (in billions of then-year dollars)
2001 baseline	233
2012 (baseline)	395.7
March 2013	390.4
December 2014	391.1
December 2015	379
December 2016	100
December 2017	406.1
April 2019[a]	428.4
December 2019	397.8
December 2020	Not reported
December 2021	Not reported

[a]Data from 2019 include Block 4 modernization costs.

The program has reduced the price of each F-35 aircraft, especially for the F-35A variant, which makes up the majority of DOD's planned F-35 fleet. Aircraft are procured in groups, also known as production lots. In October 2019, the program office finalized the contract for lots 12 through 14 and surpassed its goal of reducing the negotiated unit price of an F-

35A to less than $80 million by lot 14, as shown in figure 4. Lot 14 includes aircraft that will be delivered through 2023.

Figure 4: F-35A Aircraft Unit Costs Decreased Over Time, as of February 2022



Source: GAO analysis of Department of Defense data. | GAO-22-105128

Accessible Data Table for Figure 4(Part 1 of 2)

Production lot number	Number of aircraft in lot
1	2
2	6
3	8
4	11
5	22
6	23
7	24
8	29
9	42
10	78
11	102
12	111
13	116
14	124

Accessible Data Table for Figure 4(Part 1 of 2)

Production lot number	Unit price by lot (in millions of dollars)
1	241.2
2	180.7
3	146.2
4	125
5	120
6	117.3
7	111.8
8	107.9
9	102
10	94.3
11	89.2
12	82.4
13	79.2
14	77.9

Note: F-35A aircraft unit costs include the F-35A airframe and the F135 engine costs. The figure also reflects the September 2021 contract modification that affected lots 12 through 14.

In May 2020, we reported that program officials stated they negotiated lower unit prices by working with the airframe contractor to leverage economic order quantity purchases and investing in cost reduction initiatives.[14] Economic order quantities involve the contractor making large purchases of components for multiple production lots to get lower prices and reduce aircraft production costs. In addition, the program office and prime contractors continued to work on various initiatives to further lower production costs. In 2017, the program office initiated the F-35 Lightning II Affordability Strategy partnering with industry to develop and execute cost reduction initiatives for both the F-35 aircraft and the F135 engine. This resulted in the Blueprint for Affordability, a strategy that enabled cost reduction initiatives across prime and subcontractor production lines with the targeted goal of reducing per unit cost by the Lot 13 contract. For example, in 2019, Lockheed Martin received about $170 million to further lower its production costs. In addition, Pratt & Whitney received $131 million in government funds to lower engine costs. According to program officials, in total, these efforts have achieved $72.8 billion in cost savings or cost avoidances and could result in up to $11.3 billion in additional savings over the life of the program (through 2077).

[14]GAO-20-339.

F-35 Block 4 Modernization Effort

In addition to the F-35 original development program, DOD is pursuing a modernization effort known as Block 4, estimated to cost over $15 billion. DOD is using a different development approach for Block 4 called continuous capability development and delivery, which is loosely based on the Agile software development process. With this approach, the program office plans to incrementally deliver capabilities to the warfighter. For example, rather than take years to develop and deliver all the required capabilities to the warfighter at one time, the program office intends to incrementally develop, test, and deliver small groups of capabilities. Lockheed Martin is expected to sequentially develop four software increments that make up each software drop. These increments are intended to refine and further develop capabilities over time as each is tested by the developmental and operational test fleets. Examples of these capabilities include a technology to avoid aircraft collisions and radar enhancements.

The over $15 billion cost of the Block 4 effort exceeds the statutory and regulatory thresholds for what constitutes a major defense acquisition program.[15] In 2016, we recommended that the Secretary of Defense manage it as a separate major defense acquisition program to provide better oversight of Block 4 activities.[16] DOD did not concur with our recommendation, and it continues to manage Block 4 within the larger F-35 program. Congress subsequently passed the NDAA for Fiscal Year 2017, which it amended in 2020, that contained a requirement for DOD to submit a report containing certain elements of an acquisition program baseline—in essence, a full program business case—to include the cost, schedule, and performance information for Block 4.[17] The program has released the Block 4 report to Congress each year.

[15]Major 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 $525 million, or for procurement of more than $3.065 billion, in fiscal year 2020 constant dollars. DOD Instruction 5000.85, Major Capability Acquisition (Aug. 6, 2020) (incorporating change 1, Nov. 4, 2021). See also 10 U.S.C. § 4201. The text of this statute was previously codified at title 10, section 2430(a)(1) of the U.S. Code until it was transferred on January 1, 2022.

[16]GAO-16-390.

[17]Pub. L. No. 114-328, § 224(d) and Pub. L. No. 116-92, § 166.

Relatedly, in April 2019, we found that the F-35 program started Block 4 development without a complete business case identifying baseline cost and schedule estimates, which was inconsistent with leading acquisition practices.[18] Therefore, we recommended that the Secretary of Defense ensure that the F-35 program office completed its business case for the initial Block 4 capabilities under development before initiating additional development work. To date, the F-35 program completed nearly all of the documentation that is required of major defense acquisition programs, although it completed some of these documents after Block 4 development began. For example, the F-35 program office drafted, completed, or updated baseline documentation for key acquisition documents such as the Acquisition Strategy. A Block 4 Test and Evaluation Master Plan is also required, which the program has drafted, but not yet finalized.

ALIS

One of the elements that comprise the F-35 system, ALIS, has not lived up to DOD's expectations, as we have reported for several years.[19] ALIS is supposed to provide the logistics tools that F-35 program participants need to operate and sustain the aircraft. The logistics system consists of computer hardware and multiple software applications designed to support different squadron activities, such as supply chain management, maintenance, training management, and flight scheduling. However, we have identified numerous long-standing issues with ALIS, including that the system is not user friendly and does not provide the sustainment-related capabilities that were promised.[20] In March 2020, we found that problems with ALIS posed significant challenges to day-to-day F-35 operations.[21] In March 2021, we reported that DOD was replacing ALIS

[18]GAO-19-341.

[19]GAO-20-316 and GAO, *F-35 Sustainment: DOD Needs a Plan to Address Risks Related to Its Central Logistics System,* GAO-16-439 (Washington, D.C.: Apr. 14, 2016).

[20]GAO, *F-35 Sustainment: DOD Needs a Plan to Address Risks Related to Its Central Logistics System,* GAO-16-439 (Washington, D.C.: Apr. 14, 2016); and *F-35 Sustainment: Need for Affordable Strategy, Greater Attention to Risks, and Improved Cost Estimates,* GAO-14-778 (Washington, D.C.: Sept. 23, 2014).

[21]GAO-20-316.

with a new system named the Operational Data Integrated Network (ODIN).[22]

F-35 Program Postponed Final Development Milestone but Continues to Buy Many Aircraft under Revised Delivery Schedule

We found that F-35 simulator delays continue to prevent DOD from completing initial operational test and evaluation and the program office has postponed the full-rate production decision—the final development milestone.[23] The duration of this delay is not clear; however, the program is years behind schedule in completing development while continuing to acquire up to 152 aircraft per year. The more aircraft produced before operational testing is complete, the higher the risk of increased costs to retrofit those aircraft if issues are discovered. While the F-35 program modified its delivery schedule to accommodate supply chain challenges and delays due to the COVID-19 pandemic, contractors continue to deliver airframes and engines late and with quality issues.

Simulator Delays Continue to Prevent Completion of Operational Testing, which Raises Risks of Increasing Retrofit Costs

The time frame for completing initial operational test and evaluation is delayed to an undetermined date because of developmental delays with the Joint Simulation Environment, which we refer to as the simulator. The simulator runs the F-35's mission systems software along with other software models (such as other weapons and modern threat systems) to provide a simulated environment for conducting complex test scenarios that the program office cannot replicate in a real-world environment. The program office completed the final remaining open-air weapons trial in June 2021 but needs to complete 64 simulated test trials in the simulator

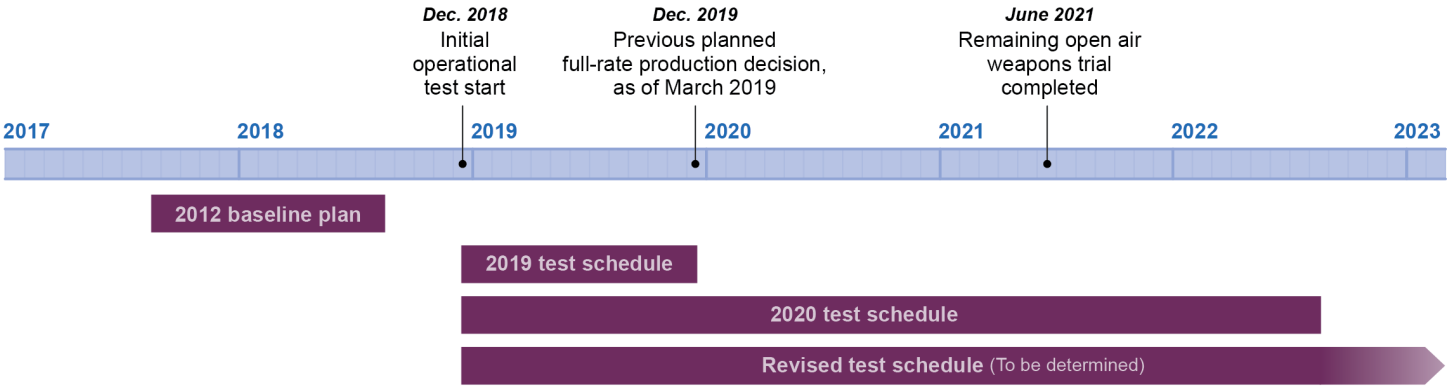
[22]GAO-21-226.

[23]Initial operational test and evaluation is conducted on production, or production representative articles, to determine whether systems are operationally effective and suitable to support a full-rate production decision.

before initial operational testing will be finished. Before DOD can conduct the final 64 simulated test trials, the simulator must be fully developed.

For the past few years, we have reported that the program had technical challenges with the simulator's development, leading to repeated delays.[24] These delays led the program to postpone completion of initial operational testing multiple times, and it has yet to finalize its testing schedule, as shown in figure 5.

Figure 5: F-35 Initial Operational Test and Evaluation Schedule Is Not Yet Determined



Source: GAO analysis of Department of Defense data. | GAO-22-105128

Facing ongoing delays and development challenges, the program office initiated an independent feasibility study between December 2020 and May 2021 to assess the simulator's technical requirements and development schedule. The study found, among other things, that:

- the simulator's technical requirements were achievable;
- the program had the personnel with the technical abilities to complete the remaining development work;
- it was feasible for the program office to complete simulator development, verification, validation, accreditation and operational test agencies to begin final operational testing in the simulator by August 2022, which at that time was the program's estimated time frame for completing the simulator; and
- there was risk of schedule delay if the program continued to identify new deficiencies with the simulator.

[24]GAO-21-226; GAO-20-339; and GAO-19-341.

As of January 2022, the program had not committed to completing the simulator by August 2022 and has not yet released a revised schedule for doing so. Program officials told us that they will release the revised simulator schedule when the acquisition program baseline is approved, the date of which has yet to be determined. As a result, the program has not determined when it will conduct the necessary simulated testing to complete initial operational testing.

The program office has not yet committed to the remaining simulator development schedule, in part, because it continues to find deficiencies with the simulator. During and after the independent study, DOD continued to identify and correct deficiencies with the simulator, which, as noted above, the study warned could lead to additional schedule delays. As of December 2021, there were 54 open simulator deficiencies, 32 of which the program has determined it must fix and verify before beginning to use the simulator for conducting the remaining 64 simulated test flights. Echoing the independent study results, program officials stated that as those deficiencies are resolved, additional deficiencies with the simulator may be discovered when they test and verify the proposed fixes. This process takes time and could lead to more schedule delays.

Producing Large Numbers of Aircraft before Completing Testing Poses a Cost Risk

As a result of delays in completing initial operational testing, DOD postponed the F-35 full-rate production decision but continues to buy aircraft at near full production rates. According to program officials, the program office expects to release a new program cost and schedule baseline at some point in the near future, which would include a full-rate production date. As of February 2022, officials told us that the program had completed a draft but had not finalized a new program cost and schedule baseline. The program office has delayed full-rate production several times since the program began, as we have previously reported. At this point the full-rate production decision is expected to occur over a decade later than what the program office originally planned.

Continuing to purchase aircraft at high rates before completing testing can increase retrofit costs as the program continues to identify and resolve deficiencies. As of December 2021, the program office expected to resolve all four of its open critical deficiencies with the aircraft before the full-rate production decision. Open critical deficiencies include issues with the night vision camera and cabin overpressurization.

However, the program also has 822 other less-critical deficiencies open but does not plan to close all of them prior to the full-rate production decision and will not address some. See appendix III for further details on overall deficiencies. Sometimes fixing deficiencies requires that the contractor redesign and replace equipment on aircraft already delivered, referred to as retrofitting. The more aircraft produced and delivered prior to resolving deficiencies, the greater the likelihood that the program will have to retrofit aircraft, at the expense of the government.

If the full-rate production decision occurs in 2023, we estimate that the program will have delivered 1,115 aircraft before finishing operational testing. This estimate represents about one-third of the total aircraft forecasted to be purchased through the program. This includes all planned aircraft purchased by the US, partner nations, and foreign military sales. The program is also purchasing aircraft at relatively high rates—up to 152 per year, a number higher than some planned production rates after the draft full-rate production decision. Our past work indicates that purchasing large numbers of aircraft before completing testing, resolving deficiencies, and reaching the full-rate production milestone and its associated requirements, increases the risk of additional retrofit costs.[25] At the same time that DOD is purchasing aircraft at these high rates, those that are already in the fleet are not performing as well as expected. For example, in July 2021 we reported that F-35 mission capable rates—a measure of the readiness of an aircraft fleet—have recently improved but continue to fall short of warfighter requirements.[26]

The program continues to take actions to address our prior recommendations and resolve technical issues before making its full-rate production decision. For example, in 2018, we recommended, and DOD concurred, that the F-35 program office identify steps needed to ensure the F-35 meets reliability and maintainability requirements before each variant reaches maturity.[27] Although reliability and maintainability metrics slightly declined this year as compared with 2020, the program office is prioritizing funding and implementing initiatives to improve its reliability

[25]GAO, *KC-46 Tanker Modernization: Aircraft Delivery Has Begun, but Deficiencies Could Affect Operations and Will Take Time to Correct,* GAO-19-480. (Washington, D.C.: June 12, 2019).

[26]GAO-21-439.

[27]GAO-18-321.

and maintainability metrics in line with our previous recommendations.[28] See appendix IV for further details on each variant's reliability and maintainability performance.

Furthermore, the program is assessing and continuing to resolve outstanding technical issues with the aircraft, such as problems with the F-35C electronic warfare system and a sensor window coating issue on all variants. We also reported on some technical issues last year, which have yet to be resolved. See appendix V for more details.

Delivery Schedule Modified to Mitigate Effects of Long Standing Supply Chain Challenges and COVID-19

We found that the program office modified the contracted delivery date of near-term aircraft to help the contractor and the production line recover from issues with ongoing supply chain challenges exacerbated by the COVID-19 pandemic. In particular, prior to the pandemic, we reported that late aircraft deliveries were largely a result of suppliers delivering parts to the production line later than needed.[29] As we reported in March 2021, COVID-19 exacerbated these long-standing supply-chain issues and caused labor disruptions, leading to late deliveries of aircraft. In September 2021, after facing significant production delays in 2020 and 2021 due to COVID-19 and the resulting supply chain issues, the program office and contractors modified the delivery schedule for aircraft on contract for delivery in years 2020 to 2023. Program officials explained that they took these steps to reflect the unavoidable challenges of operating during the COVID-19 pandemic and to not unfairly penalize the contractor.

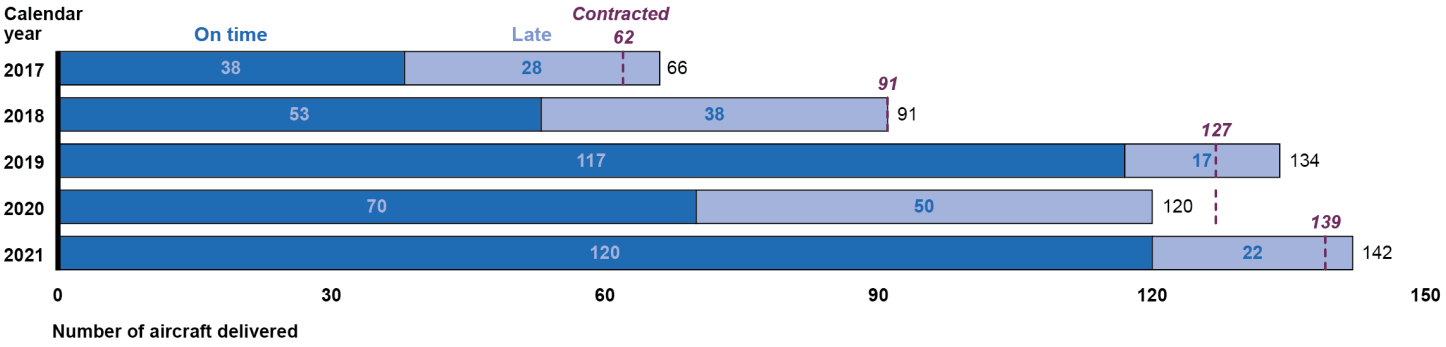
By modifying the delivery dates for aircraft contracted for delivery from 2020 to 2023, the program office provided relief to the contractor's production line. The program modified the contracted delivery dates of some aircraft delivered during this time frame, thereby revising what aircraft were considered late deliveries. In particular, after the modifications, some aircraft considered late were determined to be on time. For example, after modifying the delivery schedule, 50 out of 120 aircraft delivered in 2020 were considered late, as shown in figure 6.

[28]In 2018, 2019 and 2020, we made a series of recommendations to improve reliability and maintainability metrics. GAO-18-321, GAO-19-341 and GAO-20-339.

[29]GAO-18-321 and GAO-19-341.

Before the contract modification, 85 out of 120 would have been considered late.

Figure 6: F-35 Aircraft Deliveries, On Time and Late, 2017 through 2021



Source: GAO analysis of Department of Defense data. | GAO-22-105128

Accessible Data Table for Figure 6
Number of aircraft delivered

Fiscal year	On time	Late	Total	Number contracted
2017	38	28	66	62
2018	53	38	91	91
2019	117	17	134	127
2020	70	50	120	127
2021	120	22	142	139

Note: The figure reflects deliveries by calendar year. Delivery totals for 2020 and 2021 reflect the modified contract dates. Aircraft contracted for a particular year may have been delivered in a different year. For example, Department of Defense officials told us that seven aircraft contracted for delivery in 2020 were delivered early in 2019. Contracted numbers reflect the total number of aircraft on contract for delivery that calendar year.

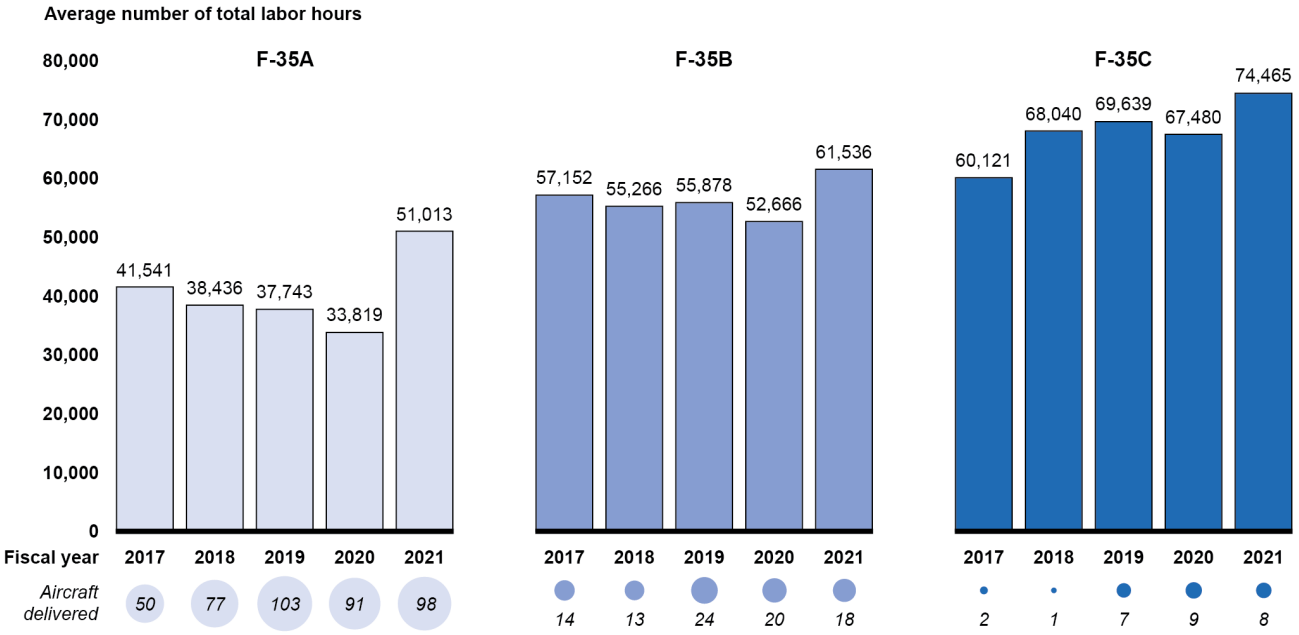
We found that the modified delivery schedule may provide relief to suppliers. For example, with the reduced demand for parts for the production line, the program office can finish establishing suppliers to replace parts made in Turkey before future aircraft contracts are finalized. In July 2019, DOD removed Turkey from the F-35 program. The Under Secretary of Defense for Acquisition and Sustainment directed that the F-35 program establish alternative sources for parts made in Turkey and stop placing new orders with Turkish suppliers after March 2020. As of January 2022, the program office identified alternative suppliers for all Turkish parts, and according to program officials, all of the 817 airframe parts and 181 of the 188 engine parts are qualified from the new sources.[30] According to program officials, the remaining seven parts are to be qualified by March 2022. Although the program office has finalized

[30]According to program officials, new suppliers are required to go through qualification and testing to ensure the design integrity for their parts.

contracts for alternate suppliers, officials stated that they are still in the process of finalizing contracts for future aircraft lots, which will allow them to understand the final cost effects of Turkey's removal from the supply chain. While there are ongoing negotiations to lower the cost of the identifying and standing up new suppliers, as of July 2021, the program spent $1.355 billion and planned to spend about $46.6 million more to finish the Turkish parts replacement effort for the airframe and engine.

We also found that, in addition to the late deliveries described above, other production metrics associated with the airframe varied in 2021. For example, airframes are taking more work hours to build, on average, for all variants. According to DOD representatives, the increase in labor hours includes time for the suppliers to build parts of the plane, such as the wing, which is what contributed to the growth in labor hours last year (see figure 7). The contractor is spending less time on scrap, rework, and repair due to a combination of improvement initiatives and an increase in production quantity of the F-35C. For example, the contractor went from delivering one F-35C in 2018 to about eight F-35C's per year from 2019 through 2021, providing the contractor learning opportunities for assembling the aircraft more efficiently, which is reflected in the metrics (see figure 8).

Figure 7: Average Total Labor Hours for Each F-35 Variant Increased in 2021



Source: GAO analysis of Department of Defense and Lockheed Martin data. | GAO-22-105128

Accessible Data Table for Figure 7(Part 1 of 3)
F-35A

Fiscal year	Average number of total labor hours	Number of aircraft delivered
2017	41,541	50
2018	38,436	77
2019	37,743	103
2020	33,819	91
2021	51,013	98

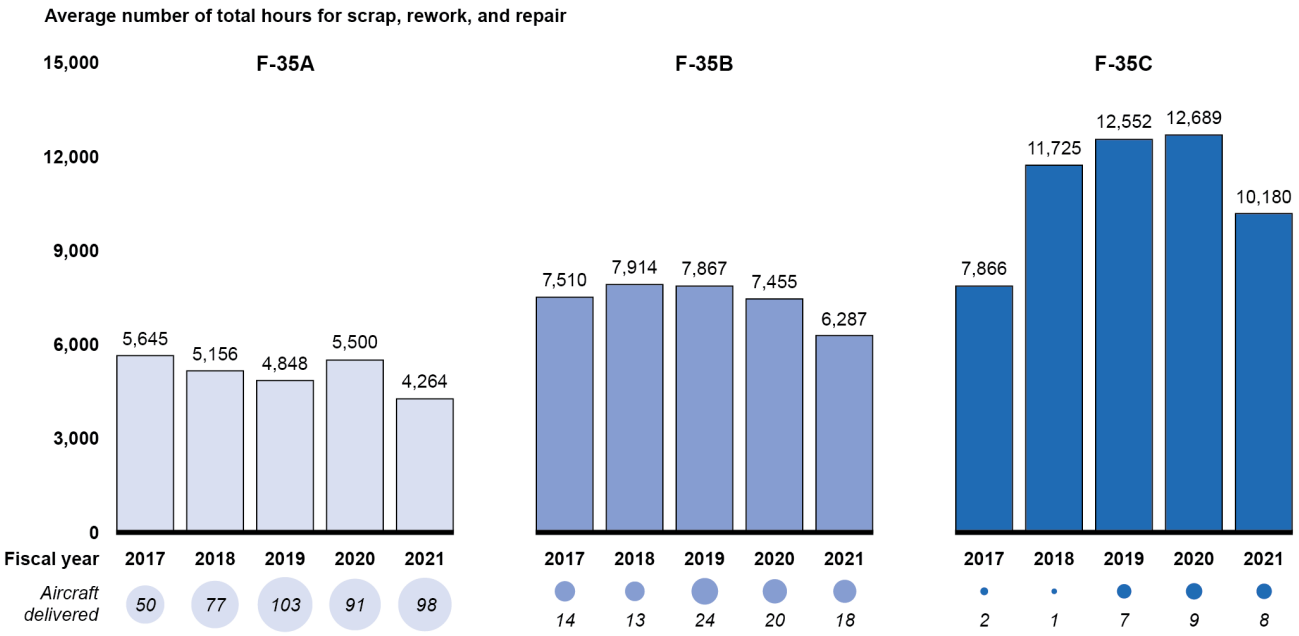
Accessible Data Table for Figure 7(Part 2 of 3)
F-35B

Fiscal year	Average number of total labor hours	Number of aircraft delivered
2017	57,152	14
2018	55,266	13
2019	55,878	24
2020	52,666	20
2021	61,536	18

Accessible Data Table for Figure 7(Part 3 of 3)
F-35C

Fiscal year	Average number of total labor hours	Number of aircraft delivered
2017	60,121	2
2018	68,040	1
2019	69,639	7
2020	67,480	9
2021	74,465	8

Figure 8: Average Hours for Scrap, Rework, and Repair for Each F-35 Aircraft Variant



Source: GAO analysis of Department of Defense and Lockheed Martin data. | GAO-22-105128

Accessible Data Table for Figure 8(Part 1 of 3)
F-35A

Fiscal year	Average number of total hours for scrap, rework, and repair	Number of aircraft delivered
2017	5,645	50
2018	5,156	77
2019	4,848	103
2020	5,500	91
2021	4,264	98

Accessible Data Table for Figure 8(Part 2 of 3)
F-35B

Fiscal year	Average number of total hours for scrap, rework, and repair	Number of aircraft delivered
2017	7,510	14
2018	7,914	13
2019	7,867	24
2020	7,455	20
2021	6,287	18

Accessible Data Table for Figure 8(Part 3 of 3)
F-35C

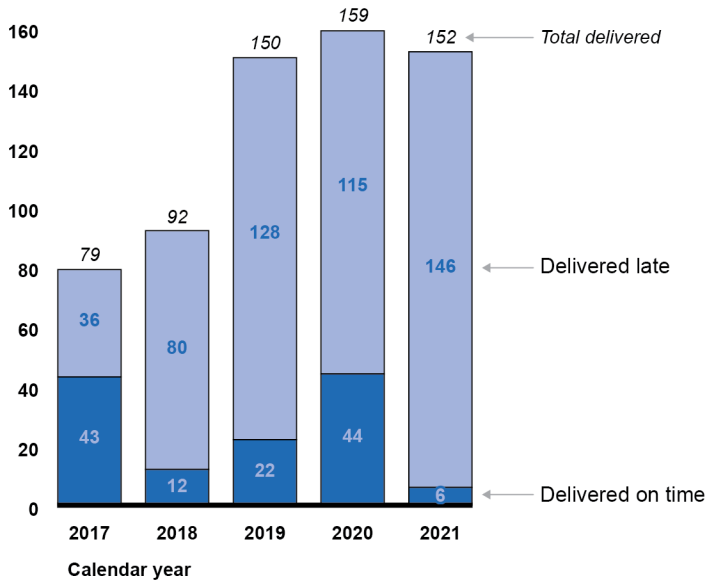
Fiscal year	Average number of total hours for scrap, rework, and repair	Number of aircraft delivered
2017	7,866	2
2018	11,725	1
2019	12,552	7
2020	12,689	9
2021	10,180	8

Nearly All Engines Were Late and Engine Modernization Planning Is Underway

In 2021, the engine contractor—Pratt & Whitney—continued to deliver fewer F135 engines on time. Program officials stated the later deliveries were primarily due to quality issues that required resolution before engines could be accepted by the government. These officials stated that quality issues—for example, some of the raw material used in production was manufactured by an incorrect method— resulted in the contractor delivering nearly all of the engines in 2021 late, as shown in figure 9. According to contractor representatives, no additional engines were late due to COVID-19-related delays since February 2021. In August 2021, a

contractor representative reported that DOD requested the engine contractor address issues with late deliveries and quality control. In response, this representative stated that a corrective action plan was submitted and steps were implemented to enhance delivery performance.

Figure 9: On-Time F135 Engine Delivery Declined in 2021



Source: GAO analysis of Pratt & Whitney data. | GAO-22-105128

Accessible Data Table for Figure 9
Number of engines reported delivered

Fiscal year	Delivered on time	Delivered late	Total delivered
2017	43	36	79
2018	12	80	92
2019	22	128	150
2020	44	115	159
2021	6	146	152

The F-35 program is in the early stages of planning to modernize the F-35 engine. According to program officials, the program will need to modernize the current engine to provide the additional power and thermal management capabilities (i.e., the ability of the engine to cool and support other systems on the aircraft) necessary to support future Block 4 capabilities. According to program officials, as of July 2021, DOD is considering two options: upgrading the current engine via enhanced

engine package options, produced by Pratt & Whitney, or developing a new engine through an Adaptive Engine Transition Program, which would be competed among potentially interested contractors.

- The enhanced engine package is a Pratt & Whitney program that would build on the technology of the existing engine and be applicable to all aircraft variants. Pratt & Whitney representatives stated that if the engine is required to work with all variants, there would be some degradation in performance to accommodate the lift fan for the F-35B variant, allowing it to perform short takeoffs and landings. Further, these representatives noted that it has also developed an option that would increase performance for the F-35A and F-35C engines. These options would be integrated into the fleet over time, resulting in minimal effects on sustainment, according to F-35 Joint Program officials.
- The Air Force is sponsoring the Adaptive Engine Transition Program approach, which would result in an entirely new engine for the U.S. F-35A and C variants with additional thrust and range. Air Force officials told us that the F-35 is being flown harder than originally anticipated, and an upgraded engine is imperative for meeting increasing demands. This approach will not work for the F-35B variant, according to Air Force officials. Therefore, if an engine modernization is a requirement for all three variants—F-35A, F-35B, and F-35C—and Adaptive Engine Transition Program is selected for the F-35A and F-35C, then another engine modernization effort would still be required for the F-35B. According to program officials, this would result in two separate engine development efforts and have an impact on sustainment strategies and sustainment costs due to the fleet of F-35s operating two unique engines.

The NDAA for Fiscal Year 2022 directed DOD to take actions to plan for F-35 engine modernization.[31] These actions include that, in conjunction with their fiscal year 2023 budget submissions, the Air Force provide details of an acquisition strategy for an Adaptive Engine Transition Program engine into the F-35A aircraft and that the Navy report on the integration of an advanced engine into the F-35B and F-35C and submit an acquisition strategy. Both services are to develop an implementation plan for integration into the fleet no later than fiscal year 2027.

[31]National Defense Authorization Act for Fiscal Year 2022, Pub. L. 117-81, §§242, 243.

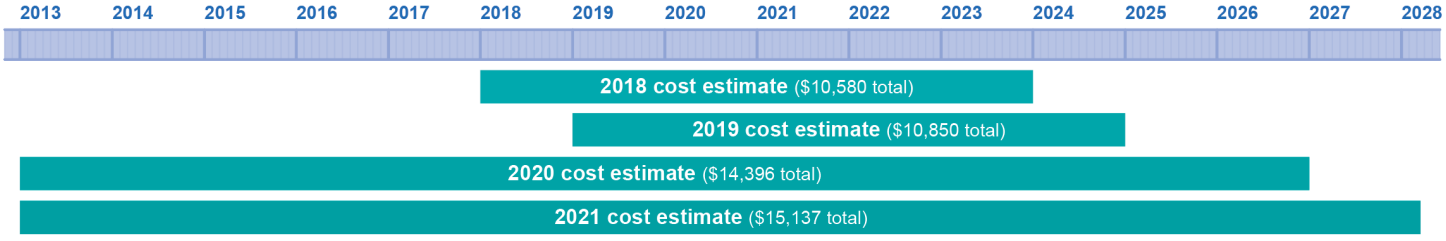
F-35 Modernization Cost and Schedule Continue to Grow, and Changes Aimed at Improving Future Outcomes Are Underway

The F-35 program, now 4 years into its Block 4 modernization efforts, continues to experience cost increases and schedule expansion. Costs continued to rise during 2021 due to crucial hardware development and testing upgrades, among other things. In 2021, the program office added 3 years to its Block 4 schedule and now expects to extend Block 4 development and delivery into fiscal year 2029, in part, due to the addition of new capabilities.[32] The program office is changing Block 4 development efforts to increase software quality and on-time deliveries, but it is too soon to evaluate the effects of these changes.

Modernization Will Cost More and Take Longer due to Persistent Software Quality Issues and Key Hardware Upgrades

In 2021, the F-35 Block 4 development cost estimate increased to $15.14 billion, which is $741 million more than its 2020 estimate of $14.4 billion. This most recent estimate is also $4.6 billion more than the 2018 baseline, in part, because DOD expanded the scope of its estimate to reflect all related costs, as shown in figure 10.

Figure 10: Change in Block 4 Cost Estimates from 2018 through 2021 (2012 Then-Year Dollars in Millions)



Source: GAO analysis of Department of Defense data. | GAO-22-105128

[32]In prior years, based on information provided to us at that time, we have reported that the F-35 program office estimated that Block 4 development and delivery would be completed as early as 2024. This year, the program office provided us with a document from October 2018, which identified that Block 4 capabilities would be delivered as late as 2026. We have updated this report to reflect this new information.

Note: The 2018 and 2019 estimates reflect a 6-year time frame as the Department of Defense focused its estimates on the future year's defense program. The future year's defense program is the department's projected spending for the current budget year and at least the next 4 years. The 2020 and 2021 estimate includes costs for the entirety of the program, including all prior years' actual costs and the additional years estimated to completion from the original 2018 estimate. Additionally, the 2021 cost estimate includes Block 4 development through 2028. However, the program office now plans to deliver the final Block 4 capabilities in 2029.

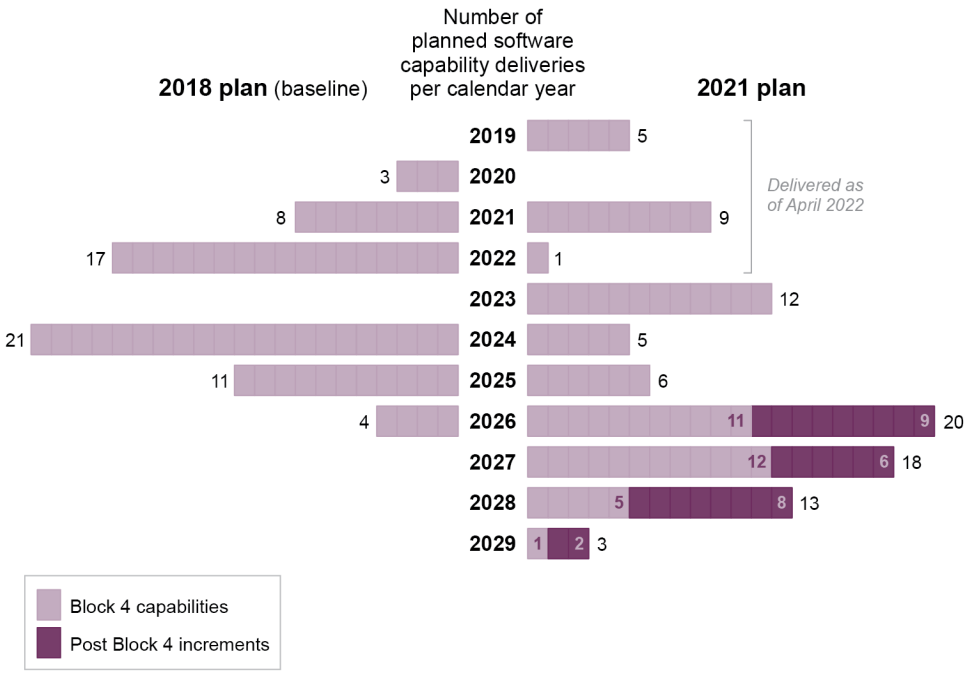
The primary drivers for the increase in the 2021 cost estimate include:

- The estimated cost of the Technology Refresh 3 (TR-3) development effort grew by $330 million. TR-3 is the suite of hardware and some software technologies that will provide updated processing capability, display units, and increased memory to the aircraft. Program officials consider TR-3 a critical enabler to future Block 4 capabilities that are expected to be delivered starting in 2023 because those capabilities cannot function on the current hardware, known as Technology Refresh 2 (TR-2). According to program officials, much of the increase in TR-3 costs occurred because its development is more complex than originally expected.
- Testing and lab upgrades caused an additional $312 million in cost growth. The majority of these investments are intended to increase flight test capacity by modernizing the aging test aircraft that support weapons development. Further, according to Director of Operational Test & Evaluation (DOT&E) officials, the increase in flight test capacity is required to adequately verify the performance of numerous Block 4 capabilities, such as the integration of numerous weapons.

In addition to the cost increase, the program office continues to face delays in delivering Block 4 capabilities, prolonging the overall Block 4 schedule. As of 2021, the program office now plans to complete Block 4 capability deliveries 3 years later than the original schedule due to software quality issues, funding challenges, and the addition of new capabilities, among others.[33] In addition, the program office has begun planning for the development and delivery of additional, post-Block 4 capabilities beyond the original capabilities planned for Block 4. Figure 11 shows the overall delay of planned capabilities in the 2018 baseline schedule compared to the planned capabilities in the 2021 schedule and how Block 4 capabilities will also coincide with post-Block 4 modernization efforts, according to program officials.

[33]GAO-21-226.

Figure 11: Revised Delivery Plan for Block 4 and Post-Block 4 Capabilities



Source: GAO representation of program office data. | GAO-22-105128

Accessible Data Table for Figure 11(Part 1 of 2)
2018 plan (baseline)
Number of planned software capability deliveries

calendar year	Block 4 capabilities	Post Block 4 increments	Total
2019	9		9
2020	13		13
2021	13		13
2022	2		2
2023	14		14
2024	15		15
2025	5		5

Accessible Data Table for Figure 11(Part 1 of 2)
2021 plan
Number of planned software capability deliveries

Calendar year	Block 4 capabilities	Post Block 4 increments	Total
2019	4[a]		9
2020	1[a]		13
2021	9[a]		13
2022	2		2
2023	12		14
2024	6		15
2025	5		5
2026	11	9	20
2027	12	6	18
2028	5	8	13
2029	1	2	3

Note: In prior years, based on information provided to us at that time, we have reported that the F-35 program office estimated that Block 4 development and delivery would be completed as early as 2024. This year, the program office provided us with a document from October 2018, which identified that Block 4 capabilities would be delivered as late as 2026. We have updated this report to reflect this new information.

This graphic represents the F-35 program office's Block 4 and post Block 4 software-enabled capability delivery plans from 2018 and 2021, respectively. We have previously reported that Block 4 is composed of 66 capabilities, but some of those capabilities are hardware enabled and not represented in this graphic. Furthermore, since the 2018 plan, program officials explained that the program has removed some capabilities, added new capabilities, and split capabilities up into multiple increments, in part due to Turkey's removal from the program and new or changing priorities. Therefore, the total number of capabilities and the program office's time frame for delivering those capabilities have changed.

We found three contributing factors for the recent Block 4 capability schedule delays: ongoing software quality problems, a pause in Block 4 software development due to funding issues, and the addition of new Block 4 capabilities. First, persistent software quality problems have resulted in additional work and continue to delay the testing and delivery of Block 4 capabilities. As we previously reported, the contractor is expected to sequentially develop, test, and refine four software increments on the way to producing the software delivered to operational aircraft, referred to as a software drop.[34] According to Block 4 testing officials, the program needs to improve software quality to prevent adding software increments to address defects. Testing officials also stated that

[34]GAO-21-226.

this practice is not only affecting the overall schedule but also the time needed to properly test all aspects of each drop.

Since we reported in March 2021, software drops continue to require more increments than the four originally planned per drop to fix software defects.[35] For instance, a software drop delivered to the field in June 2021 contained eight increments, four more than planned, due to ongoing software fixes needed.

The second contributing factor to Block 4 capability delays was an 8-month pause in Block 4 development that arose when the program office ran out of funds due to the TR-3 cost overrun noted above. In January 2021, the contractor paused work on Block 4 development and focused its work on TR-3. Program officials stated the highest priority was to support an on-time TR-3 delivery and, therefore, additional Block 4 development was paused. Block 4 work did not resume completely until October 2021, 8 months after the contractor paused work. According to program officials, 39 of the original 66 Block 4 capabilities have been delayed as a result of the paused work.

The third contributing factor to schedule delays was the addition of new capabilities. The most recent Block 4 schedule includes capabilities that were not part of the earlier plans. Specifically, according to program officials, the overall delay in Block 4 development was also due to the addition of 25 capabilities added as part of a reprioritization of Block 4 capabilities. The 2021 pause in Block 4 work mentioned above and the desire to complete some capabilities earlier than planned led the program to reprioritize Block 4 capabilities in the latest schedule.

In addition to these delays, the program office is monitoring additional schedule risks. The TR-3 upgrade is planned to be delivered to the production line by summer 2023. However, officials noted there are still risks associated with completing both the hardware and software needed to meet this updated schedule. To address these risks, the program office is considering multiple mitigation efforts. For example, if TR-3 software is delayed beyond the time needed for production, program officials stated they would install the TR-3 hardware, which is likely to be completed at that time, and install the delayed software later. If the TR-3 hardware is delayed, the program office plans to install TR-2 hardware and software kits to fill the production gap and retrofit the aircraft with TR-3 kits when

[35]GAO-21-226.

they are available. Officials acknowledge that any further delays in TR-3 development could result in a corresponding delay to Block 4 capabilities that require TR-3 to function.

Changes to Block 4 Implementation Are Too Early to Assess

Faced with the ongoing software quality problems discussed above, in 2020, the F-35 program office and Lockheed Martin commissioned an independent review team of experts to recommend improvements in the Block 4 development process. The review covered a wide range of topics including the use of Agile software principles as well as the infrastructure, tools, and processes used by the Block 4 development teams.[36] The review, provided to the program office in November 2020, made several recommendations to improve software quality and reduce delays. In some cases, the findings of this review and its recommendations were similar to what we have reported, including increasing Agile metrics tracked and reassessing the Block 4 schedule.

As a result of this review, the program officials and Lockheed Martin representatives implemented a number of recommendations for improving software development quality, including increasing laboratory-based software testing, enhancing monitoring of development progress, adjusting the software development schedule, and negotiating the follow-on Block 4 contract. More detail on these initiatives follows; however, it is too early to assess their outcomes.

Increased laboratory-based software testing. The Independent Review Team found that the program lacked comprehensive regression and

[36]Agile software development supports the practice of shorter software delivery. Specifically, Agile calls for the delivery of software requirements in small, manageable, predetermined increments based on an “inspect and adapt” approach where the requirements change frequently and software is released in increments. GAO, *Agile Assessment Guide: Best Practices for Agile Adoption and Implementation,* GAO-20-590G (Washington, D.C.: Sept. 28, 2020).

automated testing.[37] Previously, for Block 4 software development, subject matter experts would determine the level of regression testing required. Due to the lack of automation, this testing was done less often than needed and not all code was tested. According to GAO's Agile Assessment Guide, automated regression testing is a best practice used by industry to integrate and test software frequently, which reduces the chance of human errors and ensures quality products are produced.[38] We previously reported that 23 percent of all Block 4 software defects were identified after the software was delivered to the test aircraft, when ideally the contractor would identify them in the lab beforehand.[39] Since the independent review, Lockheed Martin has increased its use of automated regression testing to find and identify defects in the lab, before the contractor delivers software to the test fleet. The program has released four software increments since initiating this additional testing and has discovered 130 defects that, according to program officials, would not have been identified without the additional testing. However, DOD recognizes that further steps are needed to continue to improve testing. For instance, in January 2022, DOT&E recommended that the F-35 program improve its lab infrastructure to better replicate flight conditions and catch defects before they are fielded to aircraft.[40]

Enhanced monitoring of software development progress. The Independent Review Team found that the program office used inconsistent tools to manage and plan software development, including the way metrics are shared between the program office and the contractor. The team recommended that the program office focus on the use of metrics to manage work. Likewise, in our March 2021 report, we recommended that the program office identify and implement automated tools to enable access to real-time data for software development metrics

[37]Automated lab testing relies on preprogrammed software code, often developed concurrently with the new functionalities being developed, to automatically test new functionalities reducing the delays in completing tests and does not rely on subject matter experts to pick and choose which software functionalities need to be tested. In addition, regression testing allows the contractor to rerun tests to ensure that previously developed and tested software still performs after changes to the software occur to incorporate new functionalities.

[38]GAO-20-590G.

[39]GAO-21-226.

[40]Department of Defense, Director, Operational Test & Evaluation, *FY 2021 Annual Report* (January 2022).

to inform program decisions and ensure the quality of data is reliable.[41] As a result of the independent review, Lockheed Martin developed a dashboard to monitor software performance metrics that track completed work and defects, among other things. Since December 2021, the program office has had real-time access to this dashboard, which, according to program officials, enhances the program's ability to conduct oversight and performance management across the program. Due to the recent implementation of the dashboard, it is too soon to tell how it has improved Block 4 development, but we will continue to monitor how the program office is using it. When taken as a whole, the implementation of the dashboard and accessibility to real-time data generally meet the intent of our March 2021 recommendation.[42]

Adjusted software development schedule. The Independent Review Team found that contractor's software development teams prioritized achieving schedule versus developing quality capabilities. The team recommended reevaluating the amount of work planned for each software development increment and the rate at which the developers can complete that work based on past performance. In addition, the team found that the program office was not following Agile processes in planning software drops and recommended that the program office redefine how it intends to use Agile principles for schedule planning, among other things. In March 2021, we reported similar findings and recommended that the program office develop more achievable time frames for Block 4 modernization by updating its Block 4 schedule to reflect historical contractor performance.[43] DOD concurred with this recommendation.

The program office decided to increase the period of time to develop Block 4 software drops from 6 to 12 months starting in 2022. Program officials stated that the longer software drop time frames will accommodate work needed to fix software defects and ease the testing backlog that occurred under the 6-month release cadence. In addition, program officials stated the increased time will allow the program to better

[41]GAO-21-226.

[42]We recommended that the Undersecretary of Defense for Acquisition and Sustainment direct the F-35 program office to identify and implement automated tools to enable access to real-time data for software development metrics to inform program decisions and ensure the quality of data is reliable. GAO-21-226.

[43]GAO-21-226.

manage the contractor's upcoming work that includes major hardware and software developments.

The program office's decision to lengthen the software development drop time frame to 12 months, however, is a movement away from Agile principles, including the ability to frequently deliver working software. According to the GAO Agile Assessment Guide, Agile development calls for the delivery of software in small and manageable predetermined increments.[44] Our past work points to industry practices that emphasize short periods, from 1 to 6 weeks, between software deliveries.[45] Instead, the program is planning to deliver longer software drops annually, with the intent of making the overall schedule more achievable than in the past.

DOT&E and other test officials stated that the shift to 12-month drops will not solve the issue of late deliveries entirely if the program office continues to add unplanned increments to software development drops. As noted above, the most recent drop, delivered in June 2021, contained a total of eight increments or four more than planned. According to a January 2022 DOT&E report, unplanned increments have led to insufficient developmental testing, overlaps between operational testing and fielding, and crucial defect discovery in fielded software.

In addition, with the shift to a longer time period between software releases, software defect fixes may take longer to deliver. Despite the additional time for testing in the new 12-month schedule, defects may still be found in the field. According to program officials, there are two ways to correct software defects if they are discovered in the field. First, the program office could add the development work needed to fix the software defect to the next software development release, which could not be completed for up to a year later. Second, development work would be added out-of-cycle, which would overlap with ongoing development and could create complications for testing the software fix. We will continue to monitor the program office's implementation of this updated software development schedule.

Applying recommendations to future contracts. The Independent Review Team found that the current contracting approach was one of the root causes for the program's challenges adapting to Agile development.

[44]GAO-20-590G.

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

The current Block 4 contract was awarded in June 2019 but was not specifically written for Agile capability development and delivery. GAO best practices for contracting for Agile development include encouraging the use of contracts that enable flexibility for contract requirements and incorporate Agile metrics, tools, and lessons learned, among other things. We found that the program has opportunities to improve in both of these areas as it develops the next Block 4 contract, scheduled for award in 2023. For example, the current contract does not incorporate all Agile best practices such as accommodating flexibility for changing requirements or to reprioritize work as capabilities change and does not include requirements for tracking Agile specific metrics, which we previously recommended.[46]

According to program officials, they are incorporating recommendations from the Independent Review Team and other Agile development efforts across DOD into the next Block 4 development contract. For example, officials from the program office state they are adjusting the contract structure to provide increased flexibility to develop and adapt to changing requirements. They stated that the new contract being negotiated will allow the program office to reprioritize work, such as shifting or adding new work, with a request letter to the contractor rather than a contract modification. Using a letter instead of a contract modification is intended to cut down on the time needed to redirect work and allow for faster development of capabilities. In addition, program officials stated the new contract is expected to streamline the data and metrics being collected. The previously mentioned metric dashboard, which will provide real-time data for the program office, will continue under the new contract as well.

The program office has taken steps to align its contracting approach with some Agile best practices. However, it is too early to determine how these intended actions will be incorporated in the next contract, which has yet to be negotiated, or the effect these actions might have on overall capability development and management, including costs. We will continue to monitor the program's progress in adapting its next Block 4 development contract to be more in line with Agile best practices.

[46]GAO-21-226.

F-35 Program Aims to Incrementally Improve Logistics System

In 2018, the F-35 program office began searching for a solution to address shortfalls with the F-35 logistics system, ALIS. The program office has changed its strategy since then and is now focused on incrementally improving and modernizing the system. We have previously reported on numerous long-standing challenges with ALIS, including technical complexity, poor usability, inaccurate or missing data, and challenges deploying the system due to its bulky hardware.[47] In addition, some ALIS software and hardware components will become obsolete in 2023, several older hardware items are no longer in production, and program officials stated that they have struggled with limited and ease of access to logistics data on contractor and operational servers. Multiple program- and contractor-led initiatives over recent years have sought to improve and redesign ALIS, costing taxpayers over $28 million. However, these efforts ultimately did not resolve underlying issues with the system.[48] The main initiatives are described below:

- The program office led a $12.4 million initiative in 2018 to develop new requirements and explore design options to modernize ALIS software and hardware. The intent of this assessment was to allow DOD to more flexibly adapt ALIS as technology changes without dependence on a single contractor.
- The Air Force launched its own initiative, known as Mad Hatter, in 2018 to test an Agile software development approach to link F-35 operators to software developers. The $15.8 million initiative experimented with getting direct user input and using commercial technologies to build new ALIS software, including four new applications to improve the user interface, according to program officials.
- Beginning in 2017, Lockheed Martin invested $45 million of its own funds to independently develop updated ALIS applications. Lockheed Martin also designed a hybrid system capable of hosting current ALIS applications and new, cloud-based applications.

[47]GAO-20-316.

[48]GAO-20-316.

Program officials stated that, ultimately, the program office did not choose to pursue one specific redesign effort but is leveraging aspects from each effort going forward. Although neither the program office nor Lockheed Martin initiatives were able to fully address the underlying issues threatening ALIS's viability, such as impending software obsolescence and the program office's limited access to data on contractor servers, program officials stated that they gained valuable experience. For example, according to program officials, the government engineers who were trained on the Agile methodology under Mad Hatter are continuing to support ALIS improvements efforts and are being virtually embedded with Lockheed Martin to support software development.

The overall acquisition approach to the logistics system has been in flux the past couple of years. In January 2020, the program office began taking steps to fully replace ALIS with a future system, which the program office refers to as ODIN, but decided a year later to incrementally improve and modernize ALIS instead. Program officials stated that, when key elements of the ALIS system are significantly improved, they intend to rename the system ODIN. Thus, the program office no longer considers ODIN to be a separate system from ALIS. In early 2021, when the program office decided against totally replacing ALIS with ODIN, it cited multiple contributing factors, including a $34 million budget cut and the ongoing improvements to ALIS. Lessons learned from pursuing ODIN as a separate program and understanding user requirements contributed to the recalibrated strategy. Furthermore, the government does not have access to all of the ALIS software code due to its proprietary nature and the lack of software licensing. According to DOD officials, obtaining a license to ALIS source code would be cost prohibitive. As a result, the program was unable to use the code it needed to help develop ODIN when it was still planning to pursue it as a completely separate system. The program office now plans to maintain and improve the legacy ALIS software on new hardware while the program office continues to work with contractors and government partners to gradually evolve software, data, and government infrastructure to achieve the goals it envisioned for ODIN.

When the program originally set course to replace ALIS with a separate, future system, it intended for this improved logistics system to have characteristics that ALIS did not have, including smaller hardware, improved program data access, greater government ownership, and greater adherence to Agile development principles. The program has achieved or plans to achieve some, but not all, of its goals (see table 1). For example, the program developed new hardware that is significantly

smaller and lighter than the legacy ALIS hardware, addressing one of the biggest concerns maintainers have told us in the past (see figure 12).[49]

Table 1: Goals, Progress, and Observations Related to F-35 Logistics System Improvement

Goal as of 2021	Progress towards goal as of January 2022	GAO observations
Smaller hardware The improved logistics system was intended to be smaller and more maneuverable for aircraft maintainers.	The program has significantly reduced the size of the logistics system hardware. In September 2020, the Department of Defense (DOD) completed testing of its first prototype of unclassified new hardware. At 134 pounds, the improved logistics system hardware is 1/10th the weight of Autonomic Logistics Information System (ALIS) hardware. The program procured 34 improved hardware kits at a cost of $4 million each in fiscal year 2021 and began fielding the new hardware in July 2021. According to program officials, the program fielded 14 of the 34 kits between July 2021 and January 2022. The program expects to replace all of the unclassified legacy ALIS hardware by late 2023.	We found that the new and smaller hardware addresses the program's goal of being smaller and more maneuverable. We previously reported that ALIS hardware typically required an entire room to function and that squadrons would not always take it on deployments due to the size of the hardware. Not only is the new hardware lighter, it is 80 percent smaller in size making it much more maneuverable.
Improved data access and greater government ownership The program office intended for the improved logistics system to be cloud-based and to have greater government ownership of maintenance data.	The program is making progress towards improving data access, obtaining rights to technical data, and pursuing software licensing to the ALIS software. To increase data accessibility to Lockheed Martin proprietary data, the program office is gradually moving ALIS data to a government-owned cloud environment, which is expected to be completed in 2025. Lockheed Martin will now deliver a Technical Data Package, containing engineering data and descriptive documentation required to support the system throughout its life cycle. The program office determined that obtaining license rights to all of ALIS software would be cost prohibitive. To further these goals, the program office reported that it has started to virtually embed government software engineers on contractor development teams and plans to ensure a continued and growing presence in the software development process.	While the program office is achieving its goal of improving data access to Lockheed Martin proprietary data, government rights and licensing will remain limited. We have previously reported that cloud environments allow federal agencies to access on-demand data.[a] Moving ALIS data onto a government-owned cloud will greatly improve the government's access. This Technical Data Package provides the basis for modifying the system and gives the government the opportunity to develop or buy the rest of the software commercially, potentially allowing for future competitive acquisition. According to program officials, the program office was unable to develop a completely organic government-owned software solution for ALIS, nor was it able to fully replace ALIS with a government-developed software solution because the acquisition of software licenses was cost prohibitive.

[49]GAO-20-316.

Goal as of 2021	Progress towards goal as of January 2022	GAO observations
		To address these issues, program officials stated that they now plan to have the lead management role over a team of government employees and contractor software developers, but some of the data will be proprietary to Lockheed Martin.
Follow principles of Agile software development Program officials intended for the improved logistics system to be acquired under the DOD's Adaptive Acquisition Framework software acquisition pathway, which uses a modern iterative development approach, such as Agile.[b]	The program office is using aspects of the Adaptive Acquisition Framework to guide its development in an Agile environment. In 2020, the program office worked with the services and partner nations to define (1) the desired improved logistics system end-state capability documented in a Capability Needs Statement and (2) how the users will work with the acquisition community in a User Agreement. The program office plans to use these two documents, required when using the software acquisition pathway, to guide future iterations of ALIS. Further, in 2019, the program office moved towards a key Agile principle with more frequent, quarterly releases of ALIS software. However, the Director of Operational Test and Evaluation stated in January 2022 that the program office would reduce frequency to two releases per year, but keep a quarterly development cycle, after 2022.	While the program office will not strictly adhere to the Adaptive Acquisition Framework, it is using selected aspects and has demonstrated a commitment to the user, which is a key principle of Agile software development. According to program officials, although the program office considers following the pathway as optional because ALIS is managed as part of the original development F-35 program, it has identified key aspects to guide future improvements to ALIS. Further, program officials stated that they are intentionally involving users in the ALIS software development process. Additionally, the program received positive feedback from users about the more frequent software releases, though releases will drop to two per year after 2022. According to program officials, users are also finding it easier to download data used by ALIS from each aircraft.

Source: GAO analysis of DOD information. | GAO-22-105128

[a]GAO, Cloud Computing: Agencies Have Increased Usage and Realized Benefits, but Cost and Savings Data Need to Be Better Tracked, GAO-19-58 (Washington, D.C.: Apr. 4,2019).

[b]The Adaptive Acquisition Framework acquisition pathways provide opportunities for program decision makers to develop acquisition strategies and employ acquisition processes that match the characteristics of the capability being acquired. Department of Defense, Operation of the Adaptive Acquisition Framework, DODI 5000.02 (Washington, D.C.: Jan. 23, 2020).

Figure 12: New Hardware Is Smaller than ALIS Hardware

ALIS: Autonomic Logistics Information System

Source: Department of Defense. | GAO-22-105128

The F-35 program office developed a plan to guide its new approach to improving the logistics system, but it does not yet reflect when the effort will be complete. This plan, spanning from 2020 to 2025, includes incremental schedules for improved software, new hardware, and the transition to a cloud-based infrastructure. Program officials noted they are coordinating with international partners on the plan and, until they come

to an agreement, they cannot identify a date to change the improved system's name to ODIN. Program officials added this would be at a point where key pieces of the logistics system are significantly improved. However, they have not yet specified what changes must be incorporated into ALIS before it will be officially considered to have evolved into ODIN. As of August 2021, the program office estimated improving the logistics system will cost $592 million for fiscal years 2021 through 2027.

While the program office continues to refine its plans for improving ALIS, transparency of this process remains important. In March 2020, we recommended that DOD develop and implement a strategy for the redesign of ALIS that clearly identifies the goals, key risks, and costs of redesigning the system.[50] Subsequently, in the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Congress required that, no later than March 1, 2021, the Office of the Under Secretary of Defense for Acquisition and Sustainment submit to Congress a strategy and implementation plan for ODIN, including an identification and assessment of goals, key risks or uncertainties, system performance metrics, and costs of designing, procuring, and fielding the ODIN system.[51] In November 2021, the DOD released the ALIS Redesign Strategy, outlining its reasoning behind its decision to improve upon ALIS through a phased approach rather than replacing the system at once, as we described above.

The strategy outlines goals, identifies system performance metrics, and states that the program office will update the annual ALIS cost estimate to reflect costs of the improvements. As a result of issuing its Strategy as well as other supporting documents, such as the transition plan described above, we closed our March 2020 recommendation as implemented. While developing a strategy is an important step, implementing it is crucial and will require sustained management attention and resources over the coming years to ensure that the redesign of ALIS is efficiently and effectively executed. We will continue to monitor DOD's efforts and progress in its redesign of ALIS and any effects on the sustainment of the F-35.

[50]GAO-20-316.

[51]Pub. L. No. 116-283, § 161(a) (2021).

Agency Comments

We provided a draft of this report to DOD for review and comment. DOD provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees; the Secretary of Defense; the Under Secretary of Defense for Acquisition and Sustainment, the Secretary of the Air Force, the 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 https://www.gao.gov/.

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

Jon Ludwigson
Director, Contracting and National Security Acquisitions

List of Committees

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

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

The Honorable Adam Smith
Chairman
The Honorable Mike Rogers
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Betty McCollum
Chair
The Honorable Ken Calvert
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: GAO Reports and Department of Defense Actions

Table 2: Selected 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 were not mature. We recommended that the program delay start of system development until critical technologies were 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 would manage risks in development.
2006 GAO-06-356	$45.7 billion 12 years $86 million	Program put 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 F-35 performed 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.

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
2014 GAO-14-322	$55.2 billion 18 years $135 million	The military services established new initial operational capabilities dates. 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 might have hindered delivery of the warfighting capabilities to the military services. We recommended that DOD conduct an assessment of the specific capabilities that could be delivered and those that would 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.
2016 GAO-16-390	$55.1 billion 18 years $130.6 million	DOD planned to begin what it referred 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 have presented 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.

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
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 original program 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. We 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.
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 planned to provide a report to Congress by March 2019.	The program office planned 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 John S. McCain 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 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 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. DOD has taken some action and we have closed three of the four recommendations as implemented. 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. Though these items were completed after DOD conducted additional development work, as of July 2020, the F-35 program office has completed an independent cost estimate, an approved test and evaluation master plan, and systems engineering plan. We closed the recommendation as implemented.
2020 GAO-20-316	$57.3 billion 19 years $144.7 million	The Autonomic Logistics Information System (ALIS) is integral to supporting the F-35 fighter jet's operations and maintenance. We noted that we previously reported on key risks associated with the system, such as challenges deploying the F-35 with ALIS, inaccurate data that reside in ALIS, and ineffective training for personnel who need to use ALIS. We reported that DOD and the prime contractor had a variety of initiatives underway for re-designing ALIS.	We suggested that Congress consider requiring DOD to develop a performance measurement process for ALIS. We also recommended that DOD track how ALIS is affecting readiness of the F-35 fleet and develop a strategy for the ALIS redesign.	DOD concurred with both of our recommendations and identified actions that it was taking or planned in response. We agreed that DOD was taking positive steps in addressing issues with ALIS, including the decision to replace ALIS with a future system that it has named the Operational Data Integrated Network (ODIN). In November 2021, DOD published and subsequently submitted to Congress an F-35 ALIS Redesign Strategy. The strategy includes an identification of goals, key risks, and other important aspects of the desired pathway for the redesign. We closed this recommendation as implemented.

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
2020 GAO-20-339	$57.3 billion 19 years $144.7 million	In 2019, the F-35 program conducted much of its planned operational testing but extended the schedule by 9 months, which delayed the program's full-rate production decision to between September 2020 and March 2021. In addition, the program was not meeting manufacturing leading practices identified by GAO and its Block 4 development cost estimate did not adhere to GAO leading practices.	We suggested that Congress extend DOD's Block 4 modernization reporting requirement beyond 2023 to extend to the end of the effort. We also made five recommendations to the Secretary of Defense to submit production risks to Congress prior to full-rate production, to establish a Block 4 cost estimate baseline that covers all costs, and to take other steps to improve the Block 4 cost estimate. These steps were to complete a work breakdown structure, conduct a risk and uncertainty analysis, and consider technology risk assessments to help inform the Block 4 development cost estimate.	While DOD did not concur with two of our recommendations—including to evaluate production risks and update its Block 4 cost estimate with a program-level plan, it identified actions that, if implemented, would meet the intent of these recommendations. DOD concurred with our three other recommendations.
2021 GAO-21-226	$57.5 billion 20 years $131.3 million	The program office delayed full-rate production to an unknown date due to ongoing delays with simulator testing. Block 4 cost and schedule increased, and the program faced challenges in tracking Block 4 software development metrics.	We made three recommendations to the Undersecretary of Defense for Acquisition and Sustainment to direct the F-35 program office to update its Block 4 schedule to reflect historical performance and develop more achievable time frames; identify and implement automated tools to enable access to real-time data for software development metrics; and set software performance target values for critical software quality metrics.	DOD concurred with all three of our recommendations and identified actions it would take in response.

Source: GAO. | GAO-22-105128

[a]The 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.

Appendix II: Objectives, Scope, and Methodology

This report fulfills two mandates:

- 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 seventh report under that provision.
- The National Defense Authorization Act for Fiscal Year 2020 includes a provision for GAO to submit a report on the F-35 program's production and Block 4 progress within 30 days of the President's budget submission for Fiscal Years 2021-2025. This is the third report under that provision.

In this report, we (1) describe any remaining risks with completing the original development program as it progresses towards full-rate production; (2) assess the Department of Defense's (DOD) progress and improvement in developing, testing, and delivering modernization capabilities; and (3) describe DOD's plan for improving the program's logistics system.

To identify the remaining risks with the original development program as it progresses towards full-rate production, we reviewed the costs, schedule, and performance plans and compared progress in certain areas with the goals established in its 2012 baseline to identify any significant trends. We reviewed test schedules and program briefings in order to assess progress on test events completed and those that remain. We conducted interviews with DOD test authorities and pilots at Edwards Air Force Base and spoke with officials from the program office, the office of the Director, Operational Test and Evaluation, the officials responsible for developing the Joint Simulation Environment, Lockheed Martin (the prime airframe contractor), and Pratt & Whitney (the prime engine contractor) to discuss key aspects of operational testing progress, including flight testing results, future test plans, and progress of Joint Simulation Environment development and testing.

To identify potential production and manufacturing risks in the original development program, we obtained and analyzed the production metrics from the program office, Lockheed Martin, Pratt & Whitney, and the

Defense Contract Management Agency on their aircraft and engine delivery rates from 2017 through 2021 and discussed reasons for any delivery delays and plans for improvements with the engine contractor. We also obtained documentation from DOD and the contractors regarding completed airframe and engine delivery schedule. We analyzed these data to determine how many airframe and engines were delivered per year and how many of these deliveries were late. Further, we analyzed DOD's production schedule to determine how, if at all, DOD modified its schedule in response to production line pressures. We discussed steps taken to improve quality and on-time delivery of parts with Lockheed Martin and Pratt & Whitney representatives. We also interviewed these contractor representatives and program officials regarding the progress of identifying and validating new suppliers to manufacture parts originally produced in Turkey and associated costs.

To identify new F-35 technical risks, progress in addressing previously identified technical risk, and progress in resolving deficiencies, we interviewed the same officials mentioned above and discussed progress since March 2021. We reviewed program and contractor information on deficiency reports, mitigations, resolutions, and the deficiency resolution process. We obtained reliability and maintainability metrics from the program office and corroborated those with the same metrics that we requested from Lockheed Martin. We obtained the most recent data that were available within our time frame for conducting the assessment. We compared the reliability and maintainability metrics with those we reported in our March 2021 report to assess progress made in achieving those goals. We met with officials to discuss any outliers in the data and any other circumstances that would contribute to a particular metric rising or falling since we last reported on these data.

To assess DOD's progress in developing and delivering modernization capabilities and remaining risks, we reviewed program documentation, including cost and schedule estimates for Block 4 capability development and testing. Specifically, we compared the DOD F-35 Block 4 development cost estimates from 2018 to 2021 to identify cost increases.[1] To determine the extent to which the contractor delivered Block 4 capabilities on time and to evaluate changes to the Block 4 modernization schedule, we compared the 2018, 2020, and 2021 revisions of the Air System Playbook (the Block 4 modernization development, test, and

[1]The F-35 program office provides this annual report to Congress in response to the Block 4 Modernization annual reporting requirement. National Defense Authorization Act for Fiscal Year 2017, Publ. L. No. 114-328, § 244(d)(2017).

delivery schedule). To describe the F-35 program office's intended improvements to increase Block 4 software quality, we reviewed the program's November 2020 Independent Review Team findings and recommendations for Block 4. Additionally, to assess how well the F-35 Block 4 current contract adheres to GAO's Agile contracting best practices, we compared contract and program documentation with the three contracting best practices found in GAO's Agile Assessment Guide.[2]

We interviewed officials within the program office, DOD test authorities at Edwards Air Force base, Defense Contract Management Agency officials who oversee the airframe contractor, and Lockheed Martin contractor representatives to discuss the Block 4 software development process and schedule. Specifically, we discussed the reasons why the number of planned increments for each software drop and the actual number of increments differed, the process for identifying and resolving defects associated with Block 4 software, the progress of Block 4 capability testing and delivery, and the intended changes to the upcoming Block 4 contract. We also spoke with test pilots and Department of Operational Test and Evaluation officials about Block 4 testing and changes to the development time frames.

To describe DOD's plan for improving its logistics system, we reviewed program briefings and DOD documentation, including the Autonomic Logistics Information System (ALIS) Redesign Strategy and the ALIS to Operational Data Integrated Network (ODIN) Roadmap. We interviewed program officials to discuss their approach to the logistics system improvements and factors contributing to their decisions. We interviewed DOD test officials at Edwards Air Force base to discuss progress in ODIN hardware and ALIS software testing. We also interviewed contractor representatives from Lockheed Martin, the primary contractor for ALIS, to understand their perspective on the plan for incremental improvements.

We determined that all the data we used were sufficiently reliable for the purposes of responding to 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 oversight offices, such as the Defense Contract Management Agency. In addition, we reviewed official program

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

documentation on the Block 4 efforts and corroborated it through interviews with officials across DOD involved in the effort, such as the Director of Operational Test and Evaluation.

We conducted this performance audit from March 2021 to April 2022 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 III: Status of F-35 Open Deficiencies

As of December 2021, the F-35 program had 826 open deficiencies, which is slightly lower than the 872 we reported in March 2021.[1] 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. The test officials categorize deficiencies according to their potential effect 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 office 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 before testing is complete.[2] DOD concurred with our recommendation and stated that the resolution of critical deficiencies identified during testing would be addressed prior to the full-rate production decision.[3]

As of December 2021, of the 826 open deficiencies, the program office characterized four as category 1 and 822 as category 2. This represents seven fewer open category 1 deficiencies than we reported in March 2021. According to program officials, initial fixes for all four category 1 deficiencies have been implemented and are awaiting verification. Specifically, two fixes are expected to be verified through testing in the first half of 2022. One other is expected to be closed in the middle of 2022. The final category 1 deficiency is under investigation and is expected to require technology development to resolve. According to program officials, the program office does not plan to resolve all of the category 2 deficiencies because the program office, in consultation with

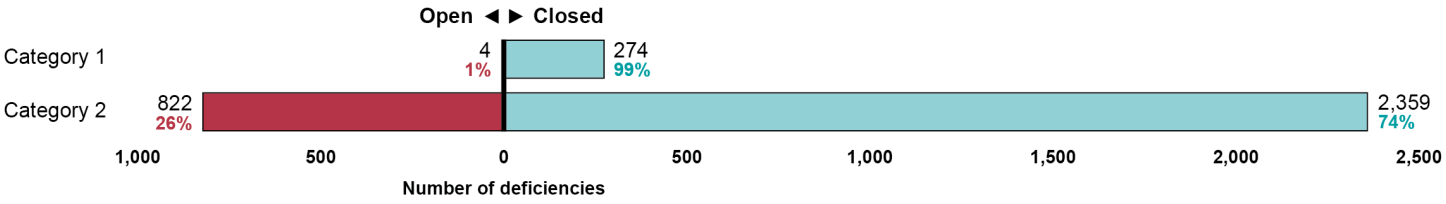
[1]GAO-21-226.

[2]GAO-18-321.

[3]GAO-18-321.

the warfighters and contractors, have determined that they do not need resolution. Figure 13 shows the total number of category 1 and 2 deficiencies that the program has closed since testing began in December 2006 and the number of deficiencies that remain open as of December 2021.

Figure 13: Progress Made in Closing Deficiencies Identified since December 2006, as of December 2021



Source: GAO analysis of Department of Defense data. | GAO-22-105128

Accessible Data Table for Figure 13

	Number open	Percentage open	Number open	Percentage open
Category 1	4	1%	274	99%
Category 2	822	26%	2359	74%

Appendix IV: F-35 Reliability and Maintainability Metrics

Since 2020, the program's reliability and maintainability performance improved for four metrics but declined in some cases. The reliability and maintainability goals are aimed at ensuring that an aircraft will be available for operations as opposed to out-of-service for maintenance. The mean time to repair the F-35A and F-35C improved. The maintenance man hour per flight hour and mean flight hours between maintenance events for the F-35B also improved. The mean time to repair and mean flight hours between critical failures got worse for the F-35B. The mean flight hours between maintenance events got worse for the F-35A and the F-35C. Mission reliability and mean flight hours between removals also got worse for the F-35A. The rest of the metrics stayed the same since June 2020. Although the program is still not meeting 13 of its 24 reliability and maintainability goals, measurable

improvements in these goals can take time to manifest.[4] For example, fielded aircraft must be modified and flown for many hours before the program can measure improvements. Table 3 shows each F-35 variants' performance against these metrics' targets, as of December 2021, the most recent available metrics.

[4]Program officials stated that, while none of the variants are at or above the current targets established in the Joint Strike Fighter Operational Requirements Document—which outlines the requirements the Department of Defense and the military services agreed the F-35 should meet, they do meet more realistic targets approved by the F-35 Joint Executive Steering Board.

Table 3: The F-35 Reliability and Maintainability Metrics' Performance as of December 2021

	Contractually required	F-35A	F-35B	F-35C
Mission reliability measures the probability of successfully completing a mission of average duration	Metric is contractually required	Metric is at or above minimum targets	Metric is at or above current targets	Metric is at or above current targets
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	Metric is contractually required	Metric is at or above current targets	Metric is at or above current targets	Metric is at or above current targets
Mean time to repair measures the amount of time it takes a maintainer to repair a failed component or device	Metric is contractually required	Metric is at or above minimum targets	Metric is at or above minimum targets	Metric is at or above current targets
Maintenance man hours per flight hour measures the average amount of time spent on scheduled and unscheduled maintenance per flight hour[a]	Metric is contractually required	Metric is at or above current targets	Metric is at or above current targets	Metric is at or above current targets
Mean flight hours between maintenance events also referred to as the logistics reliability metric, measures time between maintenance, unscheduled inspections, and servicing actions	not available	Metric is at or above minimum targets	Metric is at or above current targets	Metric is below minimum targets
Mean flight hours between removals measures the time between part removals from the aircraft for replacement from the supply chain	not available	Metric is at or above minimum targets	Metric is below minimum targets	Metric is at or above minimum targets
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	not available	Metric is below minimum targets	Metric is below minimum targets	Metric is at or above current targets
Mean corrective maintenance time for critical failure measures the amount of time it takes to correct critical failure events	not available	Metric is below minimum targets	Metric is below minimum targets	Metric is below minimum targets

Source: GAO analysis of contractor data. | GAO-22-105128

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 July 2021 through September 2021.

[a]Maintenance man hours per flight hour is tracked as unscheduled, scheduled, and total. We report the total metric in this table because it is an F-35 Operational Requirements Document requirement.

Appendix V: Status of Selected F-35 Technical Risks

The F-35 program continues to address technical risks identified in the field. Since our 2021 report, the program office identified new risks with air separation module delamination in all F-35 variants, F-35C degraded cable system performance, F-35B vertical tail bushing migration, targeting system issues on the F-35A, and rudder hinge pin retention hardware. The program office 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

Air Separation Module delamination. The Air Separation Module, common to all F-35 variants, is part of the On-Board Inert Gas Generating System, which provides nitrogen enriched air to the fuel tanks. Within the module, a fiber bundle has been separating from the unit's core, affecting the amount of nitrogen being produced, degrading the inerting of the aircraft fuel tanks. This degradation increases the risk of explosion in the event of a lightning strike. The program office is currently identifying the root cause of the problem and a way to fix it but has short-term and long-term mitigation plans in place. For example, long-term mitigation efforts include a plan for a full redesign in 2023.

F-35C electronic warfare aileron coax cable. In 2021, the F-35C variant experienced degraded electronic warfare system performance, the root cause of which was identified as insufficient cable strain relief, improper cable routing, and poor cable design. While testing of initial fixes are complete, the program office is working with the contractor to identify a permanent solution.

F-35B vertical tail bushing migration. The bushings, which is a piece that keeps two surfaces from rubbing together, in the vertical tail forward shear fitting can bind, or jam, due to the magnitude, duration, and frequency of loads imposed during high angle of attack flight conditions going beyond design limits, causing the bushing to move or migrate out of place. The program office has completed a redesign of the affected

vertical tail part to address the issue. The program office planned to begin retrofitting aircraft in the fleet in December 2021.

Electro-Optical Targeting System window durability. The program office identified a problem with window coating durability on the Electro-Optical Targeting System when operating in certain environments—like those with high amounts of sand and dust—at a level beyond requirements for those environments. The program office is actively working a recovery plan which includes recurring inspections, increased repair capacity, supply increases, design specification changes, and a potential for new coating technologies.

Rudder hinge pin retention hardware. On an F-35A aircraft, the middle rudder hinge bolt was found to have moved out of place, which could lead to aircraft damage or loss of the rudder surface in flight. The program is implementing a design change and performing inspections of aircraft until changes are fully incorporated.

Technical Risks Identified in GAO's Previous Reports

F-35A gun titanium blast panel cracking. Two aircraft experienced cracking in the blast panel in front of the gun. The program is conducting recurring visual inspections following each gunfire event to ensure that the cracks are not spreading and the panel is still safely in place. The F-35 program has replaced the panel with a newer panel that has larger fastener holes as an interim fix. Blast panels are being repaired on an as-needed basis. Aircraft acquired under lot 10, those delivered in 2018, and later incorporate the redesigned panel in production. Fleet retrofit is pending funding.

Forward engine side link bushings migration. Beginning in June 2019, the program discovered the movement of bushings in F-35 engine. The movement, or migration, of these bushings resulted in a risk of in-flight engine shutdown due to damage from that debris. The program office redesigned the bushings assembly on this part of the engine, and a production break-in is planned to begin in the fourth quarter of 2022. The program office is inspecting the bushings every 60 flight hours, during scheduled engine inspections. According to program officials, the program office plans to start retrofit of the new configuration in March 2023.

On-Board Inert Gas Generation System line failure. The program office found that some F-35As in depot had a cracked system that replaces oxygen with nitrogen in the fuel tank. The system protects the fuel tanks against explosion, but cracks create risk of the fuel tank igniting if struck by lightning during a thunderstorm. The program office developed a two-phase plan to provide relief to the April 2020 F-35A lightning restriction through either inspections or another method of verifying the system's integrity. Aircraft retrofits are planned to finish in September 2024.

Appendix VI: GAO Contact and Staff Acknowledgments

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Staff Acknowledgments

In addition to the contact name above, the following staff members made key contributions to this report: Justin Jaynes (Assistant Director), Jillena Stevens (Analyst-in-Charge), James Bennett, Gioia Chaouch, Emile Ettedgui, Laura Greifner, Jennifer Leotta, Kya Palomaki, Christine Pecora, Alyssa Weir, and Lauren Wright.

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