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F-35 Lightning II: Background and Issues for Congress

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F-35 Lightning II: Background and Issues for Congress

The F-35 Lightning II is a strike fighter aircraft and the Department of Defense's (DOD's) largest procurement program. Lockheed Martin manufactures the aircraft for the U.S. Air Force, Marine Corps, Navy, and international partners and customers. Nineteen governments have agreed to purchase F-35s; of those governments, seven are U.S. allies and considered partners that share the cost of development with the United States. DOD, which plans to purchase 2,470 of the aircraft, approved full-rate production of the F-35 on March 12, 2024, 23 years after the start of the development program—called the Joint Strike Fighter (JSF). By the time the F-35 reached that milestone, Lockheed Martin had produced more than 990 F-35s. The program is managed by a Joint Program Office (JPO) of more than 2,200 personnel worldwide. The JPO oversees development of three different variants: the F-35A for the Air Force, the F-35B for the Marine Corps, and the F-35C for the Navy and Marine Corps. According to a March 2024 DOD press release, the F-35 “offers multi-mission capability, including strategic attack, suppression/destruction of enemy air defenses, offensive/defensive counter air, anti-surface warfare, strike coordination and reconnaissance, and close air support. It brings stealth, sensor fusion, and interoperability to enable access in contested environments and enhances situational awareness.”

The JPO is upgrading the aircraft in order to remain relevant against future threats, such as advanced fighter aircraft, uncrewed aircraft, or long-range surface-to-air missiles. Those technical upgrades necessitate improvements to the F135 engine that powers the aircraft. The latest F-35 upgrade program has faced technical challenges.

DOD's 2023 Selected Acquisition Report estimates the current cost of a single F-35 to range from \$62.2 million to \$77.2 million, considering the benefit of the sale of aircraft to foreign governments. The U.S. Government Accountability Office (GAO) in April 2024 reported that the cost to sustain the fleet of aircraft through 2088 would be \$1.58 trillion, a 44% increase over GAO's 2018 estimate. GAO attributed the cost increase to several factors, including the Air Force's intent to operate the F-35 11 years longer than previously planned and the fleet's failure to meet performance goals for availability, reliability, and maintainability.

The Biden Administration's proposed FY2025 defense budget includes about \$12.4 billion for the F-35 program, an amount that would, if adopted by Congress, fund the procurement of 42 F-35As for the Air Force and 13 F-35Bs for the Marine Corps. The request would also support the purchase of 13 F-35Cs, nine for the Navy and four for the Marines. The request also asks Congress for \$2.1 billion for F-35 research and development.

Congress could decide whether or not to consider

- the appropriate number of F-35s to purchase;
- development issues with F-35 hardware and software upgrades;
- delivery, acceptance, and availability of F-35 aircraft;
- enhancements for the F135 engine and its power and thermal management system;
- supply chain considerations;
- F-35 readiness and availability;
- the merits of a block-buy approach; and
- whether to revisit certain Foreign Military Sales.

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Introduction

The F-35 Lightning II serves as the leading strike-fighter aircraft for the Air Force, Marine Corps, and Navy. A strike-fighter aircraft is capable of air-to-ground (strike) and air-to-air (fighter) combat operations. Congress closely follows the F-35 program, as it is the Department of Defense's (DOD's) largest procurement effort in terms of cost. According to DOD's Selected Acquisition Report, DOD estimates a total cost of at least \$485.2 billion to develop and produce 2,470 aircraft and engines.¹

DOD plans to acquire these F-35s for the Air Force, Marine Corps, and Navy through the mid-2040s.² Seven U.S. allies are cost-sharing partners in the program, and other governments have placed orders for hundreds of additional F-35s. By March 2024, Lockheed Martin, the manufacturer, had already produced more than 990 of the jets.³ The Joint Program Office (JPO), which manages the program, oversees development of three different variants: the F-35A for the Air Force, the F-35B for the Marine Corps, and the F-35C for the Navy and Marine Corps.

The Biden Administration's proposed FY2025 defense budget requests \$12.4 billion for the F-35 program's three variants (See **Table 4**). If approved by Congress, the money would procure 42 F-35As for the Air Force, 13 F-35Bs for the Marine Corps, 13 F-35Cs for the Navy and Marines, advance procurement of future aircraft, and continuing modifications. The request also includes about \$2.1 billion for F-35 research, development, test, and evaluation.⁴ DOD in March 2024 approved the start of full-rate production.⁵

Although the start of full-rate production is a sign of maturity, DOD has said the platform requires additional capability to counter future threats. According to DOD, the latest software and hardware upgrades—called Block 4 modernization and Technical Refresh 3—are behind schedule, because of development and supply chain challenges.⁶

This report provides information regarding the F-35 and its variants, the JPO's pursuit of upgrades, production quantities, manufacturing locations, a map of F-35 bases, international participation, a funding profile, legislative activity, and potential issues for Congress. Congressional oversight and budgetary decisions about the F-35 could affect the military capabilities of the Air Force, Marine Corps, and Navy; the services' funding requirements; the aerospace industrial base; and U.S. foreign policy considerations. For a more extensive history of the F-35 program, see CRS Report RL30563, *F-35 Joint Strike Fighter (JSF) Program*.

¹ Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023, p. 23, [https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/\(U\)F-35_MSAR_Dec_2023.pdf](https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/(U)F-35_MSAR_Dec_2023.pdf).

² The program of record includes 2,456 production aircraft and 14 for flight testing through research and development funding. U.S. Government Accountability Office, *F-35 Sustainment: Costs Continue to Rise While Planned Use and Availability Have Decreased*, 24-106703, 2024, p. 1, <https://www.gao.gov/assets/gao-24-106703.pdf>.

³ U.S. Department of Defense, "F-35 Program Achieves Milestone C and Full Rate Production," March 12 2024.

⁴ Office of the Under Secretary of Defense (Comptroller) Chief Financial Officer, *Program Acquisition Cost by Weapon System, United States Department of Defense Fiscal Year 2025 Budget Request, March 2024*, DoD-cover-Portrait-2-v4 (defense.gov).

⁵ U.S. Department of Defense, "F-35 Program Achieves Milestone C and Full Rate Production," March 12 2024.

⁶ Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023, p. 23, [https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/\(U\)F-35_MSAR_Dec_2023.pdf](https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/(U)F-35_MSAR_Dec_2023.pdf).

Background

The F-35 in Brief

DOD conceived the Lightning II—under the Joint Strike Fighter (JSF) program—as a relatively affordable, fifth-generation aircraft that the department could procure in highly common versions for the Air Force and the Navy.

All three versions of the F-35—the F-35A, F-35B, and F-35C—are single-seat aircraft with advanced stealth characteristics and the ability to fly at supersonic speeds for short periods. The F-35A has conventional take-off and landing (CTOL) capabilities, the F-35B has short take-off and vertical landing (STOVL) capabilities, and the F-35C is an aircraft carrier variant. The three versions vary in their combat ranges and payloads (see **Figure 1**). All three carry primary weapons internally to maintain a stealthy radar signature and can carry additional weapons externally on missions requiring less stealth.

What Is a Fifth-Generation Fighter?

Analysts generally consider fifth-generation fighters to be an evolution in aircraft design over fourth-generation or 4.5-generation fighters. Fifth-generation technologies include stealth coatings and shaping, an internal weapons bay, composite materials, advanced radar and sensors, integrated avionics, and the ability to *supercruise* (i.e., fly at supersonic speeds without the use of an afterburner).

Comparing Fifth-Generation Fighter Development

The U.S. Air Force F-22 air superiority fighter and the F-35 are considered the first fifth-generation aircraft. Russia's Su-57 is being developed as a stealthy aircraft that uses thrust vectoring to enhance maneuverability, and an advanced sensor suite. Some argue that development problems have delayed technologies that would make the Su-57 a fifth-generation fighter.⁷ In 2017, the People's Republic of China accepted into service its first fifth-generation fighter, the J-20. The J-20 has reportedly flown with engines made in China.⁸ An April 2024 China Aerospace Studies Institute paper states that the Peoples Liberation Army Air Force “appears to be capable of introducing between 48-60 J-20s per year.”⁹

What Comes Next?

The U.S. Air Force is reviewing requirements for a Next-Generation Air Dominance platform, a sixth-generation fighter to replace the F-22.¹⁰ Sixth-generation technologies may include improved stealth, directed energy, hypersonic weapons, sensors enabled by artificial intelligence, a variable cycle engine, and the ability to operate alongside uncrewed aircraft. The United Kingdom, Italy, and Japan are working on a sixth-generation fighter, and France, Germany, and Spain are pursuing a separate sixth-generation fighter.

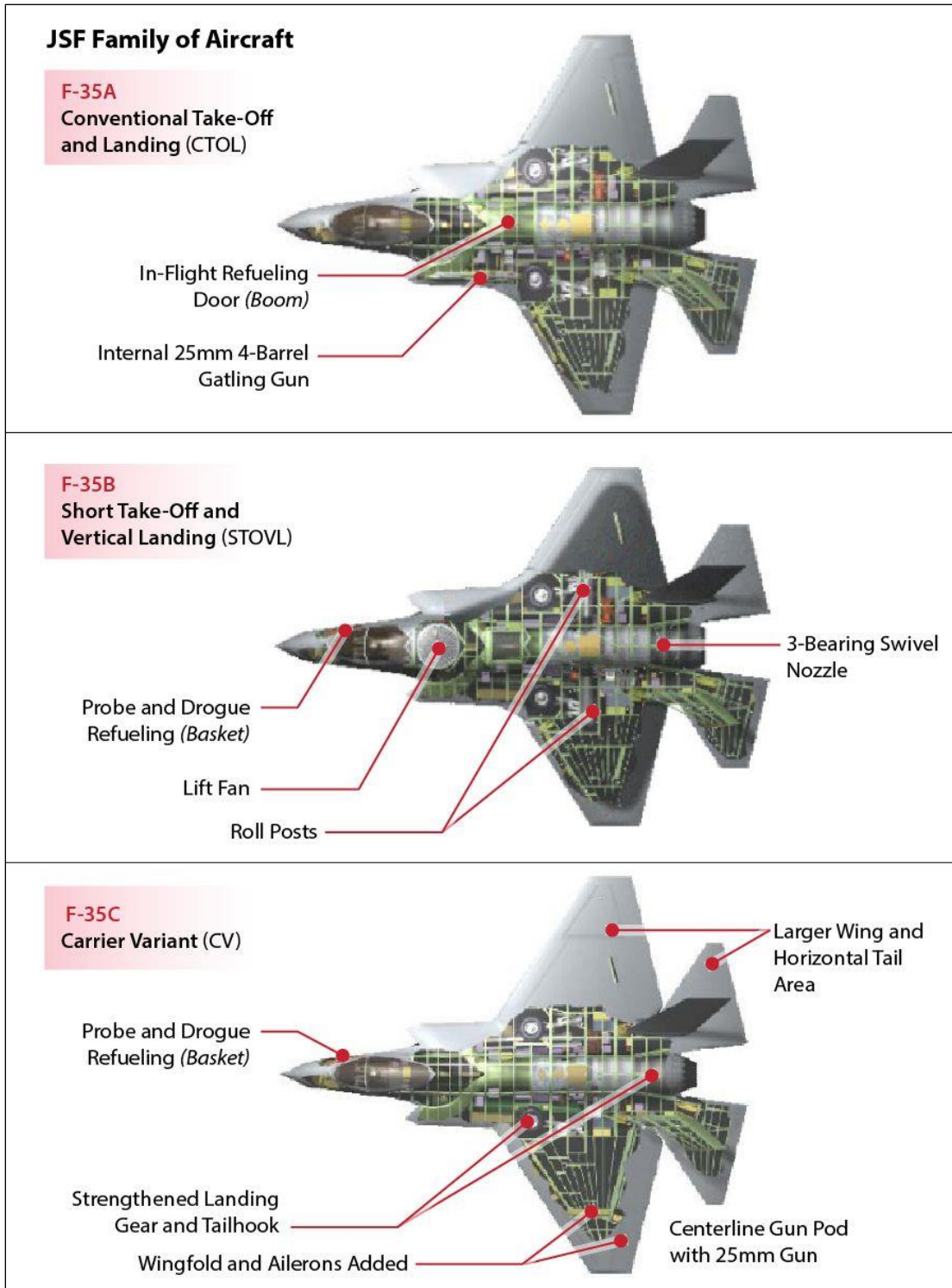
⁷ Ryan Bauer and Peter A. Wilson, “Russia’s Su-57 Heavy Fighter Bomber: Is It Really a Fifth-Generation Aircraft,” RAND, August 17, 2020.

⁸ Reuben Johnson, “China’s J-20 Fighter, Seems to Have a New Homegrown Engine, After Years of Struggle,” *Breaking Defense*, July 18, 2023.

⁹ Eli Tirk, “Status of 41st Aviation Brigade Transition to the J-20,” China Aerospace Studies Institute, Air University, p. 2-3, April 2024.

¹⁰ Secretary of the Air Force Public Affairs, “Kendall Highlights Accomplishments, Urgency to Finish Transitioning to Great Power Competition,” U.S. Air Force, September 16, 2024.

Figure I. F-35 Variants



Source: CRS graphic adapted from Joint Program Office Briefing.

Three Service Versions

DOD is buying three distinct F-35 versions tailored to the needs of the military services. Differences among the aircraft include the manner of takeoff and landing, fuel capacity, and carrier suitability. All three variants share stealth characteristics, weapons, avionics, and the same basic engine, and can fly at speeds of up to 1.6 Mach.¹¹ The combat radius ranges from 450 to 600 nautical miles.

Air Force Conventional Take-Off and Landing (CTOL) Version (F-35A)

The Air Force plans to procure 1,763 F-35As, a Conventional Take-off and Landing (CTOL) version of the aircraft. According to one source, the U.S. Air Force has 412 F-35A aircraft in service.¹² The Air Force intends for F-35As to replace Air Force F-16 fighters and A-10 attack aircraft.¹³ The Air Force plans for the F-35A to be a more affordable complement to the Air Force's F-22 Raptor air superiority fighter.¹⁴

The combination of the F-15 and F-16 represented the Air Force's earlier-generation "high-low"¹⁵ mix of air superiority fighters and more affordable dual-role aircraft. The service followed that approach with the F-22 and F-35A, supplemented by the F-15EX and the F-16.¹⁶ The Air Force is reviewing plans to develop a sixth-generation fighter that operates with current fighters and unmanned aircraft called the Collaborative Combat Aircraft. In a March 2023 speech describing the service's approach, then-Air Force Chief of Staff Charles Q. Brown Jr. explained that the Air Force is "bringing on the F-35 to be the cornerstone of our fighter fleets. We're procuring the F-15EX."¹⁷ Brown also explained that the Air Force is "bringing on the next generation of air dominance family of systems," including the potential purchase of at least 1,000 uncrewed Collaborative Combat Aircraft.¹⁸

¹¹ Mach, as defined by National Aeronautics and Space Administration's (NASA's) Glenn Research Center, is the ratio of the speed of an object divided by the speed of sound. Aircraft that fly at speeds between Mach 1.0 and Mach 5.0 are supersonic. Hypersonic objects fly at speeds of at least Mach 5, about 1 mile per second. For more on hypersonic missile defense. See CRS In Focus IF11623, *Hypersonic Missile Defense: Issues for Congress*, by Kelley M. Saylor.

¹² Data from *Aviation Week Intelligence Network*, Fleet Discovery tool, July 3, 2024.

¹³ Department of the Navy, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Selected Acquisition Report December 31, 2022, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2022_SARS/F-35_SAR_Dec_2022_25_July_2023.pdf.

¹⁴ For more on the F-22 program, see CRS Report RL31673, *Air Force F-22 Fighter Program*.

¹⁵ The term *high-low mix* refers to a force consisting of a combination of high-cost, high-capability aircraft and lower-cost, more affordable aircraft. A high-low mix strikes a balance between the goal for having a minimum number of very high capability tactical aircraft to take on the most challenging projected missions and the goal of being able to procure tactical aircraft sufficient in total numbers within available resources to perform all projected missions.

¹⁶ For more on the high-low mix, see Lieutenant General (ret.) Joseph Guastella, Lieutenant Colonel (ret.) Eric Gunzinger, and Douglas A. Birkey, "Accelerating Fifth-Gen Airpower," *Air and Space Forces Magazine*, April 27, 2023.

¹⁷ General Charles Q. Brown, Jr., "Airmen in the Fight," transcript of March 2023 speech to the Air Force Association Air Warfare Symposium.

¹⁸ General Charles Q. Brown, Jr., "Airmen in the Fight," transcript of March 2023 speech to the Air Force Association Air Warfare Symposium.

Marine Corps Short Take-Off and Vertical Landing (STOVL) Version (F-35B)

The Marine Corps plans to procure 353 F-35Bs, a short take-off and vertical landing (STOVL) version of the aircraft.¹⁹ As of July 2024, the Marines had 150 F-35Bs in service.²⁰ The Marine Corps has expressed a preference for aircraft capable of vertical operations; such aircraft can take off and land ashore in areas lacking access to an improved runway. The Marine Corps has indicated that F-35Bs are to replace Marine Corps AV-8B Harrier vertical/short takeoff and landing attack aircraft, as well as Marine Corps F/A-18A/B/C/D strike fighters, which are CTOL aircraft. The Marine Corps has chosen to purchase the F-35B in lieu of the F/A-18E/F strike fighter, which is also a CTOL aircraft.²¹ The end of FY2024 marked the planned halfway point in the Marines' transition to the F-35B and F-35C. Navy leaders provided testimony to Congress in April 2024 stating that the F-35

is the core of the future fighter fleet and plays a critical role in the Navy and Marine Corps' future Distributed Maritime Operations and Expeditionary Advanced Base Operations (EABO) warfighting concepts, providing a lethal and survivable strike and sensor platform. Ship and land-based F-35Bs and F-35Cs will continue to be the backbone of the [Department of the Navy] air combat superiority.²²

F-35B Issues

The JPO first developed the STOVL variant—the most complicated of the three—a replacement for the Marine Corps' AV-8B Harrier fleet. Issues with the F-35B created a three-year slowdown to the entire F-35 program and added \$6.5 billion to its development.²³

The engineering challenge with the F-35 was to develop an aircraft capable of vertical takeoff, vertical landing, and hovering in flight.²⁴ The aircraft needed to be light enough to take off vertically. But the engine would also require special lift-fan to hover, which added weight. The program employed a special "STOVL Weight Attack Team" to trim the added pounds.²⁵

Another technical issue unique to the F-35B concerned the ships on which it was landing. In a vertical landing, the F-35B engine rotates and points downward. The exhaust would bear down on the amphibious assault ships, damaging the decks and deck coatings. The Navy undertook ship modifications to ease the stress.²⁶

¹⁹ Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023, p. 103. To permit STOVL operations, the F-35B has an engine exhaust nozzle at the rear than can swivel downward, and a mid-fuselage lift fan connected to the engine that blows air downward to help lift the forward part of the plane.

²⁰ Data from *Aviation Week Intelligence Network*, Fleet Discovery tool, July 3, 2024.

²¹ For more on the F/A-18E/F program, see CRS Report RL30624, *Navy F/A-18E/F and EA-18G Aircraft Program*.

²² Statement of Nickolas H. Guertin, Assistant Secretary of the Navy (Research, Development and Acquisition); Lieutenant General Bradford Gering, Deputy Commandant for Aviation; and Rear Admiral Michael Donnelly, Director Air Warfare, before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee on Department of the Navy Fiscal Year 2025 Budget Request for Tactical Aviation, April 16, 2024.

²³ Joseph Trevithick, "These are the Briefings President-Elect Trump Got on the F-35, Air Force On, and Nukes," *The War Zone*, Dec. 1, 2019.

²⁴ Joe Pappalardo, "Weight Watchers: How a Team of Engineers and a Crash Diet Saved the Joint Strike Fighter," *Smithsonian Air & Space Magazine*, November 2006.

²⁵ Ibid.

²⁶ Michael Fabey and Bill Sweetman, "U.S. Navy Details Amphibious Ship Mods For F-35B," *Aviation Week Intelligence Network*, June 3, 2013.

Navy Carrier-Suitable Version (F-35C)

The Navy plans to procure a total of 273 F-35Cs, a version of the aircraft designed to be launched from an aircraft carrier; the Marines plan to purchase 67 F-35Cs.²⁷ The United States had 90 F-35Cs in service as of July 2024.²⁸ The F-35C is also known as the “CV” version of the F-35; CV is the naval designation for aircraft carrier. The Navy is operating carrier air wings with a combination of F/A-18E/F aircraft (which the Navy has been procuring since FY1997) and F-35Cs. The Navy’s latest upgraded version, F/A-18 Block III Super Hornets, is equipped with advanced computing capabilities, an open mission systems processor, some stealth characteristics, and an advanced cockpit system.²⁹ The F-35C is the Navy’s first aircraft designed for stealth. The Air Force, in contrast, has operated stealthy bombers and fighters for decades.

Engine

The F-35 is powered by the Pratt & Whitney F135 engine, which was derived from the F-22’s F119 engine.³⁰ The F135 engine is designed with more than 40,000 pounds of thrust and contains stealth technologies beyond those of fourth-generation engines.³¹ Pratt & Whitney produces the F135 engine at facilities in East Hartford and Middletown, CT. Rolls-Royce builds the vertical lift system for the F-35B in Indianapolis, IN, as a subcontractor to Pratt & Whitney.

Sustainment

According to the JPO, the F-35 is the first tactical aircraft program to have its digital sustainment tools designed along with the aircraft.³² The Autonomic Logistics Information System (ALIS) is designed to report information about an individual F-35’s health to manage maintenance. The system has hardware and software and both government-owned and contractor-owned assets.³³ Because ALIS encountered development and operational issues, the JPO is moving from ALIS toward a system known as the Operational Data Integrated Network (ODIN). ODIN is a cloud-based method of tracking maintenance and sustainment data of the fleet. According to the Director of Operational Test & Evaluation, the transition from ALIS to ODIN hardware is scheduled to be complete in 2025.³⁴

Program History

The JSF program began in the 1990s. Three different airframe designs were proposed by Boeing, Lockheed Martin, and McDonnell Douglas (teamed with Northrop Grumman and British

²⁷ Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023, p. 103. Features for carrier suitability include strengthened landing gear and airframe, an arresting hook to permit catapult launches and arrested landings, and folding wing tips for more compact storage aboard ship.

²⁸ Data from *Aviation Week Intelligence Network*, Fleet Discovery tool, July 3, 2024.

²⁹ Seapower Staff, “Boeing Completes F/A-18 Super Hornet Upgrade Ahead of Schedule,” *Seapower*, June 27, 2024. NAVAIR, “F/A-18 E/F Super Hornet,” <https://www.navair.navy.mil/product/FA-18EF-Super-Hornet>.

³⁰ Pratt & Whitney’s parent firm is RTX Corporation headquartered in Arlington County, VA.

³¹ Pratt & Whitney, “Pratt & Whitney F135 Engine Fast FACTS,” May 7, 2024.

³² F-35 Lightning II Joint Program Office, “Alis/Odin Autonomic Logistics Information System / Operational Data Integrated Network,” jsf.mil/alis.

³³ Director, Operational Test & Evaluation, *FY 2023 Annual Report*, p. 52, <https://www.dote.osd.mil/Portals/97/pub/reports/FY2023/dod/2023f-35jsf.pdf?ver=CwYFf-qisrEiTGHwDpzQmg%3d%3d>.

³⁴ *Ibid.*

Aerospace).³⁵ In November 1996, DOD announced that Boeing and Lockheed Martin would compete in the program’s concept demonstration phase, with Pratt & Whitney providing propulsion hardware and engineering support.³⁶ Boeing and Lockheed Martin each won contracts to build and test-fly two aircraft to demonstrate their competing concepts for all three planned JSF variants.³⁷

In October 2001, DOD selected the Lockheed Martin design and the JSF program entered the system development and demonstration (SDD) phase. Pratt & Whitney won a separate contract to develop the aircraft’s engine. The Defense Acquisition Executive approved a low-rate initial production quantity of 465 aircraft in six early-production lots.³⁸

DOD designed the F-35 program to involve both foreign governments and other countries’ industrial bases. Tom Burbage, then a Lockheed Martin vice president and the first general manager of the F-35 program, wrote that the United Kingdom “was the prime partner, but other allies were also invited to join the program up front, as equals.”³⁹ (See “International Participation.”)

Engine Development

The Air Force has since 2007 funded advanced engine research for technologies that could potentially feed into future fighter programs.⁴⁰ In 2016, under an Adaptive Engine Transition Program (AETP), General Electric (GE) and Pratt & Whitney received contracts worth approximately \$1 billion each to develop advanced engines that could serve as an option for the F-35.⁴¹ The resulting Pratt engine was known as the XA101; GE’s engine was the XA100. The Air Force estimated the cost of integrating either engine for use on the F-35 at \$6 billion.⁴² In March 2023, Air Force Secretary Frank Kendall said the service would not integrate either the XA101 or the XA100 onto the F-35 aircraft. Instead, Kendall requested funding for an Engine Core Upgrade program for the Pratt & Whitney F135 engine.⁴³ Congress did not fund integration of a new engine resulting from AETP research onto the F-35 in the FY2024 Further Consolidated Appropriations Act, (P.L. 118-47).

³⁵ Arthur Sheridan and Robert Burns, “F-35 Program History—From JAST to IOC,” AIAA Aviation Forum, June 25-29, 2018, Atlanta Georgia, 2018 Aviation Technology, Integration, and Operations Conference, p. 3.

³⁶ Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023, p. 14.

³⁷ Subsequent to the selection of the Boeing and Lockheed Martin designs, Boeing acquired McDonnell Douglas and merged the two firms’ JSF teams. Arthur Sheridan and Robert Burns, “F-35 Program History—From JAST to IOC,” AIAA Aviation Forum, June 25-29, 2018, Atlanta Georgia, 2018 Aviation Technology, Integration, and Operations Conference, p. 3.

³⁸ Office of the Secretary of Defense, *Selected Acquisition Report (SAR): F-35*, December 31, 2010, p. 36.

³⁹ Tom Burbage, Betsy Clark, and Adrian Pitman, with David Poyer, *F-35: The Inside Story of the Lightning II*, (New York, NY: Skyhorse Publishing, 2023), pp. 76-79.

⁴⁰ Gregory Sanders and Nicholas Velasquez, “Keeping the U.S. Military Engine Edge: Budget and Contract Trends,” *Center for Strategic and International Studies*, October 31, 2022.

⁴¹ Aaron Mehta, “US Air Force Funds Next Advanced Engine Stage,” *Defense News*, July 1, 2016.

⁴² Steve Trimble and Guy Norris, “U.S. to Reveal F-35 Propulsion Plan Soon,” *Aviation Week & Space Technology*, December 16, 2022, <https://aviationweek.com/defense/aircraft-propulsion/us-air-force-reveal-f-35-propulsion-plan-soon>.

⁴³ Stephen Losey, “Pentagon Rethinks F-35 Engine Program, Will Upgrade F135,” *Defense News*, March 13, 2023.

Entry into Initial Operational Test and Evaluation (IOT&E)

The DOD's Director of Operational Test and Evaluation (DOT&E) approved the F-35's entry into Initial Operational Test and Evaluation (IOT&E) on December 3, 2018.⁴⁴ The DOT&E noted later that the F-35 entered IOT&E with 873 unresolved deficiencies, 13 of which were classified as "Category 1 'must-fix' items that affect safety or combat capability."⁴⁵ The DOT&E reported that the program's high level of concurrency—a term referring to significant production of jets during the process of development and testing—could necessitate substantial costs to incorporate the lessons learned in testing. According to the DOT&E, "IOT&E, which provides the most credible means to predict combat performance, likely will not be completed until ... over 600 aircraft will already have been built."⁴⁶ According to DOD, 990 aircraft were built by the time IOT&E ended.⁴⁷ (See "Entry into Full-Rate Production.")

COVID-19-Related Production Slowdown

On May 19, 2020, officials from Lockheed Martin, which was experiencing COVID-19-related supply chain delays, announced a restructuring of the F-35 production plan. The new plan was designed to minimize workforce impacts at the principal F-35 production line in Fort Worth, TX. Lockheed Martin estimated that it would produce between 117 and 123 F-35s during 2020—a reduction from 141 F-35 planned deliveries. Lockheed Martin had previously changed production methods and cleaning protocols to protect its workforce from COVID-19.⁴⁸

COVID-19-related supply chain issues have continued to affect F-35 production. A July 2022 note to Lockheed Martin's investors explained that the company planned to produce fewer F-35 aircraft because of "COVID-19 and other impacts experienced by the F-35 enterprise."⁴⁹ Lockheed Martin said it planned to deliver "in the range of 147-153 aircraft per year in 2023 and 2024, before the company achieves its 156-aircraft delivery target in 2025."⁵⁰ In 2023, Lockheed Martin delivered 98 F-35s.⁵¹

Program Management

The Department of the Air Force and the Department of the Navy jointly manage and staff the Joint Strike Fighter (JSF) joint program office (JPO). The JPO manages the development, production, and sustainment of the aircraft. Service Acquisition Executive (SAE) responsibility alternates between the two departments. When the Air Force has SAE authority, the F-35 program director is from the Navy, and vice versa. Congress required in the National Defense Authorization Act (NDAA) for FY2022 (P.L. 117-81, §142) that the JPO's sustainment functions

⁴⁴ Robert Behler, Director, Operational Test and Evaluation, *FY2018 Annual Report*, January 2019, p. 23.

⁴⁵ Anthony Capaccio, "F-35's Gun That Can't Shoot Straight Adds to Its Roster of Flaws," *Bloomberg News*, January 30, 2020.

⁴⁶ Director, Operational Test & Evaluation, *FY 2017 Annual Report*, January 2018, p. 39.

⁴⁷ U.S. Department of Defense, "F-35 Program Achieves Milestone C and Full Rate Production," March 12 2024.

⁴⁸ See, inter alia, Anthony Capaccio, "Lockheed Slowing F-35 Production Amid Covid-Related Parts Delays," *Bloomberg News*, May 19, 2020, and Valerie Insinna, "Lockheed slated to miss F-35 delivery target in 2020 as supply chain struggles to keep up," *Defense News*, May 19, 2020.

⁴⁹ News Release, "Lockheed Martin Reports Second Quarter 2022 Financial Results," Exhibit 99.1, p. 4, Ex 99.1 Q2 2022 (lockheedmartin.com).

⁵⁰ Ibid.

⁵¹ Lockheed Martin, "Statement: 2023 F035 Deliveries," January 2, 2024.

be transferred to the Navy and Air Force by 2027, and the acquisition functions be similarly transferred to the services by 2029.

DOD told the U.S. Government Accountability Office (GAO) in February 2024 that the department “is in the process of identifying resources to support the integration of F-35 sustainment requirements within DOD’s working capital funds to transition supply support to the military services.”⁵² In April 2024 testimony to Congress, Andrew Hunter, Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics, said the service is working to “assume greater management, planning, and execution roles of sustainment functions, both to improve aircraft availability and further reduce sustainment costs.”⁵³

Modernization Issues

The F-35’s integration of advanced sensors and weapons, both internally and with other aircraft, differs from other aircraft. Software is the main enabler of the F-35’s integration. Periodic hardware upgrades help to enable those software improvements.

The JPO has combined upgrades to the F-35’s software and other capabilities in an iterative development process known as Continuous Capability Development and Delivery (C2D2). According to DOD budget documents, C2D2 is designed to improve the F-35’s ability to maintain air dominance against evolving threats.⁵⁴ The most recent effort at upgrading hardware and software began in 2014, with an Air Force analysis of F-35 capability gaps.

The results of that analysis informed the goals for what is called “Block 4” modernization. In March 2017, DOD’s Joint Requirements Oversight Council approved the development plan for Block 4.⁵⁵ The Block 4 modernization effort includes software development and a Technical Refresh 3 (TR-3) effort to enable the insertion of more than 50 software upgrades.⁵⁶ According to Air Force budget documents, Block 4 would develop and integrate an advanced sensor suite, improved electronic warfare systems, and long-range precision weapons such as the Advanced Anti-Radiation Guided Missile-Extended Range.⁵⁷ Block 4 also would reportedly increase data fusion and interoperability with other weapons systems.⁵⁸

L3Harris Technologies manages the TR-3 subprogram that provides the computing power to enable Block 4 capabilities. According to L3Harris, TR-3 includes an integrated core processor to handle data from the radar, distributed aperture system, electronic warfare and communications systems, and the cockpit and helmet displays. L3 Harris indicated that TR-3 is expected to

⁵² U.S. Government Accountability Office, *F-35 Sustainment: Costs Continue to Rise While Planned Use and Availability Have Decreased*, GAO-24-106703, 2024, p. 8, <https://www.gao.gov/assets/d24106703.pdf>.

⁵³ Andrew P. Hunter and Lieutenant General Richard G. Moore Jr., “Presentation to the House Armed Services Subcommittee on Tactical Air and Land Forces: Subject: Air Force, Fixed-Wing Tactical and Training Aircraft Programs,” April 16, 2024.

⁵⁴ Department of Defense FY2025 Budget Estimates, Air Force, Justification Book 3 of 4, p. 205, <https://www.saffm.hq.af.mil/LinkClick.aspx?fileticket=zJI27eStzNY%3d&portalid=84>.

⁵⁵ Ibid.

⁵⁶ Steve Trimble, “Defense Department, Lockheed Eye Expansion of F-35 Modernization Plan,” *Aviation Week Intelligence Network*, June 27, 2019.

⁵⁷ Department of Defense FY2025 Budget Estimates, Department of the Air Force, Justification Book Volume 3 of 4 Research, Development, Test, and Evaluation, Air Force, p. 204, <https://www.saffm.hq.af.mil/LinkClick.aspx?fileticket=zJI27eStzNY%3d&portalid=84>.

⁵⁸ Ibid.

provide the electronic unit for the panoramic cockpit display and boost the aircraft’s memory system.⁵⁹

The C2D2 effort has encountered developmental difficulties. According to the DOT&E,

The current Continuous Capability Development and Delivery (C2D2) process has not been able to keep pace with adding new increments of capability as planned. Software changes, intended to introduce new capabilities or fix deficiencies, often introduced stability problems and adversely affected other functionality.⁶⁰

GAO has been documenting the F-35 upgrade effort’s cost increases and missed timelines. In May 2020, GAO reported that the 2018 cost estimate for Block 4 modernization had grown from \$10.6 billion to \$12.1 billion (See **Table 1**).⁶¹ In 2021, GAO reported that Block 4 costs had risen to \$14.4 billion and that the F-35 program was still working through more than 800 deficiencies.⁶² GAO defines deficiencies as “instances where the weapon system either does not meet requirements or where the safety, suitability, or effectiveness of the weapon system could be affected.”⁶³ In May 2023, GAO reported that Block 4 modernization costs had again increased, this time to \$16.5 billion and that JPO anticipated the delivery of Block 4 capabilities in 2026.⁶⁴ In April 2024, GAO reported the cost of Block 4 had remained the same, but stated that the JPO had acknowledged many Block 4 capabilities would not be available until the 2030s.⁶⁵

Because of continued Block 4 cost growth, GAO had recommended since 2016 that Block 4 be managed as a separate program.⁶⁶ Congress agreed and the FY2024 NDAA (P.L. 118-31, §225(a)) designates Block 4 and TR-3 as a major subprogram.

Table 1. F-35 C2D2 Budget Request, FY2024-FY2029
(in millions of dollars)

	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	Total
F-35A	1,275.268	1,124.207	1,192.42	1,160.61	975.101	989.293	6,716.899
F-35B	544.625	480.759	517.621	460.787	449.975	439.567	2,893.334
F-35C	543.834	466.186	493.845	466.356	428.356	417.407	2,815.984
International	306.563	265.912	215.209	193.862	n/a	n/a	981.546
Total	2,670.29	2,337.064	2,419.095	2,281.615	1,853.432	1,846.267	13,407.76

Source: FY2025 Air Force and Navy Budget Justification books, RDT&E accounts. Table does not include prior-year funding.

Note: N/a is not applicable.

⁵⁹ L3Harris Technologies Infographic, F-35-TR-3-Infographic-sas-62431_web.pdf (l3harris.com).

⁶⁰ Director, Operational Test and Evaluation, *FY2019 Annual Report*, December 20, 2019, p. 19.

⁶¹ U.S. Government Accountability Office, *F-35 Joint Strike Fighter: Actions Needed to Address Manufacturing and Modernization Risks*, GAO-20-339, 2020.

⁶² U.S. Government Accountability Office, *F-35 Joint Strike Fighter: Cost and Schedule Risks in Modernization Program Echo Long-Standing Challenges*, GAO-21-105282, 2021 pp. 4, 11.

⁶³ Ibid.

⁶⁴ U.S. Government Accountability Office, *Tactical Aircraft: Technical, Delivery, and Affordability Challenges Complicate DOD’s Ability to Upgrade Its Aging Fleet*, GAO-23-106694, 2023, p. 2.

⁶⁵ Lieutenant General Michael Schmidt, “Statement Before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee,” April 16, 2024.

⁶⁶ *F-35 Joint Strike Fighter: Program Continues to Encounter Production Issues and Modernization Delays*, GAO-24-106909, May 2024, p. 7.

TR-3 is also delayed.⁶⁷ In 2019, the JPO stated that Lockheed Martin would begin delivering F-35s with TR-3 in lot 15, scheduled for CY2023.⁶⁸ In July 2024, the Air Force accepted delivery of the first F-35s with a limited version of TR-3.⁶⁹

In its FY2022 report, the DOT&E reported that the F-35 program was still fielding “immature, deficient, and insufficiently tested Block 4 mission systems software to fielded units.”⁷⁰ According to the DOT&E, the JPO had not yet planned for operational testing of the TR-3 hardware configuration and, consequently, flight test instrumentation for TR-2 and upgraded TR-3 aircraft were unlikely to be available. As a result, operational test squadrons may lack sufficient test aircraft.⁷¹

The Air Force stopped accepting delivery of F-35A aircraft in July 2023, pending completion of TR-3 software. In April 2024, JPO Program Executive Officer Lieutenant General Michael Schmidt testified to Congress that a Software Architecture Independent Review Team working with JPO found that the TR-3’s hardware was “a significant complicating factor in software integration.”⁷²

According to Schmidt, July 2024 is the “first realistic opportunity” for delivery of a “truncated” TR-3 version for training,⁷³ and Lockheed Martin delivered the first two F-35s with a limited version of TR-3 on July 19, 2024.⁷⁴

Another GAO report explains that the supplier of the TR-3’s integrated core processor, a component essential to aircraft operations, continues to experience delays, according to program officials.⁷⁵ The program office’s stated goal is to resume “sufficient” supplier production capacity by December 2024.⁷⁶

The JPO has indicated that an underlying microprocessor for TR-3 has been a Diminished Manufacturing Source (DMS) since 2018, meaning the microprocessor is in danger of becoming obsolete, and stated that “As a result, the Program must attempt lifetime buys or initiate redesigns.”⁷⁷ The JPO added that DMS notifications in general are “a major problem,” and the F-35 program plans to establish a “Pre-Planned Product Improvement approach to Technical Refresh programs rather than a reactive DMS approach.”⁷⁸

⁶⁷ Valerie Insinna, “F-35 upgrade plan awaiting approval from top Pentagon acquisition exec,” *Defense News*, October 2, 2018.

⁶⁸ Director, Operational Test and Evaluation, *FY2019 Annual Report*, December 20, 2019, p. 21.

⁶⁹ Vanessa Montalbano, “Pentagon Accepts First F-35s Enabled With Incomplete TR-3 Upgrade,” *InsideDefense.com*, July 19, 2024.

⁷⁰ Director, Operational Test and Evaluation, *FY2022 Annual Report*, January 2023, p. 46.

⁷¹ *Ibid.*

⁷² Lieutenant General Michael Schmidt, “Statement Before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee,” April 16, 2024, p. 6.

⁷³ Brian Everstine, “F-35 Office Targeting July for Long-Awaited Avionics Upgrade,” *Aviation Week Intelligence Network*, April 16, 2024.

⁷⁴ Vanessa Montalbano, “Pentagon Accepts First F-35s Enabled with Incomplete TR-3 Upgrade,” *InsideDefense.com*, July 19, 2024.

⁷⁵ *F-35 Joint Strike Fighter: Program Continues to Encounter Production Issues and Modernization Delays*, GAO-24-106909, May 2024.

⁷⁶ *Ibid.*

⁷⁷ Correspondence to Congressional Research Service from F-35 Joint Program Office, submitted on March 6, 2024, and response received May 10, 2024.

⁷⁸ *Ibid.*

The JPO has undertaken two reviews to address ongoing issues. In 2023, the Defense Acquisition Executive directed a “Technical Baseline Review” that found “numerous Block 4 capabilities will not deliver until the 2030s due to technical complexity, software efficiency, human and financial resourcing, flight test capacity, lab quality and capacity, and lack of defined requirements.”⁷⁹ A JPO-ordered Software Architecture Independent Review concluded that “until the underlying hardware is fully mature, the F-35 Program will continue to struggle with software integration efficiency.”⁸⁰ As a result of the two review efforts, the JPO is defining a “Reimagined Block 4 as ‘must-have’ content to maintain competitive advantage against our adversaries.”⁸¹ According to Lieutenant General Schmidt, this “Reimagined Block 4,” is “what industry can actually deliver.”⁸² “Reimagined Block 4” still requires agreement from DOD acquisition leaders, the Joint Staff, the U.S. military services, and the steering board governing the F-35 program, Schmidt wrote.⁸³

TR-3 and Delivery Delays

As mentioned in the prior section, the U.S. Air Force stopped accepting deliveries of F-35s in July 2023. The Air Force resumed acceptance of F-35s in July 2024 but is withholding payment of \$5 million per aircraft until TR-3 is complete.⁸⁴ According to a 2024 GAO report, the decision to stop deliveries could create financial and schedule risks for DOD.⁸⁵ The report said it could also create issues with certification, because the program typically averages 13 certifications a month; DOD and Lockheed Martin are planning to increase the average to 20 certifications each month to speed delivery of stored aircraft.⁸⁶ The report said:

...upon completing aircraft production, Lockheed Martin—in cooperation with the program office—is parking every TR-3 enabled F-35 at production facilities to await the permanent TR-3 hardware kits and new software, which will not be available for installation until June 2024 at the earliest. If Lockheed Martin delivers the software on this timeline, it will need to park aircraft produced over the last several months at various facilities.... Lockheed Martin is projected to exceed its maximum parking capacity and will need to develop a plan to accommodate more parked planes.⁸⁷

Engine Core Upgrade

According to the JPO, the Block 4 and TR-3 upgrades necessitate power and cooling upgrades to the F135 engine. Pratt & Whitney is conducting an Engine Core Upgrade (ECU) to add range and thrust, as well as to provide cooling to the engine. The JPO estimates the upgrade would allow the engine to fly for 2,000 hours before an overhaul.⁸⁸

⁷⁹ Lieutenant General Michael Schmidt, “Statement Before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee,” April 16, 2024, p. 16.

⁸⁰ *Ibid.*, p. 7.

⁸¹ *Ibid.*

⁸² *Ibid.*

⁸³ *Ibid.*

⁸⁴ Mike Stone, “Pentagon Withholds \$5 million per F-35 Jet As Deliveries Resume,” *Reuters*, August, 29, 2024.

⁸⁵ *F-35 Joint Strike Fighter: Program Continues to Encounter Production Issues and Modernization Delays*, GAO-24-106909, May 2024.

⁸⁶ *Ibid.*

⁸⁷ *Ibid.*

⁸⁸ U.S. Government Accountability Office, *F-35 Joint Strike Fighter: More Actions Needed to Explain Cost*, GAO-23-106047, 2023, p. 36.

In November 2023, the JPO announced the award of a sole-source contract to Pratt & Whitney for the F135 ECU. The JPO announcement stated: “The anticipated contract actions will provide F135 ECU design maturation, test article manufacturing and development, test asset procurement, validation and verification activities, weapon system integration for air system capabilities, test equipment procurements, and developmental hardware procurements for the F-35A, F-35B, and the F-35C variants.”⁸⁹

According to a May 2023 GAO report, program officials estimated that an engine core upgrade to support Block 4 software enhancements on the F-35 could be available in 2032. Program officials also told GAO that an ECU with an enhanced power and thermal management system (PTMS) was “the only viable option to address the decreased vertical lift for the F-35B caused by the weight increase of the aircraft.”⁹⁰ At the time, the JPO had not analyzed the technical maturity of options to add power and cooling to support the F-35’s electronics. As of April 2024, the ECU effort was in a risk reduction phase.⁹¹ Lieutenant General Schmidt confirmed in an April 2024 congressional hearing that the Air Force budget request for ECU is \$527 million.⁹²

The JPO is planning a new F-35 PTMS subprogram to provide engine upgrades beyond Block 4. Schmidt said during the same hearing that he would be able to “fully answer” questions about PTMS in 2025.⁹³ The program is considering whether to modernize the existing PTMS or develop an entirely new one.

According to a May 2024 GAO report, “The options range significantly in estimated costs, development time frames, and the amount of increased cooling capacity that each will provide the aircraft.”⁹⁴ Development cost estimates range from \$3.7 billion to \$4.5 billion, GAO noted.⁹⁵ Program officials stated that they are working on a comprehensive cost estimate for the engine and the thermal management subprogram.⁹⁶

Autonomic Logistics Information System (ALIS)

Another supporting system for the F-35 is the Autonomic Logistics Information System (ALIS). ALIS is a data-tracking system designed to improve maintenance. But according to government and press reports, the system was not as automated as planned, required labor-intensive data entry, was vulnerable to cyberattack, and sometimes produced incorrect results.⁹⁷

⁸⁹ John A. Tirpak, “F-35 Program Will Give Pratt Sole-Source Engine Upgrade Work,” *Air and Space Forces Magazine*, November 28, 2023.

⁹⁰ Government Accountability Office, “F-35 Joint Strike Fighter: More Actions Needed to Explain Cost Growth and Support Engine Modernization Decision,” May 2023.

⁹¹ CQ Transcripts, “House Armed Services Subcommittee on Tactical Air and Land Forces Holds Hearing on Fiscal Year 2025 Department of Defense Fixed-Wing Tactical and Training Aircraft Programs Budget Request,” April 16, 2024.

⁹² Ibid.

⁹³ Ibid.

⁹⁴ U.S. Government Accountability Office, *F-35 Joint Strike Fighter: Program Continues to Encounter Production Issues and Modernization Delays*, GAO-24-106909, 2024, pp. 30-31, <https://www.gao.gov/assets/gao-24-106909.pdf>.

⁹⁵ Ibid.

⁹⁶ Ibid.

⁹⁷ Director, Operational Test and Evaluation, *FY2017 Annual Report*, January 2018, p. 53. John A. Tirpak, “F-35 Program Dumps ALIS for ODIN,” *Air Force*, January 21, 2020, <https://www.airforcemag.com/f-35-program-dumps-alis-for-odin/>.

ALIS Transition to ODIN

Some of the problems with ALIS stemmed from its 1990s-based software architecture.⁹⁸ By early 2020, DOD had proposed a replacement for ALIS—a cloud-based system called the Operational Data Integrated Network (ODIN).⁹⁹

According to program officials, ODIN is designed to be more user-friendly, less prone to error, and have improved hardware. Officials added that ODIN would initially run ALIS software as well as future ODIN software releases. ODIN is designed to work with F-35s that have a TR-3 hardware package.¹⁰⁰

As of April 2024, the JPO was working on a transition program called ALIS-to-ODIN (A2O). According to Lieutenant General Schmidt, the program is continuing to upgrade ALIS software to address obsolescence issues, cybersecurity concerns, and data quality.¹⁰¹ In 2023, the JPO fielded unclassified ODIN hardware for maritime and land-based sites, replaced ALIS hardware with ODIN hardware, and tested classified ODIN hardware elements.¹⁰²

Dual Capability

Some F-35As are dual-capable aircraft (DCA), meaning that the aircraft have the ability to deliver conventional weapons as well as nuclear weapons; a portion of these aircraft are to be deployed in Europe. According to a JPO official, in October 2023, the United States certified the F-35A to carry the B61-12 nuclear gravity bomb.¹⁰³

The 2018 Nuclear Posture Review stated that the F-35, along with the B61-12 nuclear gravity bomb, “will preserve the DCA contribution to regional deterrence stability and assurance. In parallel with its warhead LEP [Life Extension Program], the B61-12 will be equipped with a guidance tail kit to sustain the military capability of existing B61 variants.”¹⁰⁴

In 2021, two F-35As completed the final flight test exercise of the nuclear design certification process. The two aircraft from U.S. Air Force Air Combat Command released B61-12 Joint Test Assemblies in a full weapon system demonstration at the Tonopah Test Range in Nevada, led by the Air Force Nuclear Weapons Center, the JPO, Sandia National Labs, and Air Combat Command.¹⁰⁵

⁹⁸ Lara Seligman, “F-35 Sustainment Challenges Mount As Global Fleet Grows,” *Aviation Week and Space Technology*, April 5, 2018, <http://aviationweek.com/defense/f-35-sustainment-challenges-mount-global-fleet-grows>.

⁹⁹ John A. Tirpak, “F-35 Program Dumps ALIS for ODIN,” *Air Force*, January 21, 2020, <https://www.airforcemag.com/f-35-program-dumps-alis-for-odin/>.

¹⁰⁰ John A. Tirpak, “F-35 Program Dumps ALIS for ODIN,” *Air Force*, January 21, 2020, <https://www.airforcemag.com/f-35-program-dumps-alis-for-odin/>.

¹⁰¹ Lieutenant General Michael Schmidt, “Statement Before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee,” March 29, 2023, pp. 8-11.

¹⁰² Lieutenant General Michael Schmidt, “Statement Before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee,” April 16, 2024, pp. 19-20.

¹⁰³ Michael Marrow, “Exclusive: F-35A officially certified to carry nuclear bomb,” *Breaking Defense*, March 08, 2024.

¹⁰⁴ Department of Defense, “Nuclear Posture Review,” February 2018, p. 50, <https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF>.

¹⁰⁵ U.S. Air Force First Lieutenant Lindsey Heflin, “F-35A Completes Milestone 5th Gen Fighter Test with Refurbished B61-12 Nuclear Gravity Bombs,” Air Combat Command press release, October 4, 2021.

Funding for DCA development has been carried alternately in Air Force RDT&E accounts, F-35 Squadrons, and C2D2. The Air Force requested \$21.611 million in FY2025, similar to funding levels in FY2023 and FY2024.¹⁰⁶

According to a North Atlantic Treaty Organization (NATO) fact sheet, seven NATO members contribute to DCA, and the members have two roles: “The first is to provide conventional air power capabilities, such as air policing and combat support, on a day-to-day basis. The second is to operationally deploy nuclear weapons in a conflict.”¹⁰⁷ F-35s equipped to carry nuclear weapons for NATO’s nuclear deterrence are to be based in Europe.¹⁰⁸ According to the Bulletin of the Atomic Scientists, “Approximately 100 U.S. nuclear weapons are estimated to be stored at six bases in five countries, with one additional base (RAF Lakenheath) currently undergoing modernization to potentially store nuclear weapons in the future.”¹⁰⁹

Entry into Full-Rate Production

To begin full-rate production, the F-35 needed to complete IOT&E. More than 60 tests involved in IOT&E required a type of software called the Joint Simulation Environment (JSE). According to one source, the JSE was designed to simulate virtual sorties, but the JSE encountered a series of development delays. Litigation over the intellectual property rights to underlying Lockheed Martin software also delayed the JSE.¹¹⁰

According to the DOT&E’s 2023 report, the JSE completed testing in September 2023, which paved the way for the March 2024 full-rate production decision.¹¹¹

Director of Operational Test & Evaluation Dr. Douglas C. Schmidt stated during an April 2024 congressional hearing that DOD must continue to improve digital assets, such as the JSE. He said, “It’s more than just having the digital assets. We also have to make sure that those assets are calibrated appropriately based on open air exercises and being able to feed that back in a synergistic loop where the digital environments get more representative and higher fidelity.”¹¹²

Readiness

According to GAO, the F-35 fleet is not meeting performance goals for availability, reliability, and maintainability.¹¹³ Readiness challenges include “a heavy reliance on contractors, inadequate training, lack of technical data, lack of spare parts, and lack of support equipment,” GAO reported in April 2024.¹¹⁴

¹⁰⁶ Department of Defense Fiscal Year 2025 Budget Estimates, Air Force, Justification Book Volume 3 of 4, Research, Development, Test, and Evaluation, p. 669.

¹⁰⁷ North Atlantic Treaty Organization Factsheet, “NATO’s Nuclear Sharing Arrangements,” February 2022.

¹⁰⁸ Netherlands Ministry of Defense, “F-35 to Take Over Nuclear Role of the Netherlands Within NATO from F-16,” May 30, 2024.

¹⁰⁹ Hans Kristensen, Matt Korda, Eliana Johns, and Mackenzie Knight, “Nuclear Weapons Sharing, 2023,” *Bulletin of the Atomic Scientists*, November 8, 2023.

¹¹⁰ Steve Trimble, “F-35 Clears Long-Delayed Full-Rate Production Milestone,” *Aviation Week Intelligence Network*, March 13, 2024.

¹¹¹ Director, Operational Test and Evaluation, *FY2023 Annual Report*, January 2024.

¹¹² Comments by Dr. Douglas C. Schmidt, Director, Operational Test & Evaluation, during House Armed Services Tactical Air and Land Forces Subcommittee hearing on April 16, 2024.

¹¹³ U.S. Government Accountability Office, *F-35 Sustainment: Costs Continue to Rise While Planned Use and Availability Have Decreased*, GAO-24-106703, 2024, p 8.

¹¹⁴ *Ibid.*

Citing data from DOD and Lockheed Martin, the GAO report states that the Air Force fleet of F-35A aircraft's mission capable rate, a metric of a fleet's health and readiness, was 51.9 percent in 2023—below the service's 80% minimum target.¹¹⁵ The Navy and Marine Corps set mission-capable target at 75%, but neither the F-35B nor the F-35C hit the minimum; the F-35B registered 59.7%.¹¹⁶ The F-35C notched the highest mission capable rate at 61.9%, according to GAO.¹¹⁷

The Congressional Budget Office (CBO) noted similar aircraft availability figures in a February 2023 report.¹¹⁸ “Between 2021 and 2022, F-35As’ availability fell by 11 percentage points. F-35Bs’ availability also fell by 7 percentage points, and F-35Cs’ availability rose by 5 percentage points,” according to the report, which also observed that flight hours for the F-35A and F-35B have declined.¹¹⁹ The F-35C has flown more hours since 2019 than the other F-35 platforms, CBO stated.¹²⁰

Cost and Funding

The F-35 program receives (or in the past received) funding from the Air Force, Department of the Navy, and Defense-Wide research, development, test, and evaluation (RDT&E) accounts. The program received Defense-Wide RDT&E funding in FY1996, FY1997, and FY1998. The program receives Non-Treasury Funds for research and development from its partner governments, as well as draws from Air Force and Navy aircraft procurement accounts, the Air Force Military Construction (MilCon) account, and the Navy MilCon account.

Total Program Acquisition Cost¹²¹

The Selected Acquisition Report (SAR) issued in December 2023 and released in August 2024 assessed the sum of development, procurement, and MilCon costs of the F-35 aircraft subprogram in constant (i.e., inflation-adjusted) FY2012 dollars to be about \$291.8 billion. This total includes about \$66.9 billion in research and development, about \$221.3 billion in procurement, and about \$3.5 billion in MilCon funding.¹²²

In then-year dollars (meaning dollars from various years that are not adjusted for inflation), the F-35 airframe's total acquisition cost is \$401.1 billion. This total includes about \$71.3 billion for research and development, about \$325.8 billion for procurement, and about \$4 billion for MilCon. The corresponding engine cost is \$84.1 billion, for a total program cost of \$485.2 billion.¹²³

¹¹⁵ U.S. Government Accountability Office, *F-35 Sustainment: Costs Continue to Rise While Planned Use and Availability Have Decreased*, GAO-24-106703, 2024, p. 9.

¹¹⁶ *Ibid.*

¹¹⁷ *Ibid.*

¹¹⁸ Congressional Budget Office, “Availability and Use of F-35 Fighter Aircraft: An Update,” <https://www.cbo.gov/publication/58902>, February 2023.

¹¹⁹ *Ibid.*

¹²⁰ *Ibid.*

¹²¹ Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023, p. 23. This is the most recent Selected Acquisition Report issued for the program.

¹²² The procurement cost figure does not include the cost of several hundred additional F-35s that are to be procured by other countries that are participating in the F-35 program. The figure does, however, assume certain production-cost benefits for DOD aircraft that result from producing F-35s for other countries.

¹²³ Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023, p. 22.

Unit Costs

In 2014, DOD set a goal to reduce the price of the F-35 to \$80-\$85 million per aircraft—an amount comparable to previous-generation fighters—by 2019.¹²⁴

As noted in **Table 2**, the 2023 SAR estimated the average unit recurring flyaway cost of an F-35A at \$62.2 million in constant 2012 dollars. The figure assumed the sale of 371 Foreign Military Sales (FMS) aircraft and 547 international partner aircraft. The SAR defines flyaway cost as the cost of hardware, including the airframe, vehicle systems, mission systems, engine, and engineering change orders over the life of the program.¹²⁵

As of December 2023, the F-35 program’s acquisition unit cost (or PAUC, meaning total acquisition cost divided by 2,470 research and development and procurement aircraft) was \$162.4 million. The F-35’s average procurement unit cost (or APUC, meaning total procurement cost divided by 2,456 production aircraft) was \$132.7 million, in constant FY2012 dollars.¹²⁶

Table 2. F-35 Projected Unit Recurring Flyaway Cost

(Assumes 2,470 U.S. sales and 918 international sales)

	F-35A	F-35B	F-35C
\$M (CY2012)	62.2	74.6	77.2

Source: Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023, p. 27.

Note: The hardware cost includes the airframe, vehicle systems, mission systems, engine, and engineering change order costs over the life of the program. The cost assumes the benefit of 371 Foreign Military Sales aircraft and 547 international partner aircraft.

Critics have noted that the SAR’s reported costs do not accurately represent the true cost of developing and acquiring the F-35 because of faulty assumptions about factors such as future inflation rates and production learning curves.¹²⁷

Engine Costs

In 2023, the JPO finalized a contract with Pratt & Whitney worth \$5.2 billion for 278 F135 engines. The agreement had an option for one additional year of production, which would increase the purchase price to about \$8 billion.¹²⁸

The 2022 SAR noted that power and cooling demands are increasing: “The engine is currently providing bleed air that is double what it was specified to provide and as a result is running hotter,

¹²⁴ Jason Scott, “F-35s to Sell for as Low as \$80 Million in 2019, Pentagon Says,” *Bloomberg.com*, March 11, 2014. Valerie Insinna, “Lockheed Extends F-35 Cost-Cutting Initiative to Save Billions,” *Defense News*, July 11, 2016.

¹²⁵ Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023, p. 27.

¹²⁶ *Ibid.*, p. 23.

¹²⁷ A detailed critique of the SAR figures with suggestions for alternatives appeared in *Time* magazine’s “Battleland” blog. Authored by Winslow Wheeler of the Center for Defense Information, the most relevant entries are <http://nation.time.com/2013/06/04/alphabet-soup-paucs-apucs-urfs-cost-variances-and-other-pricing-dodges/> and <http://nation.time.com/2013/06/05/the-deadly-empirical-data/>.

¹²⁸ Michael Marrow, “Pentagon, Pratt Finalize F-35 Lot 15-17 Engine Deal,” *Breaking Defense*, March 6, 2023.

which will lead to earlier than anticipated removals with an increased life cycle cost of \$32 billion.”¹²⁹

The 2023 SAR breaks down costs for the F135 engine subprogram. The report assessed the engine subprogram in inflation-adjusted FY2012 dollars to total \$61 billion. The SAR reports the then-year dollar cost for development, procurement, and construction for the engine at \$84.1 billion. The current estimate for the engine, which would cost an average of \$18 million per F135, rises by 5.6%, the SAR states, over the program’s original baseline. That cost increase is driven by the new Engine Core Upgrade program. The baseline will change again in the future to comply with P.L. 118-31 §225 §226, to initiate Block 4 and Engine and Power Thermal Management Upgrade subprogram, the report states.¹³⁰

Sustainment Costs

According to an April 2024 GAO report, F-35 sustainment costs increased from \$1.1 trillion in 2018 to about \$1.6 trillion in 2023. According to the report, “One reason for the increase in cost estimates is the extension of the service life of the aircraft,” to 2088, 11 years longer than DOD previously planned.¹³¹ GAO also noted,

Other key factors in determining future costs for the program are the number of planned aircraft procurements, where and when new aircraft will enter the services’ fleets, the planned retirement dates of the aircraft, and inflation cost factors.¹³²

The services have reduced the per-aircraft, per-year cost between 2020 and 2023—primarily by reducing aircraft flight hours and, in the case of the Air Force, increasing the affordability target.¹³³

Price Negotiations

F-35s have been produced under low-rate initial production contracts, which are negotiated in a series of what are called annual production “lots.” The U.S. government and Lockheed Martin have negotiated 17 production lots of aircraft to date.

The most recent contract was signed in December 2022, when the F-35 JPO and Lockheed Martin agreed to a \$30 billion deal for the production of 398 F-35s for Lots 15 and 16, with an option for Lot 17. The deal capped negotiations that began in 2019. As announced, Lot 15 was reported to include 145 aircraft. Lot 16 included 127 aircraft, and Lot 17 included options for 126 aircraft.¹³⁴

According to Lieutenant General Michael Schmidt, the program executive officer for the F-35 program, Lockheed Martin submitted a proposal for Lot 18 and Lot 19 production in October 2023. In testimony to the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee, Schmidt wrote:

¹²⁹ Department of the Navy, *F-35 Lightning II Joint Strike Fighter (JSF) Program: December 2022 Selected Acquisition Report*, December 31, 2022, cleared for publication July 31, 2023, p. 22.

¹³⁰ Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023, p. 25.

¹³¹ U.S. Government Accountability Office, *F-35 Sustainment: Costs Continue to Rise While Planned Use and Availability Have Decreased*, GAO-24-106703, 2024, p. 1.

¹³² *Ibid.*, pp. 3-4.

¹³³ *Ibid.*, p. 5. An affordability target is the amount of money a military service projects it may be able to spend each year to operate an aircraft.

¹³⁴ Michael Marrow, “JPO, Lockheed finalize \$30 billion lot 15-17 JSF agreement,” *Inside Defense*, January 3, 2023.

In recent F-35 production lots, suppliers have experienced significant financial pressures driven by labor wage inflation, material inflation and increased European energy prices. We continue to work to drive down the cost of the air vehicle; however, these realities may drive an increase to prices in the Lot 18-19 production contract.... Beyond the Lot 18 and 19 contract, we must consider longer-term contract arrangements to stabilize the F-35 industrial base and utilize industry standard indices.¹³⁵

Schmidt added that the F-35 program seeks to purchase Lots 20-24 through a block-buy approach, saying that the use of economic order quantity funding could save up to \$1.1 billion over the four lots.¹³⁶

Lockheed Martin and the JPO in November 2024 said they reached a “handshake deal” for the next two production lots of F-35s—Lots 18 and 19—involving about 300 aircraft.¹³⁷ Lockheed Martin officials said they do not expect to sign a formal contract for Lots 18 and 19 before the end of 2024.¹³⁸

Long-Term Affordability

According to Lieutenant General Michael Schmidt, the cost of the F-35 could grow if prices for wages, material, and energy continue to rise. DOD leaders say that the services reduced their previously planned FY2024 request for F-35s because of congressionally directed budget caps. For example, the Air Force in its FY2025 budget request reduced the number of F-35s and F-15EX by six each. The service also reportedly asked Congress to retire multiple types of combat aircraft—56 A-10s, 32 F-22s, 65 F-15C/Ds, and 11 F-16C/Ds.¹³⁹

Air Force Secretary Frank Kendall told the House Armed Services Committee that because of constraints imposed by the Fiscal Responsibility Act of 2023 (P.L. 118-5), he made a tradeoff between procurement and research and development (R&D). He noted, “We’re taking a little bit of risk in procurement. We’re scaling that back modestly, from what we had previously planned, in order to get on with the modernization of the R&D part of the budget, which we have to get to, to remain competitive.”¹⁴⁰ The Air Force’s decision would effectively reduce the size of the service’s fighter fleet. The service has asked to add funding for development of future fighters to counter future threats.

Procurement Quantities

Planned Total Quantities

The F-35 program of record is 2,456 aircraft for the Air Force, Marine Corps, and Navy. Within the total, the program includes 1,763 F-35As for the Air Force, 273 F-35Cs for the Navy, and 67 F-35Cs and 353 F-35Bs for the Marine Corps. DOD also had 14 research and development

¹³⁵ Lieutenant General Michael Schmidt, “Statement Before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee,” April 16, 2024, pp. 18-19.

¹³⁶ *Ibid.*

¹³⁷ John A. Tirpak, “Lockheed and F-35 Program Office Have Handshake Deal on Next Two Lots,” *Air & Space Forces Magazine*, November 21, 2024.

¹³⁸ Robert Wall, “Lockheed Martin CFO Warns Of Delay In F-35 Contract Action,” *Aviation Week Intelligence Network*, December 4, 2024.

¹³⁹ Chris Gordon, “Air Force Plans to Divest 250 Aircraft in 2025, Shrinking Fleet to New Low,” *Air and Space Forces Magazine*, March 11, 2024.

¹⁴⁰ CQ Congressional Transcripts, *House Armed Services Committee Holds Hearing on the Fiscal Year 2025 Air Force Budget Request*, April 17, 2024.

aircraft.¹⁴¹ Congress in its FY2024 NDAA and Further Consolidated Appropriations Act provides funding and authority for an additional six test-configuration aircraft.

DOD began procuring F-35s in FY2007. DOD plans had envisioned steadily increasing the procurement rate of F-35As for the Air Force to a sustained rate of 80 aircraft per year by FY2015, completing the planned procurement of 1,763 F-35As by about FY2034.¹⁴² However, the Air Force requested just 48 F-35 for FY2020. Congress added funding for 62 in the Further Consolidated Appropriations Act of FY2020 (P.L. 116-94).¹⁴³

Congress has continued to increase funding for the F-35 above DOD's request. In the Further Consolidated Appropriations Act of FY2024 (P.L. 118-47), Congress provided funding for 51 F-35As, three more than the Air Force had requested. For FY2025 and FY2026, the service has requested 42 aircraft. Service budget documents for FY2025 state plans to increase the number to 47 in FY2027 and FY2028 and 48 aircraft in FY2029.¹⁴⁴

The Marine Corps and Navy had once planned to complete the procurement of 680 F-35Bs and F-35Cs by about FY2025. The Navy and Marine Corps are now saying they plan to purchase F-35s through FY2029. For FY2025, the Marine Corps is requesting funding for 13 F-35B aircraft and 4 F-35Cs. The Navy is requesting funding for 13 F-35C CV aircraft.¹⁴⁵

Potential Change in Marine Corps Procurement

On March 23, 2020, the Marine Corps released a “New Force Design Initiative” outlining proposed changes to its force structure. The Marine proposal would require 54 fewer F-35Bs than the 353 F-35Bs and 67 F-35Cs¹⁴⁶ in the existing program of record. The proposal would offset those reductions by increasing to 110 the number of F-35Cs, while retaining the same overall total of 420 aircraft.¹⁴⁷

In the summer of 2022, the Marine Corps began an effort called Project EAGLE to assess its future aviation plans. As part of Project EAGLE, the service said it plans to publish an Aviation Plan in December 2024.¹⁴⁸

On April 16, 2024, Marine Corps Lieutenant General Bradford Gering, the deputy commandant for aviation, told the Tactical Air and Land Forces Subcommittee of the House Armed Services

¹⁴¹ Department of Defense, *F-35 Lightning II Joint Strike Fighter (JSF) Program (F-35)*, Modernized Selected Acquisition Report, December 31, 2023.

¹⁴² CRS Report RL30563, *F-35 Joint Strike Fighter (JSF) Program*, by John R. Hoehn, p. 14.

¹⁴³ Details about why Congress increased funding from the 48 aircraft requested by the Air Force are included in H.Rept. 116-84. Congress added funding for 60 F-35As, as well as two additional test-configuration aircraft of each type of F-35.

¹⁴⁴ DOD FY2025 Budget Estimates, Air Force, Justification Book, Volume 1 of 2, p. 9, <https://www.saffm.hq.af.mil/Portals/84/documents/FY25/FY25%20Air%20Force%20Aircraft%20Procurement%20Vol%20I.pdf?ver=trnnCwkcSenGdKVniZvWHQ%3d%3d>.

¹⁴⁵ DOD FY2025 Budget Estimates, Navy, Justification Book Volume 1 of 3, Aircraft Procurement, Navy, Budget Activities 01-04, p. 13, <https://www.saffm.hq.af.mil/Portals/84/documents/FY25/FY25%20Air%20Force%20Aircraft%20Procurement%20Vol%20I.pdf?ver=trnnCwkcSenGdKVniZvWHQ%3d%3d>.

¹⁴⁶ U.S. Marine Corps, *Force Design 2030*, March 2020, p. 7.

¹⁴⁷ Statement of Nickolas H. Guertin, Assistant Secretary of the Navy (Research, Development and Acquisition); Lieutenant General Bradford Gering, Deputy Commandant for Aviation; and Rear Admiral Michael Donnelly, Director Air Warfare, before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee on Department of the Navy Fiscal Year 2025 Budget Request for Tactical Aviation, April 16, 2024.

¹⁴⁸ “Project EAGLE: Reorienting Marine Aviation’s Lift Vector toward 2040,” Marine Corps Association, January 5, 2024.

Committee that the Marines increased the number of F-35s per squadron from 10 to 12.¹⁴⁹ Marine Corps plans would also include changing the mix of 18 operational squadrons to 12 F-35B squadrons and 6 F-35C squadrons.¹⁵⁰

Manufacturing Locations

The F-35 has a large manufacturing footprint. According to Lockheed Martin, 1,650 suppliers across 47 U.S. states contribute to the F-35. Major U.S. and foreign defense companies supply many of the F-35's key subsystems, which include the following:

- Lockheed Martin builds the aircraft's forward section and completes final assembly in Fort Worth, TX.
- Northrop Grumman builds the midsection in Palmdale, CA, and the AN/APG-81 Advanced Electronically Scanned Array Radar in Linthicum, MD.
- BAE Systems in the United Kingdom makes the tail.
- Pratt & Whitney produces the F135 engine in East Hartford and Middletown, CT.
- Rolls-Royce builds the F-35B lift system in Indianapolis, IN.
- Raytheon makes the Electro-Optical Distributed Aperture System in locations including Goleta, CA.¹⁵¹
- Collins Aerospace and Elbit Systems of America make the Helmet Mounted Display in Ft. Worth, TX.¹⁵²
- The UK-based company Martin Baker assembles the US16 Ejection Seat in Ft. Worth, TX.
- BAE Systems in Manchester and Nashua, NH, has contracts to upgrade the F-35's electronic warfare system.
- L3Harris Technologies provides the TR-3 Integrated Core Processor and Panoramic Cockpit Display Electronic Unit, and Aircraft Memory System.
- Final assembly and checkout facilities are located in Cameri, Italy, and Nagoya, Japan.

Basing

F-35s are located around the globe. As more aircraft are produced, the United States and other governments continue to make decisions about where to base them.

The first F-35s began test flights out of Edwards AFB in California and at Nellis AFB in Nevada. Pilots and maintainers began training at Eglin AFB in Florida and Luke AFB in Arizona.¹⁵³ In

¹⁴⁹ Statement of Nickolas H. Guertin, Assistant Secretary of the Navy (Research, Development and Acquisition); Lieutenant General Bradford Gering, Deputy Commandant for Aviation; and Rear Admiral Michael Donnelly, Director Air Warfare, before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee on Department of the Navy Fiscal Year 2025 Budget Request for Tactical Aviation, April 16, 2024. The prior mix included four F-35C squadrons.

¹⁵⁰ The Marine Corps' plan previously called for four F-35C squadrons. As of April 2024, the Marines had eight operational squadrons.

¹⁵¹ Raytheon is an RTX subsidiary.

¹⁵² Collins Aerospace is also an RTX subsidiary.

¹⁵³ Michael C. Sirak, "Building Homes for F-35s," *Air and Space Forces Magazine*, February 24, 2015.

Notes: Date of map March 26, 2024. Includes basing locations of partner-nation F-35s. The red square identifies major maintenance hubs.

Ship Activations: USS *Essex*, USS *Wasp*, USS *America*, HMS *Queen Elizabeth*, USS *Carl Vinson*, ITS *Cavour*, USS *Makin Island*, USS *Abraham Lincoln*, HMS *Prince of Wales*, USS *Tripoli*, USS *Boxer*, USS *George Washington*, ITS *Trieste* 2024, USS *Theodore Roosevelt* 2025, USS *Kearsarge* 2026, USS *Ronald Reagan* 2026, JS *Izumo* 2027, USS *Bataan* 2028, USS *J.F. Kennedy* 2028, USS *John Stennis* 2028, JS *Kaga* 2028.

Base Locations: Air Force Active Duty: Edwards AFB, CA; Eglin AFB, FL; Eielson AFB, AK; Hill AFB/Ogden Air Logistics Center, UT; Luke AFB, AZ; Nellis AFB, NV; Tyndall AFB, FL. **Marine Corps Active Duty:** MCAS Beaufort, SC; MCAS Cherry Point, NC; MCAS Miramar, CA; MCAS Yuma, AZ. **Navy Active Duty:** NAS Fallon, NV; NAS Lemoore, CA; Patuxent River, MD. **National Guard and Reserve:** Burlington ANGB, VT; Dannelly, ANGB, AL; Ebbing ANGB, AR; Homestead Air Reserve Base, FL; Jacksonville ANGB, FL; NAS Joint Reserve Base Fort Worth TX; Truax ANGB, WI. **Europe:** Amendola AB, IT; Cameri, IT; Evenes AB, NO; Ghedi, IT; Kleine-Brogel AB, BE; RAF Lakenheath, UK; Lask, PL; Leeuwarden AB NL; RAF Marham, UK; Nevatim, IL; Orland MAS, NO; Payerne AB, CH; Skrydstrup AB, DK; Swidwin AB, PL; Volkel AB, NL. **Asia:** Cheongju AB, SK; MCAS Iwakuni, JP; Komatsu AB, JP; Misawa AB, JP; Nyttabaru AB, JP. **Australia:** RAAF Tindal, AU; RAAF Williamtown, AU.

International Participation

The F-35 program is DOD’s largest international cooperative program. DOD has pursued allied participation as a way to defray some development and production costs and ensure export sales.

Eight allied countries—the United Kingdom, Canada, Denmark, the Netherlands, Norway, Italy, Turkey, and Australia—initially participated in the F-35 program under a memorandum of understanding (MOU) for the SDD and Production, Sustainment, and Follow-On Development (PSFD) phases of the program. These eight countries have contributed varying amounts of research and development funding to the program, receiving in return differing levels of participation in the program.

International participation in the F-35 program is divided into three levels, according to the amount of money a country contributes to the program—the higher the amount, the greater the nation’s influence on aircraft requirements, design, and access to technologies gained during development. Level 1 partner status requires approximately 10% contribution to aircraft development and allows for fully integrated office staff and a national deputy at the director level.¹⁵⁸ The United Kingdom is the only Level I partner.

Level II partners consist of Italy and the Netherlands, contributing \$1 billion and \$800 million, respectively.¹⁵⁹ Australia, Denmark, Norway, Canada, and Turkey joined the F-35 program as Level III partners, with contributions ranging from \$125 million to \$175 million.¹⁶⁰ The United

¹⁵⁸ For a description of how international partnerships were constructed, including the nickname “the pepperoni pizza approach,” see Tom Burbage, Betsey Clark, and Adrian Pitman, with David Poyer, *F-35: The Inside Story of the Lightning II*, Skyhorse Publishing, 2023, pp. 77-82.

¹⁵⁹ Ibid.

¹⁶⁰ Ibid. Unlike the SDD phase, the Production, Sustainment and Follow-on Development (PSFD) phase does not make any distinction as to levels of participation. A single PSFD MOU covers all partner governments. In signing the PSFD MOU, partner governments state their intentions to purchase the F-35, including quantity and variant, and the JPO determines their delivery schedule. PSFD costs are divided on a “fair-share” basis according to the programmed purchase amount of the respective nation. F-35 officials decided to take a different approach, in line with the program’s goal to control costs, to avoid so-called “offset” arrangements, and promote competition as much as possible. Consequently, all partner nations have agreed to compete for work on a “best-value” basis. According to the Defense Acquisition University, about 80 countries require “offset” arrangements, which compensate the flow of money from the foreign country for the purchase of U.S. defense equipment.

States revoked Turkey's participation in the F-35 program in 2019 because of a disagreement over Turkey's acquisition and intended fielding of the S-400 Russian air defense system.¹⁶¹

The United Kingdom, which has said it plans to purchase 138 F-35s, is the most significant international partner in terms of financial commitment.¹⁶² The United Kingdom committed to spending \$2 billion, equating to about 8% of the estimated cost of SDD. A number of UK firms, such as BAE and Rolls-Royce, participate in the F-35 program.¹⁶³

The governments of Italy and the United Kingdom lobbied for F-35 assembly facilities to be established in their countries. In July 2010, Lockheed Martin and the Italian firm Alenia Aeronautica agreed to establish an F-35 final assembly and checkout facility at Cameri Air Base, Italy, to deliver aircraft for Italy and the Netherlands. The facility opened in July 2013.¹⁶⁴

Sales to F-35 partner governments are not reviewed by Congress. The F-35 has a Global Project Authorization.¹⁶⁵ The Department of State's Directorate of Defense Trade Controls is allowed, under 22 C.F.R. 126.14, to provide such authorizations, which apply to registered U.S. exporters for exports of defense articles, technical data, and defense services in support of government-to-government cooperative projects.¹⁶⁶ Such cooperation occurs pursuant to an agreement between the U.S. government and the government of the foreign country or a memorandum of understanding between DOD and the foreign country's ministry of defense.

BAE Systems Australia is investing \$107 million to build a factory to produce, apply, and maintain F-35 stealth coatings for Royal Australian Air Force F-35s. The factory is also to serve as a "regional hub" for F-35 maintenance in the region.¹⁶⁷

Sales to other countries, including Finland, Japan, South Korea, Switzerland, and elsewhere are conducted through the standard FMS process, including congressional notification. DOD and foreign partners in the JSF program have negotiated a variety of arrangements about work shares and proprietary technology.

Before losing its partner status, Turkey was to build F135 engines and conduct engine maintenance and overhaul. After Turkey's expulsion from the F-35 program, Norway and the Netherlands took on engine maintenance and training work. The Netherlands opened a StandardAero testing facility for F-35 engine maintenance in 2021; Norway declared a Kongsberg F135 engine maintenance facility operational in 2022.¹⁶⁸

¹⁶¹ For more discussion, see CRS Report R41761, *Turkey-U.S. Defense Cooperation: Prospects and Challenges*, by Jim Zanotti, and CRS Report R41368, *Turkey (Türkiye): Background and U.S. Relations*, by Jim Zanotti and Clayton Thomas.

¹⁶² "UK Restates Commitment to Full F-35 Programme of Record," *Janes*, February 6, 2024.

¹⁶³ BAE is a major partner to Lockheed Martin and provides the aft fuselage, empennage, and electronic warfare suite for the aircraft. Rolls-Royce is a subcontractor to Pratt & Whitney, producing components for the F-35B's STOVL lift system. All F-35Bs, regardless of what engine they use, employ Rolls Royce components in their STOVL lift systems.

¹⁶⁴ Luca Peruzzi, "Italy Opens F-35 Assembly Line, as Political Opposition Grows," *Flightglobal.com*, July 18, 2013, <https://www.flightglobal.com/italy-opens-f-35-assembly-line-as-political-opposition-grows/110535.article>.

¹⁶⁵ Government Accountability Office, *Joint Strike Fighter: Management of the Technology Transfer Process*, GAO-06-364, March 2006. CRS In Focus IF11437, *Transfer of Defense Articles: Foreign Military Sales (FMS)*, by Nathan J. Lucas and Michael J. Vassalotti.

¹⁶⁶ These projects are authorized under Section 27 of the Arms Export Control Act, 22 U.S.C. §2767.

¹⁶⁷ Colin Clark, "'Regional Hub' for F-35 Work: Australia Boost Up Stealth Coating Factory for Indo-Pacific," *Breaking Defense*, August 23, 2023.

¹⁶⁸ Tony Osborne, "Netherlands Opens F-35 Engine Test Facilities," *Aviation Week Intelligence Network*, October 14, 2021. Kongsberg Press Release "Norway's F135 Engine Heavy Maintenance Facility Achieves Initial Depot Capability," March 18, 2022.

International Sales Quantities

The cost of F-35s for U.S. customers depends on the total quantity of F-35s sold to other governments. The latest Selected Acquisition Report assumes the benefit of 371 Foreign Military Sales and 547 International Partner Aircraft to calculate the average unit recurring flyaway cost.¹⁶⁹

In 2020, after the Abraham Accords normalized diplomatic relations between Israel and the UAE, then-President Donald Trump proposed selling F-35s to the UAE. In January 2021, the U.S. and the UAE reportedly completed negotiations for the sale of 50 F-35s worth an estimated \$23 billion.¹⁷⁰ But shortly after taking office, U.S. President Joe Biden put a temporary hold on the sale, because of concerns about a UAE contract with the China-based 5G technology company Huawei.¹⁷¹ By December 2021, the UAE withdrew from discussions about the purchase of F-35s.¹⁷² During a 2023 Senate Foreign Relations Committee hearing, U.S. Secretary of State Antony Blinken commented on deals with the UAE, saying, “We said we’d welcome pursuing this conversation, including the F-35s.”¹⁷³

Belgium, Finland, and Switzerland chose to purchase the F-35 (see **Table 3**). Switzerland, which approved the purchase of F-35s in 2022, expects delivery of aircraft in 2028.¹⁷⁴

Potential new orders include the following:

- **Germany** announced in December 2022 that it intends to buy 35 F-35s to replace the nation’s aging Panavia Tornado fighters. The total procurement, including weapons and maintenance, was valued at around \$10 billion.¹⁷⁵
- **The Czech Republic** in January 2024 signed a letter of offer and acceptance for a planned FMS of 24 F-35 aircraft with an estimated cost of \$4.58 billion. The first aircraft is reportedly scheduled to arrive in 2031.¹⁷⁶
- The U.S. State Department in January 2024 approved the sale to **Greece** of up to 40 F-35s for an estimated \$8.6 billion.¹⁷⁷

¹⁶⁹ Office of the Secretary of Defense, *Selected Acquisition Report (SAR): F-35 Joint Strike Fighter Aircraft (F-35)*, December 2022, p. 13.

¹⁷⁰ Valerie Insinna, “Just Hours Before Biden’s Inauguration, the UAE and US Come to a Deal on F-35 Sales,” *Defense News*, January 20, 2021.

¹⁷¹ Andrew England and Simeon Kerr, “UAE Suspends Talks with US over purchase of F-35 Fighter Jets,” *Financial Times*, December 14, 2021.

¹⁷² “UAE Tells U.S. It Will Suspend F-35 Talks Following Huawei Unease,” *Reuters*, December 15, 2021.

¹⁷³ CRS Report RS21852, *The United Arab Emirates (UAE): Issues for U.S. Policy*, by Jeremy M. Sharp, p. 22. See U.S. Congress, Senate Foreign Relations Committee, *American Diplomacy and Global Leadership: Review of the FY24 State Department Budget Request*, hearings, 118th Cong., 1st sess., March 22, 2023.

¹⁷⁴ “Switzerland Risks Paying Billions if US Jets are Delivered Late,” *swissinfo.ch*, August 14, 2023. According to a *Wall Street Journal* article, U.S. officials pressured the Swiss government to shore up security near Meiringen Air Base, including building screens near the runway to prevent aviation enthusiasts from taking photographs of the aircraft and its engine. Federal police raided the Hotel Rosslı, which was owned by Chinese nationals, in nearby Unterbach.

¹⁷⁵ Sabine Siebold, Holger Hansen, and Rachel More, “Germany approves, 10 bln Euro F-35 jet deal with U.S.,” *Reuters*, December, 14, 2022.

¹⁷⁶ Tony Osborne, “Czech Republic Formally Signs F-35 Purchase Agreement,” *Aviation Week Intelligence Network*, January 29, 2024.

¹⁷⁷ Lee Ferran, “Biden unfreezes huge F-16 deal for Turkey, OKs F-35s for Greece in major geopolitical move,” *Breaking Defense*, January 27, 2024.

- In November 2024, the **Romania** signed a letter of acceptance to purchase 32 F-35s for an estimated cost of \$7.2 billion.¹⁷⁸
- **Israel’s** government on June 4, 2024, signed a letter of acceptance with the U.S. to buy 25 additional F-35s for \$3 billion, which would expand its fleet of 50 aircraft to 75.¹⁷⁹ Israel, which received its first F-35I in 2016, added a custom open architecture system on top of the aircraft’s operating system.¹⁸⁰ The aircraft also received electronic warfare and indigenous weapons updates.¹⁸¹
- **Singapore** purchased an initial 12 F-35B aircraft, and in February 2024, Defense Minister Ng Eng Hen said the nation plans to order another 8 F-35 aircraft.¹⁸²

Sales to additional countries are possible. Lockheed Martin could build 780 F-35s for the United States and for export over a five-year ordering period between FY2026 and FY2030, the JPO said in an acquisition document.¹⁸³

Table 3. International Orders

Country	Overall Quantity	F-35A Quantity	F-35B Quantity
Australia	100	100	
Belgium	34	34	
Canada	88	88	
Czech Republic	24	24	
Denmark	27	27	
Finland	64	64	
Germany	35	35	
Greece	40	40	
Israel	75	75	
Italy	90	60	30
Japan	147	105	42
Netherlands	52	52	
Norway	52	52	
Poland	32	32	
Romania	32	32	
Singapore	20	8	12
South Korea	60	60	

¹⁷⁸ Lockheed Martin Press Release, “Romania Becomes The 20th Member of the F-35 Global Alliance,” November 21, 2024, <https://news.lockheedmartin.com/2024-11-21-Romania-Becomes-the-20th-Member-of-the-F-35-Global-Alliance>.

¹⁷⁹ Seth J. Frantzman, “Amidst Gaza Tensions, Israel Signs F-35 Deal with US for 25 More Warplanes,” *Breaking Defense*, June 5, 2024.

¹⁸⁰ “Israel’s F-35 App And Its Implications,” *Aviation Week & Space Technology*, April 22, 2016.

¹⁸¹ Gideon Grudo, “The Israeli F-35s,” *Air and Space Forces Magazine*, April/May 2017, pp. 62-65.

¹⁸² Leilani Chavez, “Singapore to Buy Eight F-35 Jets, Raise Defense Budget,” *Defense News*, February 29, 2024.

¹⁸³ Steve Trimble, “Pentagon Sets Order Ceiling at 780 Between 2026-2030,” *Aviation Week Intelligence Network*, August 2, 2023.

Switzerland	36	36	
United Kingdom	138		74
Total	1146	924	158

Source: CRS research of FMS notifications and contract signings as of November 2024.

Note: Includes pledged purchases in various stages of planning and approval, which are subject to change.

Proposed Procurement and RDT&E Funding

Table 4. DOD F-35 Funding Request

(Figures in millions of dollars)

	FY2024 (enacted)	FY2025	FY2026	FY2027	FY2028	FY2029
RDT&E						
F-35A C2D2	1,275.27	1,124.21	1,192.42	1,160.61	975.10	989.29
F-35B C2D2	544.625	480.759	517.621	460.787	449.975	439.567
F-35C C2D2	543.834	466.186	493.845	466.798	428.356	417.407
F-35 Squadrons	97.231	47.132	49.156	47.709	49.561	50.539
Procurement						
F-35A	5,279.12	4,956.74	5,314.03	5,690.15	5,600.82	5,738.91
F-35A Modifications	451.80	549.70	557.90	555.60	567.10	578.40
F-35B	2,319.442	2,247.614	2,271.355	2,756.664	3,125.54	2,992.87
F-35B Modifications	311.921	282.987	388.839	582.764	253.02	258.37
F-35C	2,599.994	2,091.667	2,379.667	2,582.162	2,498.27	3,583.26
F-35C Modifications	166.909	183.92	304.684	308.201	305.51	302.51
Total	13,590.2	12,430.9	13,469.5	14,611.4	14,253.3	15,351.1

Source: Department of Defense FY2025 Budget Estimates, Department of the Air Force, Justification Book Volume 1 of 2 Aircraft Procurement, Air Force; Department of Defense FY2025 Budget Estimates, Department of the Air Force, Justification Book Volume 3 of 4 Research, Development, Test, & Evaluation, Air Force. Department of Defense FY2025 Budget Estimates, Department of the Navy, Justification Book Volume 1 of 3 and Volume 2 of 3, Aircraft Procurement Navy; Department of Defense FY2025 Budget Estimates, Department of the Navy, Justification Book Volume 5 of 5, Research, Development, Test, & Evaluation, Navy.

Note: F-35A, F-35B, and F-35C procurement figures includes funding for advance procurement. Figures do not include funding for international programs or for military construction.

Legislative Activity for FY2025

Proposals for an FY2025 National Defense Authorization Act (H.R. 8070/S. 4638)

The House, in its version of a proposed FY2025 National Defense Authorization Act, H.R. 8070, would reduce funding for F-35 procurement to purchase 10 fewer aircraft than requested by the

Biden Administration (see **Table 5**). The legislation contains a number of oversight provisions including the following:

- Section 174 states that Congress would limit the number of F-35 deliveries to 30 F-35As and nine F-35B and nine F-35C aircraft. The limitation would be imposed until the Secretary of Defense certifies to the congressional defense committees that DOD is in compliance with a number of conditions, which include developing and implementing acquisition strategies for F-35 aircraft and mission systems digital twin models, developing and implementing at least one avionics flying test bed aircraft, and developing and implementing a mission software integration laboratory to test old and new hardware and software, among other conditions. The bill would also require the Secretary to develop a way to correct and resolve a number of program deficiencies. The bill additionally would require DOD to develop a plan to address long-standing readiness and sustainment concerns and deliver a report by April 1, 2025.
- Section 217 would modify P.L. 118-31 to require at least nine C2D2 F-35 aircraft be made for developmental testing, rather than six.
- Section 343 would extend required annual Comptroller General reviews of F-35 sustainment efforts through 2027.
- Section 878 would instruct DOD to implement the Comptroller General’s recommendations pertaining to F-35 parts from the May 2023 GAO report.¹⁸⁴

The Senate Armed Services Committee (SASC) in its version of a proposed National Defense Authorization Act, S. 4638, recommends fully funding DOD’s procurement request for all variants of the F-35, and its provisions include the following:

- Section 133 states that it would modify the F-35 Propulsion and Thermal Management subprogram’s requirements “for cost-benefit and technical risk analysis.”

Proposals for an FY2025 Department of Defense Appropriations Act (H.R. 8774/S. 4921)

The House Appropriations Committee (HAC) would add funding for two additional F-35As—a total of 44—and six more F-35Cs than the Biden Administration requested. The committee’s version of the bill, H.R. 8774, recommended including funding for advanced fighter engine development—though an engine resulting from that development would not be used to power the F-35. Section 8130 includes, as FY2024 legislation had included, a prohibition on the use of funding to integrate an alternative engine onto the F-35.¹⁸⁵ Section 8129 would provide the authority to obligate money to modify up to six F-35s to a test configuration.¹⁸⁶

The Senate Appropriations Committee’s (SAC) report of the FY2025 Department of Defense Appropriations Act (S.Rept. 118-204) would reduce funding for F-35 procurement, citing

¹⁸⁴ *DOD Needs Better Accountability for Global Spare Parts and Reporting of Losses Worth Millions* GAO-23-106098, May 23, 2023.

¹⁸⁵ H.R. 8774 §8130.

¹⁸⁶ H.R. 8774 §8129.

unearned incentive fees and unjustified program growth.¹⁸⁷ The bill would add \$10 million for power and thermal management system development.¹⁸⁸

S.Rept. 118-204 expresses the concern that the projected number of Air Force fighter procurements is not adequate. The report states, “As the F-35 continues to experience extensive delays in the delivery of combat capable aircraft, and fiscal year 2025 is currently the last programmed buy for the F-15EX, absent maturation of the [Next Generation Air Dominance] platform, the Air Force has not presented a viable plan to sustaining the production and fielding of fighter aircraft.”¹⁸⁹

¹⁸⁷ S.Rept. 118-204, pp. 120, 156.

¹⁸⁸ *Ibid.*, p. 231.

¹⁸⁹ *Ibid.*, p. 234.

Table 5. FY2025 Legislative Action

	Authorization				Appropriation		
	Request	House	Senate Armed Services Committee	Enacted	House Appropriations Committee	Senate Appropriations Committee	Enacted
F-35A	4,474.16	4,012.46	4,474.16		4,548.47	4,128.86	
F-35B	2,078.23	1,878.23	2,078.23		2,018.48	1,953.81	
F-35C	1,895.03	1,695.03	1,895.03		2,616.46	1,775.24	
Total	8,447.42	7,585.72	8,447.42		9,183.41	7,857.91	

Source: H.Rept. 118-529, S.Rept. 118-188, H.Rept. 118-557, S.Rept. 118-204

Note: Procurement figures here do not include funding for advance procurement.

Legislative Activity for 2024

FY2024 National Defense Authorization Act

The Defense Department requested \$13.6 billion in FY2024 to purchase 83 F-35 aircraft (48 F-35As, 16 F-35Bs, and 19 F-35Cs). The FY2024 NDAA (P.L. 118-31) authorized funding to procure all 83 aircraft.

- Section 225 directs the Secretary of Defense to designate two new upgrade elements, the Technical Refresh-3 hardware and Block 4 software, as a single subprogram of the F-35 program. The section authorizes the purchase of two aircraft of each variant for use in developmental testing.
- Section 226 requires the service secretaries to validate requirements for the propulsion, power, and thermal management and electrical power systems of the F-35 and to provide both a cost-benefit and a technical-risk analysis of the upgrades in a report to Congress by July 1, 2024.
- Section 1070 directs the Secretary of the Air Force, the Director of the Air National Guard, and the Commander of the Air Force Reserve to provide to Congress a 12-year plan, which was due April 1, 2024, for fighter force structure, recapitalization, training, and sustainment.
- The conference report accompanying the FY2024 NDAA also directed the Secretary of Defense to brief the armed services committees by March 1, 2024, on whether F-35 aircraft parts are to be categorized as government-furnished property, including on the status of a system for tracking those parts.

FY2024 Further Consolidated Appropriations Act

The FY2024 DOD Appropriations Act, incorporated as Division A of the Further Consolidated Appropriations Act (P.L. 118-47 Division A), provides \$9.8 billion for 86 F-35 aircraft, adding funding for an additional three F-35As, bringing the total to 51, and fulfilling DOD’s request for 16 F-35Bs for the Marine Corps and 19 F-35Cs for the Navy. The law also appropriates \$2.3 billion in RDT&E funding for the F-35’s Continuous Capability Development and Delivery program.

- Section 8136 provides funding to modify up to six aircraft, two of each variant, to a test configuration, provided that the Secretary of Defense notifies congressional defense committees.
- Section 8137 prohibits funding from being used to integrate an alternative engine onto the F-35 program.

Potential Issues for Congress

Congress may or may not consider many aspects of the F-35 program.

Number of F-35s

Congress has debated the appropriate number of F-35s to purchase. Some Members argue that the United States should buy fewer F-35s than the 68 DOD requested because the program is not meeting cost, schedule, or performance metrics and note that the Air Force stopped accepting delivery of the aircraft. The House Armed Services Committee's report on the FY2025 Defense Authorization Act, for example, would authorize the purchase of 58 F-35s, 10 fewer than requested (H.Rept. 118-529).

Other Members point out that purchasing fewer F-35s would increase the cost of individual aircraft and thereby the cost of the overall program. The House Appropriations Committee, in its report on the FY2025 Defense Appropriations Bill (H.Rept. 118-557), recommended providing funding for 76 F-35s, 8 more F-35s than DOD requested.

The FY2024 NDAA (P.L. 118-31 §148) directed the Secretary of the Air Force and the Director of the Air National Guard and Commander of the Air Force Reserve to submit a 12-year plan for fighter force structure, recapitalization, training, and sustainment. The outcome of that report may inform further action on F-35 and other fighter aircraft.¹⁹⁰

Another issue for Congress may be the total number of combat aircraft in the Air Force, Marine Corps, and Navy. The number of fighter aircraft has declined from 4,556 in 1990 to 2,176 in 2022.¹⁹¹ Other aspects affecting the size of the aircraft inventory include

- the number and capability of other existing combat aircraft fleets, including the F-22, F-16, F-15EX, A-10, F/A-18 E/F Block III Super Hornet;
- the ability to deploy and sustain those aircraft against long-range anti-aircraft threats in the Pacific and elsewhere;
- the number of uncrewed aircraft, the actual capability of those aircraft in combat, and the ability to team with existing crewed aircraft; and
- the availability of support, such as refueling tankers and cargo aircraft.

Development and Sustainment Issues

The Air Force stopped accepting F-35s in July 2023, because of TR-3 software issues. The Air Force has resumed acceptance of F-35s, but Congress may consider whether or not to explore the

¹⁹⁰ As of May 23, 2024, the Air Force said it was still reviewing the final version of the Section 148 report on long-term Air Force fighter force structure.

¹⁹¹ U.S. Air Force Lieutenant General (ret.) Joseph Guastella, Douglas Birkey, and Lieutenant Colonel (ret.) Eric Gunzinger, "Accelerating 5th Generation Airpower: Bringing Capability and Capacity to the Merge," Mitchell Institute Policy Paper, June 2023.

cost to retrofit the aircraft that were delivered without the complete TR-3 software and the cost of any damage experienced by the aircraft while in storage.

As noted earlier (See “Legislative Activity for FY2025”), the House has proposed several reporting requirements and oversight aimed at improving testing of ongoing F-35 upgrades.

Separately, GAO has stated that DOD should look for ways in which the government could secure ownership over F-35 technical data rights. A 2023 GAO report summarized this recommendation:

In September 2014, we reported on long-term affordability concerns for the F-35 sustainment strategy and the implications for DOD’s decision to obtain limited technical data in the F-35 program. We recommended that to promote competition, address affordability, and inform its overarching sustainment strategy, DOD should develop a long-term Intellectual Property (IP) Strategy for the F-35 program to include, but not be limited to, the identification of (1) current levels of technical data rights ownership by the federal government and (2) all critical technical data needs and their associated costs. In May 2020, we made this a priority recommendation. However, as of May 2023, this recommendation remains open, and continues to be a missing element in the department’s efforts to plan for the future of F-35 sustainment.¹⁹²

In addition, Congress has directed that sustainment functions be transferred from the JPO to the Navy and Air Force by 2027 and that the acquisition functions be similarly transferred by 2029.¹⁹³ The services are making plans to implement that guidance, and Members of Congress may request an update about implementation. Congress might also consider requiring DOD to create and implement a long-term Intellectual Property Strategy for the F-35.

Engine Upgrades

DOD and Congress have provided funding for the F135 Engine Core Upgrade that is to power the F-35’s new Block 4 capabilities and cool the engine to preserve engine life. Program officials anticipate the need for additional power and thermal management upgrades for future F-35 capabilities.

GAO has made several recommendations for Congress to consider regarding the engine, including

- ensuring F-35 cost-estimate accuracy, checking the readiness of critical technologies,
- ensuring that the full-life cycle costs of the engine and PTMS upgrades are considered, and
- obtaining an independent cost estimate for all engine and thermal management modernization options, including integration and related aircraft upgrades.¹⁹⁴

The FY2024 Further Consolidated Appropriations Act (P.L. 118-47 §8137) prohibits DOD from using FY2024 funding to adapt a new engine for use on the F-35,¹⁹⁵ and the HAC recommends a

¹⁹² U.S. Government Accountability Office, *F-35 Aircraft: DOD and the Military Services Need to Reassess the Future Sustainment Strategy*, GAO-23-105341, 2023, p. 49.

¹⁹³ FY2022 NDAA, P.L. 117-81, §142.

¹⁹⁴ U.S. Government Accountability Office, *F-35 Joint Strike Fighter: More Actions Needed to Explain Cost Growth and Support Engine Modernization Decision*, GAO-23-106047, 2023. *F-35 Joint Strike Fighter: Program Continues to Encounter Production Issues and Modernization Delays*, GAO-24-106909, May 2024.

¹⁹⁵ P.L. 118-47, §8137.

similar prohibition for FY2025. The SASC’s version of the NDAA calls for risk reduction for the F-35’s power and thermal management system. Congress may consider sustaining its oversight of engine upgrade efforts.

Supply Chain

The F-35 supply chain may be another area of congressional interest. Lockheed Martin CEO Jim Taiclet told investors in April 2024 that he may add second and third sources of supply outside of the United States, because UK factories shuttered during COVID-19 delayed deliveries. “We’re eager to have international production and sustainment partners, and we’re going to expand that,” Taiclet said.¹⁹⁶

Prior to the COVID-19 pandemic, DOD faced other challenges with managing F-35 parts. For example, a May 2023 GAO report stated that F-35 program participants share a common spare parts pool owned by DOD but managed by contractors. The parts are held at more than 50 sites around the world. According to GAO, between May 2018 and October 2022, “one F-35 prime contractor incurred losses of over 1 million spare parts totaling over \$85 million.”¹⁹⁷ Congress may investigate further the oversight of spare parts pools.

The FY2022 NDAA (P.L. 117-81, §141) implemented a GAO recommendation providing that, in FY2027, the Secretaries of the Air Force and Navy set operational and sustainment cost constraints for the F-35. Congress could require the program to report on the progress toward achieving affordability constraints.

In addition, Congress could consider whether or not to request information about the frequency or extent of supply chain shortages, such as those faced with TR-3’s integrated core processor. (See “Modernization Issues.”)

Readiness

Some Members of Congress have expressed concern about the F-35’s 55% mission-capable rate, which GAO reported in September 2023.¹⁹⁸ The Air Force’s list of unfunded requirements contains \$612 million to purchase spare parts and equipment to make up to 208 aircraft operationally capable, a Member noted.¹⁹⁹

Air Force Chief of Staff General David Allvin told the Senate Appropriations Committee, Subcommittee on Defense, that the \$612 million would help the service “adjust the paradigm” of how it typically deploys squadrons.²⁰⁰ The money would help the Air Force to deploy squadrons of 24 aircraft to deploy in smaller units, with the spare parts kits for maintenance. “It’s really upgrading our way of presenting forces to the combatant commands and training for the high-end challenge.”²⁰¹

¹⁹⁶ Lockheed Martin Corporation Q1 2024 Earnings Call Transcript, April 23, 2024.

¹⁹⁷ U.S. Government Accountability Office, *F-35 Program: DOD Needs Better Accountability for Global Spare Parts and Reporting of Losses Worth Millions*, GAO-23-106098, 2023.

¹⁹⁸ *Ibid.*

¹⁹⁹ *Ibid.*

²⁰⁰ “Senate Appropriations Committee on Defense Holds Hearing on the Fiscal Year 2025 Air Force and Space Force Budget Request,” *CQ Transcripts*, April 9, 2024, <https://plus.cq.com/doc/congressionaltranscripts-7981684?7>.

²⁰¹ *Ibid.*

Congress may consider whether or not to provide additional funding for spare parts kits. It might wish to consider requiring or suggesting that the Air Force build flexible spare parts funding into its regular annual budget process for the future.

Block Buy for Future Procurement

As DOD approaches negotiations for production Lots 20-24, Congress may consider whether or not to authorize or appropriate funding for a block buy. The JPO and Lockheed Martin are currently negotiating a contract for the production of Lot 18 and 19 aircraft. As stated above, Lieutenant General Schmidt said a block buy for Lots 20-24 could save up to \$1.1 billion.²⁰²

A block buy does not require a program to meet the statutory requirements that govern multiyear procurement contracting.²⁰³ Multiyear procurements are required to generate significant savings, have realistic cost estimates, and have a stable need and design for items.²⁰⁴

F-35 Sales to Turkey, UAE

Congress may consider revisiting the sale of F-35s to Turkey and the United Arab Emirates.

Turkey was one of the eight original F-35 international partners on the F-35 program and is a member of NATO. The United States removed Turkey from the F-35 program in July 2019 for its purchase of the S-400 surface to air missile system—an acquisition which caused concern that Russia could obtain information concerning the F-35’s stealth capabilities. The U.S. imposed sanctions on Turkey using the Countering America’s Adversaries Through Sanctions Act (P.L. 115-44).²⁰⁵ In January 2024, the U.S. resumed sales of F-16s to Turkey, which has renewed the discussion of whether Turkey could purchase F-35s. Congress could reconsider Turkey’s participation in the program.

The United Arab Emirates reportedly withdrew its bid to buy F-35s after the Biden Administration delayed the deal over concerns about a UAE contract with the China-based 5G technology company Huawei.²⁰⁶ Congress could consider whether or not to support a sale of F-35s to the UAE in the future.

²⁰² Lieutenant General Michael Schmidt, “Statement Before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee,” April 16, 2024, p. 19.

²⁰³ 10 U.S.C. §3501.

²⁰⁴ For a more complete discussion of the MYP and Block Buy approaches, see CRS Report R41909, *Multiyear Procurement (MYP) and Block Buy Contracting in Defense Acquisition: Background and Issues for Congress*, by Ronald O’Rourke.

²⁰⁵ CRS Report R41368, *Turkey (Türkiye): Background and U.S. Relations*, by Jim Zanotti and Clayton Thomas.

²⁰⁶ Valerie Insinna and Riad Kahwaji, “UAE F-35 Deal on Life Support After Emiratis Cancel Acceptance of Weapons Package,” *Breaking Defense*, December 14, 2021.

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