

F-35 Joint Strike Fighter (JSF) Program

(name redacted)

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Summary

The largest procurement program in the Department of Defense (DOD), the F-35 Lightning II is a strike fighter aircraft being procured in different versions for the United States Air Force, Marine Corps, and Navy. Current DOD plans call for acquiring a total of 2,457 F-35s. Allies are expected to purchase hundreds of additional F-35s, and eight nations are cost-sharing partners in the program with the United States.

The F-35 promises significant advances in military capability. Like many high-technology programs before it, reaching that capability has put the program above its original budget and behind the planned schedule.

The Administration's proposed FY2017 defense budget requested about \$7.3 billion in procurement funding for the F-35 program. This would fund the procurement of 43 F-35As for the Air Force, 16 F-35Bs for the Marine Corps, 4 F-35Cs for the Navy, and continuing development.

FY2016 defense authorization act: The FY2016 defense authorization bill funded F-35 procurement at \$8.4 billion for 63 aircraft (44 F-35As, 15 F-35Bs, and 4 F-35Cs, an increase of 6 aircraft and \$722.4 million from the Administration's request), plus \$753.2 million in advance procurement. The conference report accompanying the bill included language limiting FY2016 funds for the F-35A pending a certification that aircraft delivered in FY2018 will have full combat capability with currently planned Block 3F hardware, software, and weapons carriage and a provision that would direct the Comptroller General of the United States to conduct a review and submit a report on the F-35's Autonomic Logistics Information System.

FY2016 defense appropriations bill: The final omnibus budget bill funded F-35 procurement at \$8.4 billion for 68 aircraft (47 F-35As, 15 F-35Bs, and 6 F-35Cs, an increase of 11 aircraft and \$799.9 million over the Administration's request), plus \$732.0 million in advance procurement, an increase of \$20 million from the Administration's advance procurement request. The explanatory statement accompanying the bill included language directing the Secretary of Defense to submit a report certifying that Autonomic Logistics Information System 2.0.2 equipment has been delivered and supports an Air Force declaration of Initial Operating Capability (IOC) for the F-35A.

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Introduction

In General

The F-35 Joint Strike Fighter (JSF), also called the Lightning II, is a strike fighter airplane being procured in different versions for the Air Force, Marine Corps, and Navy. The F-35 program is DOD's largest weapon procurement program in terms of total estimated acquisition cost. Current Department of Defense (DOD) plans call for acquiring a total of 2,457 F-35s¹ for the Air Force, Marine Corps, and Navy at an estimated total acquisition cost, as of December, 2015, of about \$313.3 billion in constant (i.e., inflation-adjusted) FY2012 dollars.² U.S. allies are expected to purchase hundreds of additional F-35s, and eight foreign nations are cost-sharing partners in the program.

The Administration's proposed FY2017 defense budget requested about \$7.3 billion in procurement funding for the F-35. This would fund the procurement of 43 F-35As for the Air Force, 16 F-35Bs for the Marine Corps, 4 F-35Cs for the Navy, and continuing development. The proposed budget also requested about \$1.8 billion for F-35 research and development.

Background

The F-35 in Brief

In General

The Joint Strike Fighter was conceived as a relatively affordable fifth-generation aircraft³ that could be procured in highly common versions for the Air Force and the Navy. Initially, the Marine Corps was developing its own aircraft to replace the AV-8B Harrier, but in 1994, Congress mandated that the Marine effort be merged with the Air Force/Navy program in order to avoid the higher costs of developing, procuring, and operating and supporting three separate tactical aircraft designs to meet the services' similar but not identical operational needs.^{4 5}

All three versions of the F-35 will be single-seat aircraft with the ability to go supersonic for short periods and advanced stealth characteristics. The three versions will vary in their combat ranges

¹ Thirteen of the aircraft will be acquired for flight testing through research and development funding.

² Office of the Secretary of Defense, *Selected Acquisition Report (SAR): F-35 Joint Strike Fighter Aircraft (F-35)*, December, 2015.

³ "Fifth-generation" aircraft incorporate the most modern technology, and are considered to be generally more capable than earlier-generation aircraft. Fifth-generation fighters combine new developments such as thrust vectoring, composite materials, stealth technology, advanced radar and sensors, and integrated avionics to greatly improve pilot situational awareness.

Among fighters currently in service or in regular production, only the Air Force F-22 air superiority fighter and the F-35 are considered fifth-generation aircraft. Russia and China have flown prototype fifth-generation fighters

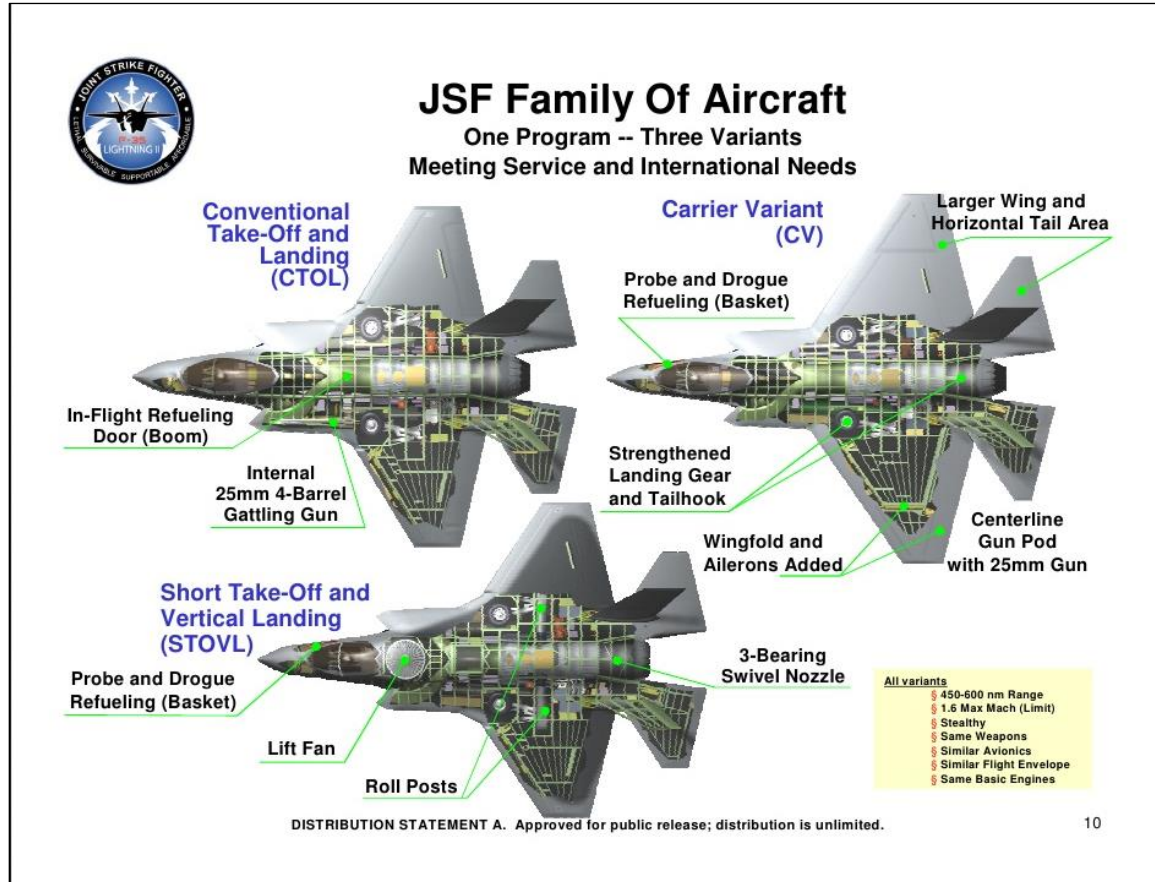
Strike fighters are dual-role tactical aircraft that are capable of both air-to-ground (strike) and air-to-air (fighter) combat operations.

⁴ The program's operational requirements call for 70% to 90% commonality among all three versions. Many of the three versions' high-cost components—including their engines, avionics, and major airframe structural components—are common. Overall, however, commonality has fallen well short of that goal; see "Joint Program Office," below.

⁵ More details on the merger of the programs can be found in "JSF Program Origin and History" below.

and payloads (see **Appendix**). All three are to carry their primary weapons internally to maintain a stealthy radar signature. Additional weapons can be carried externally on missions requiring less stealth.

Figure I. F-35 Variants



Source: F-35 Joint Program Office briefing.

Three Service Versions

From a common airframe and powerplant core, the F-35 is being procured in three distinct versions tailored to the varied needs of the military services. Differences among the aircraft include the manner of takeoff and landing, fuel capacity, and carrier suitability, among others.

Air Force CTOL Version (F-35A)

The Air Force is procuring the F-35A, a conventional takeoff and landing (CTOL) version of the aircraft. F-35As are to replace Air Force F-16 fighters and A-10 attack aircraft, and possibly F-15 fighters.⁶ The F-35A is intended to be a more affordable complement to the Air Force's F-22 Raptor air superiority fighter.⁷ The F-35A is not as stealthy⁸ nor as capable in air-to-air combat as

⁶ Stephen Trimble, "Lockheed says F-35s will replace USAF F-15s," *Flight International*, February 4, 2010.

⁷ For more on the F-22 program, see CRS Report RL31673, *Air Force F-22 Fighter Program*.

⁸ A November 13, 2009, press article states that "The F-22 had a -40dBsm all-aspect reduction requirement [i.e., a (continued...)]

the F-22, but it is designed to be more capable in air-to-ground combat than the F-22, and stealthier than the F-16.

What Is Stealth?

“Stealthy” or “low-observable” aircraft are those designed to be difficult for an enemy to detect. This characteristic most often takes the form of reducing an aircraft’s radar signature through careful shaping of the airframe, special coatings, gap sealing, and other measures. Stealth also includes reducing the aircraft’s signature in other ways, as adversaries could try to detect engine heat, electromagnetic emissions from the aircraft’s radars or communications gear, and other signatures.

Minimizing these signatures is not without penalty. Shaping an aircraft for stealth leads in a different direction from shaping for speed. Shrouding engines and/or using smaller powerplants reduces performance; reducing electromagnetic signatures may introduce compromises in design and tactics. Stealthy coatings, access port designs, and seals may require higher maintenance time and cost than more conventional aircraft.

If the F-15/F-16 combination represented the Air Force’s earlier-generation “high-low” mix of air superiority fighters and more-affordable dual-role aircraft, the F-22/F-35A combination might be viewed as the Air Force’s intended future high-low mix.⁹ The Air Force states that “The F-22A and F-35 each possess unique, complementary, and essential capabilities that together provide the synergistic effects required to maintain that margin of superiority across the spectrum of conflict.... Legacy 4th generation aircraft simply cannot survive to operate and achieve the effects necessary to win in an integrated, anti-access environment.”¹⁰

Marine Corps STOVL Version (F-35B)

The Marine Corps is procuring the F-35B, a short takeoff and vertical landing (STOVL) version of the aircraft.¹¹ F-35Bs are to replace Marine Corps AV-8B Harrier vertical/short takeoff and landing attack aircraft and Marine Corps F/A-18A/B/C/D strike fighters, which are CTOL aircraft. The Marine Corps decided to not procure the newer F/A-18E/F strike fighter¹² and instead wait for the F-35B in part because the F/A-18E/F is a CTOL aircraft, and the Marine Corps prefers aircraft capable of vertical operations. The Department of the Navy states that “The Marine Corps intends to leverage the F-35B’s sophisticated sensor suite and very low observable, fifth generation strike fighter capabilities, particularly in the area of data collection, to support the

(...continued)

requirement to reduce the radar reflectivity of the F-22 when viewed from all angles by 40 decibels per square meter], while the F-35 came in at -30dBsm with some gaps in coverage.” (David A. Fulghum and Bradley Perrett, “Experts Doubt Chinese Stealth Fighter Timeline,” *Aerospace Daily & Defense Report*, November 13, 2009, pp. 1-2.)

⁹ 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. Procuring a high-low mix is a strategy for attempting to balance 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.

¹⁰ Department of the Air Force Presentation to the House Armed Services Committee Subcommittee on Air and Land Forces, United States House of Representatives, Subject: Air Force Programs, Combined Statement of: Lieutenant General Daniel J. Darnell, Air Force Deputy Chief Of Staff For Air, Space and Information Operations, Plans And Requirements (AF/A3/5) [and] Lieutenant General Mark D. Shackelford, Military Deputy, Office of the Assistant Secretary of the Air Force for Acquisition (SAF/AQ) Lieutenant General Raymond E. Johns, Jr., Air Force Deputy Chief of Staff for Strategic Plans And Programs (AF/A8) May 20, 2009, pp. 7-8, 10.

¹¹ 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.

¹² For more on the F/A-18E/F program, see CRS Report RL30624, *Navy F/A-18E/F and EA-18G Aircraft Program*.

Marine Air Ground Task Force well beyond the abilities of today's strike and EW [electronic warfare] assets.”¹³

Navy Carrier-Suitable Version (F-35C)

The Navy is procuring the F-35C, a carrier-suitable CTOL version of the aircraft.¹⁴ The F-35C is also known as the “CV” version of the F-35, as CV is the naval designation for aircraft carrier. The Navy plans in the future to operate carrier air wings featuring a combination of F/A-18E/Fs (which the Navy has been procuring since FY1997) and F-35Cs. The F/A-18E/F is generally considered a fourth-generation strike fighter.¹⁵ The F-35C is to be the Navy's first aircraft designed for stealth, a contrast with the Air Force, which has operated stealthy bombers and fighters for decades. The F/A-18E/F, which is less expensive to procure than the F-35C, incorporates a few stealth features, but the F-35C is stealthier. The Department of the Navy states that “the commonality designed into the joint F-35 program will minimize acquisition and operating costs of Navy and Marine Corps tactical aircraft, and allow enhanced interoperability with our sister Service, the United States Air Force, and the eight partner nations participating in the development of this aircraft.”¹⁶

Engine

The F-35 is powered by the Pratt & Whitney F135 engine, which was derived from the F-22's F119 engine. The F135 is produced in Pratt & Whitney's facilities in East Hartford and Middletown, CT.¹⁷ Rolls-Royce builds the vertical lift system for the F-35B as a subcontractor to Pratt & Whitney.

Consistent with congressional direction for the FY1996 defense budget, DOD established a program to develop an alternate engine for the F-35. The alternate engine, the F136, was developed by a team consisting of GE Transportation—Aircraft Engines of Cincinnati, OH, and Rolls-Royce PLC of Bristol, England, and Indianapolis, IN. The F136 is a derivative of the F120 engine originally developed to compete with the F119 engine for the F-22 program.

DOD included the F-35 alternate engine program in its proposed budgets through FY2006, although Congress in certain years increased funding for the program above the requested amount and/or included bill and report language supporting the program.

¹³ Statement of Vice Admiral David Architzel, USN, Principal Military Deputy, Research, Development and Acquisition, LTGEN George J. Trautman III, USMC, Deputy Commandant for Aviation, [and] RADM Allen G. Myers, USN, Director of Warfare Integration, Before the Seapower and Expeditionary Warfare [sic: Forces] Subcommittee of the House Armed Services Committee [hearing] on [the] Department of the Navy's Aviation Procurement Program, May 19, 2009, pp. 1-2.

¹⁴ Features for carrier suitability include, among other things, strengthened landing gear, a strengthened airframe, and an arresting hook so as to permit catapult launches and arrested landings, as well as folding wing tips for more compact storage aboard ship.

¹⁵ Some F/A-18E/F supporters argue that it is a “fourth-plus” or “4.5” generation strike fighter because it incorporates some fifth-generation technology, particularly in its sensors.

¹⁶ Statement of Vice Admiral David Architzel, USN, Principal Military Deputy, Research, Development and Acquisition, LTGEN George J. Trautman III, USMC, Deputy Commandant for Aviation, [and] RADM Allen G. Myers, USN, Director of Warfare Integration, before the Seapower and Expeditionary Warfare [sic: Forces] Subcommittee of the House Armed Services Committee [hearing] on [the] Department of the Navy's Aviation Procurement Program, May 19, 2009, p. 1.

¹⁷ Pratt and Whitney's parent firm is United Technologies.

The George W. Bush Administration proposed terminating the alternate engine program in FY2007, FY2008, and FY2009. The Obama Administration did likewise in FY2010. Congress rejected these proposals and provided funding, bill language, and report language to continue the program.

The General Electric/Rolls Royce Fighter Engine Team ended their effort to provide an alternate engine on December 2, 2011.

Fuller details of the alternate engine program and issues for Congress arising from it are detailed in CRS Report R41131, *F-35 Alternate Engine Program: Background and Issues for Congress*.

Current Program Status

The F-35 is currently in low-rate initial production, with 154 aircraft delivered as of the end of 2015, including 10 international deliveries.¹⁸ Four to five aircraft are currently delivered each month, with the production rate scheduled to increase to 120 per year by 2019.¹⁹ In keeping with the acquisition plan that overlapped development and production (known as “concurrency”), the F-35 is also in system development and demonstration (SDD), with testing and software development ongoing; the SDD phase is approximately 80% complete and due to end in the fall of 2017.²⁰

Recent Developments

Significant developments since the previous edition of this report (April 29, 2014) include the following.

Reduction of Previously Projected Quantities

The Administration’s proposed FY2017 defense budget would fund the procurement of 43 F-35As for the Air Force, 16 F-35Bs for the Marine Corps, and 4 F-35Cs for the Navy. This is five fewer As, two more Bs, and the same number of Cs compared with FY2017 projections in the FY2016 budget.

The Air Force budget director stated that the F-35As cut from the FY2017 budget were deferred due to overall budget issues, not program performance. “Unfortunately, in this budget, we had to sacrifice modernization for current readiness, and, as a result, were forced to delay five F-35s.”²¹ The commander of the Navy’s air forces said that budget pressures might cause the Navy to reduce its planned 20 per year acquisition to as few as 12 per year.²²

¹⁸ U.S. Government Accountability Office, *F-35 JOINT STRIKE FIGHTER: Continued Oversight Needed as Program Plans to Begin Development of New Capabilities*, 16-390, April 2016, p. 13, <http://www.gao.gov/assets/680/676584.pdf>.

¹⁹ Pat Host, “F-35 Program Tripling Production, Fielding Rate By 2019,” *Defense Daily*, September 10, 2015.

²⁰ Prepared statement of the Honorable Sean J. Stackley, Assistant Secretary Of The Navy (Research, Development and Acquisition) and Lt General Christopher C. Bogdan, Program Executive Officer, F-35 before the U.S. Congress, House Committee on Armed Services, Subcommittee on Tactical Air and Land Forces, F-35 Program review, 114th Cong., 2nd sess., March 23, 2016.

²¹ Secretary of the Air Force Public Affairs, “AF presents fiscal year 2017 budget,” press release, February 9, 2016, <http://www.af.mil/News/ArticleDisplay/tabid/223/Article/652961/af-presents-fiscal-year-2017-budget.aspx>.

²² VADM Mike Shoemaker, cited in Valerie Insinna, “Budget Constraints Could Drive Slower F-35C Procurement,” *Defense Daily*, August 13, 2015.

Changes in International Orders

As noted, the F-35 is an international program, with commitments from program partners and other countries to share in the development costs and acquire aircraft. The other nations' plans have varied over time. Most recently:

- **Australia** took delivery of two F-35As in 2014 and 2015, and has announced a new order for 58 follow-on aircraft.^{23 24} However, Australia decided not to acquire F-35Bs.²⁵
- Following the election of a new government, **Canada** has deferred its decision on whether to acquire 65 F-35s. Although Canada is still a formal partner in the program, the Trudeau government has not made clear whether the F-35 will be included as a candidate for its fighter requirement. "Trudeau avoided saying whether the government would hold the promised open competition."²⁶ According to the F-35 program manager, a Canadian exit could increase the price of an F-35A to the U.S. by "about .7 to 1 percent," or about \$1 million.²⁷
- **Denmark** has confirmed an order for 27 F-35As, possibly going to 30; it had initially been expected to order 48, although the government also reportedly considered withdrawing from the program altogether.²⁸
- **Japan's** buy, initially reported as 42, will be 38 F-35s.^{29 30}
- **Norway** has taken delivery of the first two of the 52 jets it plans to buy.³¹
- **The Netherlands** received two of its planned 37 aircraft.³²
- **Singapore** "is still to confirm an order, or even to announce its preferred F-35 variant."³³
- **South Korea** "agreed to purchase 40 F-35s in September 2014 for around USD7 billion."³⁴

²³ Matt Siegel and Andrea Shalal, "Australia orders 58 F-35 Lockheed Martin stealth fighters," *Reuters.com*, April 22, 2014.

²⁴ "An update on Australian F-35s," *Australian Defence*, February 12, 2016, <http://www.australiandefence.com.au/news/an-update-on-australian-f-35s>.

²⁵ Bradley Perrett, "Australia Abandons Proposal To Order F-35B," *Aerospace Daily and Defense Report*, July 10, 2015.

²⁶ See, inter alia, Laura Payton, "Justin Trudeau refuses to renew pledge for fighter jet competition," *CTV News*, June 22, 2016, <http://www.ctvnews.ca/politics/justin-trudeau-refuses-to-renew-pledge-for-fighter-jet-competition-1.2957184>.

²⁷ Valerie Insinna, "Canada Leaving F-35 Program Would Drive Costs Up \$1 Million Per Plane," *Defense Daily*, October 22, 2015.

²⁸ Aaron Mehta, "Denmark F-35 Buy Goes Official," *Defense News*, June 9, 2016.

²⁹ Craig Hoyle, "New contract powers Japan towards F-35 assembly," *Flight International*, October 21, 2013.

³⁰ Seth Robson, "First of Japan's F-35s will be airborne by year's end," *Stars and Stripes*, May 11, 2016.

³¹ "Norway gets its first F-35 stealth fighter jets," *The Local (Norway)*, September 22, 2015.

³² Lara Seligman, "Dutch F-35s Land in the Netherlands," *Defense News*, May 26, 2016.

³³ Angus Batey, "F-35s for Singapore? Don't Hold Your Breath," *Aviation Week Show News*, February 16, 2016.

³⁴ Jon Grevatt, "US approves F-35 offset technology transfer to South Korea," *IHS Jane's Defence Industry*, December 21, 2016.

F-35 Basing Candidates Announced

On April 12, 2016, the Air Force announced that Davis-Monthan Air Force Base (AFB), AZ; Homestead Air Reserve Base, FL; Naval Air Station Joint Reserve Base Fort Worth, TX; and Whiteman AFB, MO, are candidate bases for the first Reserve-led F-35A Lightning II location.³⁵ Eielson AFB, AK, had earlier been announced as the preferred base for the first overseas F-35 squadron.³⁶

Cost Reduction

Contracted unit prices for F-35s have continued to decline with each production lot. “For example, the price (including airframe, engine and profit) of an LRIP Lot 8 aircraft was approximately 3.6 percent less than an LRIP Lot 7 aircraft, and an LRIP Lot 7 aircraft, was 4.2 percent lower than an LRIP Lot 6 aircraft.”³⁷ This is examined in more detail in “Low-Rate Initial Production,” below.

Testing Progress

DOD’s annual testing report stated, “Almost all measures of performance have improved over the past year, but most continue to be below their interim goals to achieve acceptable suitability.” From the program inception to November, 2015, 43,528 of 43,611 planned test points had been achieved.³⁸

However, “The operational suitability of all variants continues to be less than desired by the Services and relies heavily on contractor support and workarounds that would be difficult to employ in a combat environment... Aircraft fleet-wide availability continued to be low, averaging 51 percent over 12 months ending in October 2015, compared to a goal of 60 percent.” Testers found numerous other deficiencies, warning that “the current schedule to complete System Development and Demonstration (SDD) and enter IOT&E by August 2017 is unrealistic.”³⁹

Software Delays

Development of the F-35’s integrated software development continues to be a significant issue in the program. The latest information can be found in a new section on software added to this report under “Software Development.”

JSF Program Origin and History

The JSF program began in the early- to mid-1990s.⁴⁰ Three different airframe designs were proposed by Boeing, Lockheed, and McDonnell Douglas (teamed with Northrop Grumman and

³⁵ Secretary of the Air Force Public Affairs, “AF names candidate bases, criteria for choosing next F-35A sites,” press release, April 12, 2016, <http://go.usa.gov/xxhNe>.

³⁶ Secretary of the Air Force Public Affairs, “Eielson AFB selected as preferred alternative for first overseas-based F-35As,” press release, August 4, 2014, <http://go.usa.gov/xxhNw>.

³⁷ Office of the Secretary of Defense, *Selected Acquisition Report (SAR): F-35 Joint Strike Fighter Aircraft (F-35)*, March 21, 2016, p. 9.

³⁸ Director, Operational Test & Evaluation, *FY 2015 Annual Report*, January 2016, pp. 38, 43.

³⁹ Ibid, p. 35.

⁴⁰ The JSF program emerged in late 1995 from the Joint Advanced Strike Technology (JAST) program, which began in late 1993 as a result of the Clinton Administration’s Bottom-Up Review (BUR) of U.S. defense policy and programs. (continued...)

British Aerospace.) On November 16, 1996, the Defense Department announced that Boeing and Lockheed Martin had been chosen to compete in the Concept Demonstration phase of the program, with Pratt and Whitney providing propulsion hardware and engineering support. Boeing and Lockheed were each awarded contracts to build and test-fly two aircraft to demonstrate their competing concepts for all three planned JSF variants.⁴¹

The competition between Boeing and Lockheed Martin was closely watched. Given the size of the JSF program and the expectation that the JSF might be the last fighter aircraft program that DOD would initiate for many years, DOD's decision on the JSF program was expected to shape the future of both U.S. tactical aviation and the U.S. tactical aircraft industrial base.

In October 2001, DOD selected the Lockheed design as the winner of the competition, and the JSF program entered the System Development and Demonstration (SDD) phase, with SDD contracts awarded to Lockheed Martin for the aircraft and Pratt and Whitney for the aircraft's engine. General Electric continued technical efforts related to the development of an alternate engine for competition in the program's production phase.

Table 1. F-35 Variant Milestones

	First flown	Original IOC goal	Current IOC estimate
F-35A	December 15, 2006	March 2013	2016
F-35B	June 11, 2008 First hover: March 17, 2010	March 2012	Declared July 31, 2015
F-35C	June 6, 2010	March 2015	2018

Source: Prepared by CRS based on press reports and DOD testimony.

Note: IOC is Initial Operational Capability (discussed below).

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The BUR envisaged the JAST program as a replacement for two other tactical aircraft programs that were being terminated (the A-12 program, which was intended to provide a stealthy new carrier-based attack plane to replace the Navy's aging A-6 carrier-based attack planes, and the Multi-Role Fighter, which the Air Force had considered as a replacement for its F-16 fighters).

In 1995, in response to congressional direction, a program led by the Defense Advanced Research Projects Agency (DARPA) to develop an advanced short takeoff and vertical landing (ASTOVL) aircraft was incorporated into the JAST program. This opened the way for Marine Corps and UK participation in the JAST program, since the Marine Corps and the UK were interested procuring a new STOVL aircraft to replace their aging Harrier STOVL attack aircraft. The name of the program was then changed to Joint Strike Fighter (JSF) to focus on joint development and production of a next-generation fighter/attack plane.

A Joint Operational Requirements Document for the F-35 program was issued in March 2000 and revalidated by DOD's Joint Requirements Oversight Council (JROC) in October 2001. On October 24, 2001, the Defense Acquisition Board (DAB) held a Milestone B review for the program. (Milestone B approval would permit the program to enter the SDD phase.) On October 25, 2001, the Secretary of Defense certified to Congress (in accordance with Section 212 of the FY2001 defense authorization act [H.R. 4205/P.L. 106-398 of October 30, 2000]) that the program had successfully completed the CDP exit criteria and demonstrated sufficient technical maturity to enter SDD. On October 26, 2001, the SDD contracts were awarded to Lockheed and Pratt and Whitney. A Preliminary Design Review (PDR) for the F-35 program was conducted in April 2003, and Critical Design Reviews (CDRs) were held for the F-35A, F-35B, and F-35C in February 2006 (F-35A and F-35B) and June 2007 (F-35C).

⁴¹ Subsequent to the selection of the Boeing and Lockheed Martin designs, Boeing acquired McDonnell Douglas and merged the two firms' JSF teams.

As shown in **Table 1**, the first flights of an initial version of the F-35A and the F-35B occurred in the first quarter of FY2007 and the third quarter of FY2008, respectively. The first flight of a slightly improved version of the F-35A occurred on November 14, 2009.⁴² The F-35C first flew on June 6, 2010.⁴³

The F-35B's ability to hover, scheduled for demonstration in November, 2009, was shown for the first time on March 17, 2010.⁴⁴ The first vertical landing took place the next day.⁴⁵

February 2010 Program Restructuring

In November 2009, DOD's Joint Estimating Team issued a report (JET II) stating that the F-35 program would need an extra 30 months to complete the SDD phase. In response to JET II, the then-impending Nunn-McCurdy breach and other developments, on February 24, 2010, Pentagon acquisition chief Ashton Carter issued an Acquisition Decision Memorandum (ADM) restructuring the F-35 program. Key elements of the restructuring included the following:

- Extending the SDD phase by 13 months, thus delaying Milestone C (full-rate production) to November 2015 and adding an extra low-rate initial production (LRIP) lot of aircraft to be purchased during the delay. Carter proposed to make up the difference between JET II's projected 30-month delay and his 13-month schedule by adding three extra early-production aircraft to the test program. It is not clear how extra aircraft could be added promptly if production is already behind schedule.
- Funding the program to the "Revised JET II" (13-month delay) level, implicitly accepting the JET II findings as valid.
- Withholding \$614 million in award fees from the contractor for poor performance, while adding incentives to produce more aircraft than planned within the new budget.
- Moving procurement funds to R&D. "More than \$2.8 billion that was budgeted earlier to buy the military's next-generation fighter would instead be used to continue its development."⁴⁶

"Taken together, these forecasts result in the delivery of 122 fewer aircraft over the Future Years Defense Program (FYDP), relative to the President's FY 2010 budget baseline," Carter said.⁴⁷ This reduction led the Navy and Air Force to revise their dates for IOC as noted above.

March, 2010 Nunn-McCurdy Breach

On March 20, 2010, DOD formally announced that the JSF program had exceeded the cost increase limits specified in the Nunn-McCurdy cost containment law, as average procurement unit cost, in FY2002 dollars, had grown 57% to 89% over the original program baseline. Simply

⁴² "First Flight," *Defense Daily*, November 23, 2009, p. 3.

⁴³ Graham Warwick, "JSF Carrier Variant Meets Handling Goals On First Flight," *Aerospace Daily*, June 7, 2010.

⁴⁴ Graham Warwick, "F-35B Hovers for First Time," *Aviation Week/Ares* blog, March 17, 2010.

⁴⁵ Graham Warwick, "STOVL F-35B Makes First Vertical Landing," *Aviation Week/Ares* blog, March 18, 2010.

⁴⁶ Tony Capaccio, "Lockheed F-35 Purchases Delayed in Pentagon's Fiscal 2011 Plan," *Bloomberg News*, January 6, 2010.

⁴⁷ *F-35 Lightning II Joint Strike Fighter (JSF) Program Restructure Acquisition Decision Memorandum (ADM)*, Under Secretary of Defense (Acquisition, Technology & Logistics), February 24, 2010.

put, this requires the Secretary of Defense to notify Congress of the breach, present a plan to correct the program, and to certify that the program is essential to national security before it can continue.⁴⁸

On June 2, 2010, the Under Secretary of Defense for Acquisition, Technology and Logistics issued an Acquisition Decision Memorandum (ADM) certifying the F-35 Program in accordance with section 2433a of title 10, United States Code. As required by section 2433a, of title 10, Milestone B was rescinded. A Defense Acquisition Board (DAB) was held in November 2010... No decision was rendered at the November 2010 DAB... Currently, cumulative cost and schedule pressures result in a critical Nunn-McCurdy breach to both the original (2001) and current (2007) baseline for both the Program Acquisition Unit Cost (PAUC) and Average Procurement Unit Cost (APUC). The breach is currently reported at 78.23% for the PAUC and 80.66% for the APUC against the original baseline and 27.34% for the PAUC and 31.23% for the APUC against the current baseline.⁴⁹

February 2012 Procurement Stretch

With the FY2013 budget, F-35 acquisition was slowed, with the acquisition of 179 previously planned aircraft being moved to years beyond the FY2013-2017 FYDP “for a total of \$15.1 billion in savings.”⁵⁰

Initial Operational Capability

The Marine Corps declared F-35B Initial Operational Capability (IOC) on July 31, 2015. The Air Force expects to declare F-35A IOC by the end of calendar 2016; recent reports indicate it may be as early as August.⁵¹

The F-35A, F-35B, and F-35C were originally scheduled to achieve IOC in March 2013, March 2012, and March 2015, respectively.⁵² In March, 2010, then-Pentagon acquisition chief Ashton Carter announced that the Air Force and Navy had reset their projected IOCs to 2016, while Marine projected IOC remained 2012.⁵³ Subsequently, the Marine IOC was delayed.⁵⁴

⁴⁸ For a history of the Nunn-McCurdy law and options for its future, see CRS Report R41293, *The Nunn-McCurdy Act: Background, Analysis, and Issues for Congress*, by (name redacted) and (name redacted).

⁴⁹ Office of the Secretary of Defense, *Selected Acquisition Report (SAR): F-35*, December 31, 2010, p. 4.

⁵⁰ Tony Capaccio, “Pentagon Takes \$1.6 Billion From Lockheed F-35 in Biggest Cut,” *Bloomberg News*, February 13, 2012.

⁵¹ Lara Seligman, “USAF Sees No Major Hurdles To F-35 IOC,” *Aerospace Daily and Defense Report*, July 7, 2016.

⁵² The Navy had initially accelerated its estimated IOC for the F-35C to September 2014. Andrew Tilghman, “Joint Strike Fighter Timeline Moved Up,” *NavyTimes.com*, September 18, 2009. In November 2009, Lockheed announced that the first flight of an F-35C test aircraft would be delayed from the final quarter of 2009 to the first quarter of 2010. (Dan Taylor, “Navy Joint Strike Fighter Carrier Variant Test Aircraft Will Not Fly Until 2010,” *Inside the Navy*, November 9, 2009.)

⁵³ Testimony before the Senate Armed Services Committee, March 11, 2010. “Marine Corps IOC will include 15 aircraft for training at Eglin AFB, Fla., four in an operational test and evaluation detachment and the first operational squadron of 10 in Yuma, Ariz.” Amy Butler, Robert Wall, Graham Warwick and Alon Ben-David, “F-35B Achieves Vertical Landing Milestone,” *AviationWeek.com*, March 23, 2010.

⁵⁴ “The U.S. Marine Corps will scrap a December 2012 target to have its version of the Lockheed Martin Corp. F-35 Joint Strike Fighter ready for combat and isn’t setting a new date, the service’s commandant said. ‘I’m really not wringing my hands over that,’ General James Amos told reporters today at the Pentagon. ‘It will be when it will be.’”—Tony Capaccio, “Marines to Delay Combat-Readiness Target for F-35 Jet,” *Bloomberg.com*, December 14, 2010.

Congress required a formal declaration of IOCs in Section 155 of the National Defense Authorization Act for Fiscal Year 2013 (P.L. 112-239.) The current dates (by fiscal year) are shown in **Table 1**.

It should be noted that IOC means different things to different services:

F-35A initial operational capability (IOC) shall be declared when the first operational squadron is equipped with 12-24 aircraft, and Airmen are trained, manned, and equipped to conduct basic Close Air Support (CAS), Interdiction, and limited Suppression and Destruction of Enemy Air Defense (SEAD/DEAD) operations in a contested environment. Based on the current F-35 Joint Program Office (JPO) schedule, the F-35A will reach the IOC milestone between August 2016 (Objective) and December 2016 (Threshold)...

F-35B IOC shall be declared when the first operational squadron is equipped with 10-16 aircraft, and US Marines are trained, manned, and equipped to conduct CAS, Offensive and Defensive Counter Air, Air Interdiction, Assault Support Escort, and Armed Reconnaissance in concert with Marine Air Ground Task Force resources and capabilities. Based on the current F-35 JPO schedule, the F-35B will reach the IOC milestone between July 2015 (Objective) and December 2015 (Threshold)...

Navy F-35C IOC shall be declared when the first operational squadron is equipped with 10 aircraft, and Navy personnel are trained, manned and equipped to conduct assigned missions. Based on the current F-35 JPO schedule, the F-35C will reach the IOC milestone between August 2018 (Objective) and February 2019 (Threshold).⁵⁵

Additionally,

Each of the three US services will reach initial operating capability (IOC) with different software packages.

The F-35B will go operational for the US Marines in December 2015 with the Block 2B software, while the Air Force plans on achieving IOC on the F-35A in December 2016 with Block 3I, which is essentially the same software on more powerful hardware. The Navy intends to go operational with the F-35C in February 2019, on the Block 3F software.⁵⁶

Procurement Quantities

Planned Total Quantities

The F-35 program includes a planned total of 2,457 aircraft for the Air Force, Marine Corps, and Navy. This included 14 research and development aircraft and 2,443 production aircraft: 1,763 F-35As for the Air Force, 260 F-35Cs for the Navy, and 80 F-35Cs and 340 F-35Bs for the Marine Corps.⁵⁷

⁵⁵ United States Navy, United States Marine Corps, United States Air Force, *F-35 Initial Operational Capability*, June 2013.

⁵⁶ Aaron Mehta, "After 'Transformative' Year, F-35 Program Focuses on Software, Quantity," *Defense News*, January 14, 2014.

⁵⁷ "IHS Jane's Defence Insight Report: Air Platforms," June 2013. In 1996, preliminary planning estimated over 3,000 F-35s for DOD and the UK: 2,036 for the Air Force, 642 for the Marines, 300 for the U.S. Navy, and 60 for the Royal Navy. In May 1997, the QDR recommended reducing projected DOD procurement from 2,978 to 2,852: 1,763 for the Air Force, 609 for the Marines, and 480 for the Navy. (Quadrennial Defense Review Cuts Procurement in FY1999, 2000, *Aerospace Daily*, May 20, 1997, p. 280.) In 2003, the Navy reduced its planned procurement of 1,089 F-35s to (continued...)

Annual Quantities

DOD began procuring F-35s in FY2007. **Table 2** shows F-35 procurement quantities authorized through FY2014 and requested procurement quantities for FY2015. The figures in the table do not include 13 research and development aircraft procured with research and development funding. (Quantities for foreign buyers are discussed in the next section.)

Table 2. Annual F-35 Procurement Quantities

(Figures shown are for production aircraft; table excludes 13 research and development aircraft)

FY	F-35A (USAF)	F-35B (USMC)	F-35C (Navy)	Total
2007	2	0	0	2
2008	6	6	0	12
2009	7	7	0	14
2010	10	16	4	30
2011	22	13	7	42
2012	18	6	7	31
2013	19	6	4	29
2014	19	6	4	29
2015	28	6	4	38
2016	44	9	4	57
2017	43	16	4	63

Source: Prepared by CRS based on DOD data.

Previous DOD plans contemplated increasing the procurement rate of F-35As for the Air Force to a sustained rate of 80 aircraft per year by FY2015, and completing the planned procurement of 1,763 F-35As by about FY2034. The current Air Force plan increases the rate to 60 per year in 2019 and 2020; the 1,763 fleet size has not changed.

Past DOD plans also contemplated increasing the procurement rate of F-35Bs and Cs for the Marine Corps and Navy to a combined sustained rate of 50 aircraft per year by about FY2014, and completing the planned procurement of 680 F-35Bs and Cs by about FY2025. The FY2017 budget submission shows a combined F-35B and -C production rate of 32 per year in 2020.

Congress has also acted to reduce the rate of F-35 procurement. Division C of the Consolidated Appropriations Act, 2014 (P.L. 113-76), reduced the Administration's request for F-35 advance procurement in FY2015 by two F-35As and one F-35C. Those reductions were reflected in the Administration's FY2015 budget request.

Limits on DOD spending included in the 2011 Budget Control Act (BCA) may also affect F-35 acquisition rates.⁵⁸ The Air Force has already adjusted its annual acquisition rates to reflect its budgetary situation.⁵⁹

(...continued)

680 aircraft as part of the Navy/Marine Corps Tactical Aviation Integration Plan. (See CRS Report RS21488, *Navy-Marine Corps Tactical Air Integration Plan: Background and Issues for Congress*, by (name redacted) and (name redacted) .)

⁵⁸ Department of Defense, *Estimated Impacts of Sequestration-Level Funding*, April 2014, pp. 4-13-4-14, (continued...)

Low-Rate Initial Production

F-35s are currently produced under Low Rate Initial Production (LRIP), with agreements reached for the first eight lots of aircraft. Each LRIP lot includes both U.S. and international partner aircraft.

In LRIPs 5, 6, and 7, any cost overruns associated with concurrent development and production would be split equally between the contractor and the government. Prior to LRIP 4, the government bore those costs alone. In LRIP 8, the contractor is liable for 100% of any cost overrun; if actual cost is lower than the contracted cost, the contractor will receive 80% of the savings, the government 20%.⁶⁰

[Program Manager Lt. Gen. Christopher] Bogdan also is planning to negotiate the next lots of airframe purchases—LRIPs 9-10—together, signaling to the supply base that orders will continue to come and they can purchase items in bulk. LRIP 9 is slated to include 57 jets, 43 of which are for the U.S. LRIP 10 is projected to include 96 aircraft, 55 of which are U.S. orders.⁶¹

Table 3. F-35 LRIPs 5, 6, 7, and 8
(Costs in millions of dollars, per aircraft)

LRIP Lot	5 ^a	6 ^b	7 ^{c, d}	8 ^e
F-35A quantity/cost	22/105	23/103	19/98	19/95
F-35B quantity/cost	3/113	7/109	6/104	6/102
F-35C quantity/cost	7/125	6/120	4/116	4/116

Notes: Aircraft costs shown do not include engines. Quantities exclude international orders.

- a. Christopher Drew, "Lockheed Profit on F-35 Jets Will Rise With New Contract," *The New York Times*, December 17, 2012.
- b. Tony Capaccio, "Lockheed Gets Approval Of Next F-35 Production Contract," *Bloomberg News*, July 6, 2012.
- c. Amy Butler, "Latest F-35 Deal Targets Unit Cost Below \$100 Million," *Aviation Week & Space Technology*, July 30, 2013.
- d. Caitlin Lee, "Latest F-35 contracts mark new strategy to reduce costs," *Jane's Defence Weekly*, September 29, 2013.
- e. Colin Clark, "New F-35 Prices: A: \$95M; B: \$102M; C: \$116M," *Breaking Defense*, November 21, 2014.

Potential Block Buy

Block buy contracts commit the government to purchasing certain quantities of aircraft over a number of years, which allows the contractor to acquire parts in greater quantity and plan workforce levels in advance, helping to reduce cost. "By purchasing supplies in economic

(...continued)

http://www.defense.gov/pubs/2014_Estimated_Impacts_of_Sequestration-Level_Funding_April.pdf.

⁵⁹ For more information on the Air Force's plans, see CRS Report R44305, *The Air Force Aviation Investment Challenge*.

⁶⁰ Colin Clark, "New F-35 Prices: A: \$95M; B: \$102M; C: \$116M," *Breaking Defense*, November 21, 2014.

⁶¹ Amy Butler, "F-35 Chief Backs International 'Block Buy'," *Aerospace Daily and Defense Report*, November 3, 2015.

quantities, Lockheed Martin and Pratt & Whitney estimate that 8 percent and 2.3 percent cost savings, respectively, could be achievable.”⁶²

The F-35 program office is reportedly considering a block buy contract for international customers, and possibly for U.S. F-35s in subsequent lots. “Executing the ‘block buy’ would require commitments to procuring as many as 270 U.S. aircraft, as well as commitments by foreign partners to purchasing substantial numbers of aircraft.”⁶³

The buy would begin in low-rate, initial production (LRIP) lot 11, which includes deliveries in 2019. The program office’s official request for information on the block buy is expected to be included in a request for proposals (RFP) next summer, Bogdan told reporters during an Oct. 30 roundtable... The international block buy is one of multiple steps toward reducing the per-unit price of the F-35A to \$80-85 million in 2019, Bogdan says.⁶⁴

What Is Block Buy?⁶⁵

Block buy contracting (BBC) permits DOD to use a single contract for more than one year’s worth of procurement of a given kind of item without having to exercise a contract option for each year after the first year. It is similar to multi-year procurement in that DOD needs congressional approval for each use of BBC.

BBC differs from MYP in the following ways:

- There is no permanent statute governing the use of BBC.
- There is no requirement that BBC be approved in both a DOD appropriations act and an act other than a DOD appropriations act.
- Programs being considered for BBC do not need to meet any legal criteria to qualify for BBC because there is no permanent statute governing the use of BBC that establishes such criteria.
- A BBC contract can cover more than five years of planned procurements. The BBC contracts currently being used by the Navy for procuring Littoral Combat Ships, for example, cover a period of seven years (FY2010-FY2016).
- Economic order quantity (EOQ) authority does not come automatically as part of BBC authority because there is no permanent statute governing the use of BBC that includes EOQ authority as an automatic feature. To provide EOQ authority as part of a BBC contract, the provision granting authority for using BBC in a program may need to state explicitly that the authority to use BBC includes the authority to use EOQ.
- BBC contracts are less likely to include cancellation penalties.

“A full block buy, including US jets, could save anywhere from \$2 billion to \$2.8 billion, according to industry estimates.”⁶⁶ Congressional approval would be required for a U.S. block buy.⁶⁷

⁶² U.S. Government Accountability Office, *F-35 JOINT STRIKE FIGHTER: Continued Oversight Needed as Program Plans to Begin Development of New Capabilities*, 16-390, April 2016, p. 23, <http://www.gao.gov/assets/680/676584.pdf>.

⁶³ Director, Operational Test & Evaluation, *FY 2015 Annual Report*, January 2016, p. 36.

⁶⁴ Amy Butler, “F-35 Chief Backs International ‘Block Buy’,” *Aerospace Daily and Defense Report*, November 3, 2015.

⁶⁵ Description adapted from CRS Testimony TE10004, *The Status of Coast Guard Cutter Acquisition Programs*, by (name redacted) .

⁶⁶ Valerie Insinna, “Program Head Hints F-35 Contract Could Be Announced at Farnborough,” *Defense News*, July 9, 2016.

⁶⁷ For a more detailed discussion of block buy, see CRS Report R41909, *Multiyear Procurement (MYP) and Block Buy Contracting in Defense Acquisition: Background and Issues for Congress*, by (name redacted) and (name redacted) .

Program Management

The JSF program is jointly managed and staffed by the Department of the Air Force and the Department of the Navy. 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. The Navy resumed SAE authority when Air Force Lt. Gen. Christopher Bogdan was confirmed by the Senate as program manager on September 22, 2012.^{68 69}

Software Development

You can see from its angled lines, the F-35 is a stealth aircraft designed to evade enemy radars. What you can't see is the 24 million lines of software code which turn it into a flying computer. That's what makes this plane such a big deal.⁷⁰

The F-35's integration of sensors and weapons, both internally and with other aircraft, is touted as its most distinctive aspect. As that integration is primarily realized through complex software, it may not be surprising to observe that writing, validating, and debugging that software is among the program's greatest challenges. F-35 operating software is released in blocks, with additional capabilities added from one block to the next.

I'm concerned about the software, the operational software.... And I'm concerned about the ALIS [Autonomic Logistics Information System], that is another software system, basically that will provide the logistics support to the systems. – Frank Kendall, Under Secretary of Defense for Acquisition, Technology & Logistics.⁷¹

⁶⁸ U.S. Congress, Senate, *Presidential Nomination*, 112th Cong., 2nd sess., PN1838-112, at <http://thomas.loc.gov/cgi-bin/ntquery/z?nomis:112PN0183800>.

⁶⁹ In 2004, appropriations conferees followed a House recommendation to direct DOD to review this alternative management arrangement. House appropriators believed that “management of program acquisition should remain with one Service, and that the U.S. Navy, due to its significant investment in two variants of the F-35 should be assigned all acquisition executive oversight responsibilities.” (H.Rept. 108-553 [H.R. 4613], p. 234) Conferees directed that DOD submit a report on the potential efficacy of this change. Prior to the release of the DOD report, former Air Force Chief of Staff General John Jumper was quoted as saying that he also supported putting one service in charge of JSF program acquisition. (Elizabeth Rees, “Jumper Supports Single Service Retaining JSF Acquisition Oversight,” *Inside the Air Force*, August 6, 2004.) However, General Jumper highlighted the significant investment the Air Force was making in the JSF program in response to the congressional language favoring the Navy. In DOD's response to Congress, the report noted the current arrangement ensures one Service does not have a “disproportionate voice” when it comes to program decisions and that the current system is “responsive, efficient, and in the best interests of the success of the JSF program.” (U.S. Department of Defense, *Report to Congress on Joint Strike Fighter Management Oversight* [forwarded by] Michael W. Wynne, Under Secretary of Defense for Acquisition, Technology and Logistics, December 20, 2004.)

⁷⁰ David Martin, “Is the F-35 worth it?,” *60 Minutes*, February 16, 2014.

⁷¹ Aaron Mehta, “After ‘Transformative’ Year, F-35 Program Focuses on Software, Quantity,” *Defense News*, January 14, 2014.

Table 4. F-35 Software Block Schedule

Block	Attributes	Release
2B	Required for Marine IOC	Released
3i (initial)	Required for USAF IOC	Development complete; ^a release expected late 2016
3F (final)	Required for Navy IOC	Expected late fall 2017
4	Adds nuclear weapons capability (among other things)	Development to begin late 2018

Source: Prepared statement of the Honorable Sean J. Stackley, Assistant Secretary Of The Navy (Research, Development and Acquisition) and Lt General Christopher C. Bogdan, Program Executive Officer, F-35 before the U.S. Congress, House Committee on Armed Services, Subcommittee on Tactical Air and Land Forces, *F-35 Program review*, 114th Cong., 2nd sess., March 23, 2016.

- a. F-35 Joint Program Office, “Development of F-35 3i Software For USAF IOC Complete,” press release, May 9, 2016, <https://www.f35.com/news/detail/development-of-f-35-3i-software-for-usaf-ioc-complete>.

Kendall’s concern is echoed by the F-35 program manager, Lt Gen Christopher Bogdan. In testimony to the House Armed Services Subcommittee on Tactical Air and Land Forces, he noted that it is the

“complexity of the software that worries us the most.... Software development is always really, really tricky... We are going to try and do things in the final block of this capability that are really hard to do.” Among them is forming software that can share the same threat picture among multiple ships across the battlefield, allowing for more coordinated attacks.⁷²

Block 4 as a Separate Program

Development of the F-35 follow-on Block 4 software is expected to cost as much as \$8 billion. Some in Congress argue that a program of that size should part with traditional procurement practice for an upgrade and be run as a separate Major Defense Acquisition Program, with its own budget line and the concomitant reporting requirements; language to this effect was included in the Senate’s version of the FY2017 National Defense Authorization Act. This is discussed further in “Issues for Congress,” below.

Autonomic Logistics Information System

The issues cited above focused on software development for the F-35’s onboard mission systems. A supporting system, the Autonomic Logistics Information System (ALIS), also requires extensive software development and testing. “ALIS is at the core of operations, maintenance and supply-chain management for the F-35, providing a constant stream of data from the plane to supporting staff.”⁷³

DOD’s Director of Operational Test & Evaluation stated that during 2015, “(ALIS) Version 2.0.1.1 software was fielded to operational units between May and October 2015. These versions included new functions, improved interfaces, and fixes for some of the deficiencies in the earlier

⁷² Amy Butler, “Bogdan Warns Of Possible Six-Month F-35 Slip After Development Ends,” *AviationWeek.com*, February 26, 2014.

⁷³ Aaron Mehta, “After ‘Transformative’ Year, F-35 Program Focuses on Software, Quantity,” *Defense News*, January 14, 2014.

ALIS versions. However, many critical deficiencies remain which require maintenance personnel to implement workarounds to address the unresolved problems.”⁷⁴

GAO reported that

ALIS may not be deployable: ALIS requires server connectivity and the necessary infrastructure to provide power to the system. The Marine Corps, which often deploys to austere locations, declared in July 2015 its ability to operate and deploy the F-35 without conducting deployability tests of ALIS. A newer version of ALIS was put into operation in the summer of 2015, but DOD has not yet completed comprehensive deployability tests.

ALIS does not have redundant infrastructure: ALIS’s current design results in all F-35 data produced across the U.S. fleet to be routed to a Central Point of Entry and then to ALIS’s main operating unit with no backup system or redundancy. If either of these fail, it could take the entire F-35 fleet offline.⁷⁵

To date, the F-35’s operators have been coping with ALIS’s shortcomings.

Air Force Lt. Gen. Chris Bogdan told reporters that the plane could fly without the \$16.7 billion ...ALIS for at least 30 days. The software, which runs on ground computers, not the plane itself, manages the aircraft’s supply chain, aircraft configuration, fault diagnostics, mission planning, and debriefing – none of which are critical to combat flight.⁷⁶

Cost and Funding⁷⁷

Total Program Acquisition Cost⁷⁸

As of December, 2015, the total estimated acquisition cost (the sum of development, procurement, and military construction [MilCon] costs) of the F-35 program in constant (i.e., inflation-adjusted) FY2012 dollars was about \$313.3 billion, including about \$59.5 billion in research and development, about \$249.7 billion in procurement, and about \$4.1 billion in MilCon.⁷⁹

In then-year dollars (meaning dollars from various years that are not adjusted for inflation), the figures are about \$379.6 billion, including about \$55.1 billion in research and development, about \$319.1 billion in procurement, and about \$4.8 billion in military construction.

⁷⁴ Director, Operational Test and Evaluation, *FY2015 Annual Report*, January 2016.

⁷⁵ U.S. Government Accountability Office, *F-35 Sustainment: DOD Needs a Plan to Address Risks Related to Its Central Logistics System*, 16-439, April 14, 2016.

⁷⁶ Patrick Tucker, “F-35 Will Fly Despite Auditor’s Gleet-Grounding Warning,” *Defense One*, April 17, 2016.

⁷⁷ The F-35 program receives (or in the past received) funding from the Air Force, Navy, and Defense-Wide research, development, test, and evaluation (RDT&E) accounts (the Defense-Wide RDT&E funding occurred in FY1996-FY1998); Non-Treasury Funds (i.e., financial contributions from the eight other countries participating in the F-35 program)—a source of additional research and development funding; the Air Force and Navy aircraft procurement accounts (the Navy and Marine Corps are organized under the Department of the Navy, and Marine Corps aircraft development and procurement costs are funded through the Navy’s RDT&E and aircraft procurement accounts); and the Air Force MilCon account and the Navy and Marine Corps MilCon account.

⁷⁸ Figures in this section come from Office of the Secretary of Defense, *Selected Acquisition Report (SAR): F-35 Joint Strike Fighter Aircraft (F-35)*, March 21, 2016.

⁷⁹ The procurement cost figure of about \$249.7 billion does not include the cost of several hundred additional F-35s that are to be procured other countries that are participating in the F-35 program. The \$249.7 billion figure does, however, assume certain production-cost benefits for DOD aircraft that result from producing F-35s for other countries.

Prior-Year Funding

Through FY2015, the F-35 program has received a total of roughly \$99.5 billion of funding in then-year dollars, including roughly \$51.9 billion in research and development, about 46.2 billion in procurement, and approximately \$1.5 billion in military construction.

Unit Costs

As of December, 2015, the F-35 program had a program acquisition unit cost (or PAUC, meaning total acquisition cost divided by the 2,457 research and development and procurement aircraft) of about \$106.5 million and an average procurement unit cost (or APUC, meaning total procurement cost divided by the 2,443 production aircraft) of \$86.5 million, in constant FY2012 dollars.

However, this reflects the cost of the aircraft without its engine, as the engine program was broken out as a separate reporting line in 2011.

As of December, 2015, the F-35 engine program had a program acquisition unit cost of about \$21.0 million and an average procurement unit cost of \$15.7 million in constant FY2012 dollars. Just as the reported airframe costs represent a program average and do not discriminate among the variants, the engine costs do not discriminate between the single engines used in the F-35A and C and the more expensive engine/lift fan combination for the F-35B.

However, the December, 2015 Selected Acquisition Report broke out unit recurring flyaway costs of the three engines as well as the separate airframes, as follows:

Table 5. F-35 Projected Unit Recurring Flyaway Cost

(Includes hardware costs over the life of the program and assumes 612 international sales)

\$M (2012)	F-35A	F-35B	F-35C
Airframe	65.7	77.3	78.0
Engine	11.0	27.7	10.9
Total	76.7	105.0	88.9

Source: Office of the Secretary of Defense, *Selected Acquisition Report (SAR): F-35 Joint Strike Fighter Aircraft (F-35)*, March 21, 2016.

Note: Previous versions of this chart assumed 673 international sales rather than 612.

Critics note that the costs reported in the Selected Acquisition Reports contain a number of assumptions about future inflation rates, production learning curves, and other factors, and argue that these figures do not accurately represent the true cost of developing and acquiring the F-35.⁸⁰

⁸⁰ 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/>.

Other Cost Issues

Acquisition Cost and Affordability

In its latest report on the F-35 program, the Government Accountability Office questioned DOD's ability to afford the current F-35 program given other demands on budgets. This is a contrast to earlier reports, which focused more on the program's ability to meet its cost targets.

Although the estimated F-35 ... program acquisition costs have decreased since 2014, the program continues to face significant affordability challenges.... The program will require an average of \$12 billion per year to complete the procurement of aircraft through 2038. The program expects to reach peak production rates for U.S. aircraft in 2022, at which point DOD expects to spend more than \$14 billion a year on average for a decade... These affordability challenges will compound as the program competes with other large acquisition programs including the long range strike bomber and KC-46A Tanker. At the same time, the number of operational F-35 aircraft that DOD will have to support will be increasing.⁸¹

Unit Cost Projections

The F-35 program continues efforts to make the F-35 cost-competitive with previous-generation aircraft. (It should be noted that the articles cited below reference the cost of the F-35A, the simplest model.)

F-35 fighter jets will sell for as little as \$80 million in five years, according to the Pentagon official running the program.

"The cost of an F-35A in 2019 will be somewhere between \$80 and \$85 million, with an engine, with profit, with inflation," U.S. Air Force Lieutenant General Christopher Bogdan, the Pentagon's manager of the program, told reporters in Canberra today.⁸²

That article dated from 2014. More recently, efforts have been increased to reach the same target:

[Lockheed Martin] will invest up to \$170 million over the next two years to extend its existing "Blueprint for Affordability" measure ... to drive down the unit cost of an F-35A to \$85 million by 2019.⁸³

As noted in **Table 5**, the average unit flyaway cost of an F-35A is officially projected at \$76.7 million.

Engine Costs

In 2013, engine maker Pratt & Whitney embarked on a program to reduce the F-35 engine's cost.⁸⁴ Following release of data showing the "cost of acquiring the planned 2,443 airframes and associated systems rose 1%, while engine costs climbed 6.7%,⁸⁵ the program manager reportedly singled out Pratt for criticism "after having improved relations with the F-35's prime contractor,

⁸¹ U.S. Government Accountability Office, *F-35 JOINT STRIKE FIGHTER: Continued Oversight Needed as Program Plans to Begin Development of New Capabilities*, 16-390, April 2016, p. 23, <http://www.gao.gov/assets/680/676584.pdf>.

⁸² Jason Scott, "F-35s to Sell for as Low as \$80 Million in 2019, Pentagon Says," *Bloomberg.com*, March 11, 2014.

⁸³ Valerie Insinna, "Lockheed Extends F-35 Cost-Cutting Initiative To Save Billions," *Defense News*, July 11, 2016.

⁸⁴ Andrea Shalal, "Pratt must push harder to cut F-35 engine cost -Pentagon," *Reuters.com*, April 7, 2014.

⁸⁵ Doug Cameron, "Pentagon official criticizes Pratt & Whitney," *Marketwatch.com*, April 17, 2014.

Lockheed Martin Corp., securing lower prices for each batch of new airframes and closing deals far quicker than in the past.”⁸⁶

Subsequently, Pratt & Whitney has signed contracts for engines through LRIP 10 that show a steady percentage decrease in cost. The LRIP 10 announcement included a figure of \$1.95 billion for 99 engines, although as that includes program management, engineering support, production non-recurring efforts, spare modules and spare parts, it is not possible to derive a specific cost for each engine. “[Pratt & Whitney] is claiming competitive privilege in its sole-source deal for F-35 engines in not releasing its actual numbers.”⁸⁷

Pratt says that “unit prices for 86 conventional takeoff and landing (CTOL) and carrier variant (CV) propulsion systems were reduced by 2.6 percent, and unit prices for 13 LRIP 10 short takeoff and vertical landing (STOVL) propulsion systems, including Rolls-Royce Lift Systems, were reduced by 4.2 percent” compared to the previous contract.⁸⁸

The issue of engine cost transparency is addressed in “Issues for Congress,” below.

Anticipated Upgrade Costs

The degree of concurrency in the F-35 program, in which aircraft are being produced while the design is still being revised through testing, appears to make upgrades to early-production aircraft inevitable. The cost of those upgrades may vary, depending on what revisions are made during the testing process. However, the cost of such upgrades is not included in the negotiated price of each production lot.

The first F-35As, for example, were loaded with a basic software release (Block 1B) that provides basic aircraft control, but does not have the degree of sensor fusion or weapons integration expected in later blocks. “The initial estimate for modifying early-production F-35As from a basic configuration to a capable warfighting level is \$6 million per jet, plus other associated expenses not included in that figure.”⁸⁹ That would make the current cost of upgrading the earliest F-35As to Block 3F about \$100 million. In order to increase capability, the Air Force intends to upgrade the aircraft step-by-step as new software releases become available rather than waiting and jumping to the final release of Block 3F.

The cost of the major upgrade to Block 4 is discussed in “Issues for Congress,” below.

Operating and Support Costs

Since 2011, Selected Acquisition Report projected lifetime operating and sustainment costs for the F-35 fleet have been estimated at slightly over \$1 trillion,⁹⁰ “which DOD officials have deemed unaffordable. The program’s long term sustainment estimates reflect assumptions about key cost drivers that the program does not control, including fuel costs, labor costs, and inflation rates.”⁹¹ “The eye-popping estimate has raised hackles at the Defense Department and on Capitol

⁸⁶ Ibid.

⁸⁷ Ibid.

⁸⁸ Pratt & Whitney, “F-35 Joint Program Office Awards Pratt & Whitney LRIP 10 Contract for F135 Engines,” press release, July 8, 2016, <http://www.prnewswire.com/news-releases/f-35-joint-program-office-awards-pratt—whitney-lrip-10-contract-for-f135-engines-300295807.html>.

⁸⁹ Gabe Starosta, “Block Upgrades For Earliest F-35s To Cost \$6M Per Aircraft,” *InsideDefense.com*, March 26, 2014.

⁹⁰ Office of the Secretary of Defense, *Selected Acquisition Report (SAR): F-35*, editions for December, 2011 through December, 2015.

⁹¹ U.S. Government Accountability Office, *F-35 JOINT STRIKE FIGHTER: Problems Completing Software Testing* (continued...)

Hill since it was disclosed in 2011. It covers the cost of fuel, spare parts, logistics support and repairs.”⁹² It may be worth noting that “the F-35 was ... the first big Pentagon weapons program to be evaluated using a 50-year lifetime cost estimate—about 20 years longer than most programs—which made the program seem artificially more expensive.”⁹³

Operations and sustainment costs as of the December, 2015 Selected Acquisition Report were reported at \$620.8 billion in 2012 dollars (or \$1.12 trillion in then-year dollars), an increase of 3.8% over the previous total. That increase reflected a change in the expected service life of the F-35 by six years compared to the previous estimate.^{94 95}

“The operation and sustainment cost is a bigger issue,” (Air Force acquisition chief William) LaPlante said. “It’s the one that will say whether or not we can afford (the F-35) in the longer run.”⁹⁶

Operations costs are being addressed on several fronts, including changes in training, basing, support, and other approaches.

To attack this problem, the F-35 program office in October 2013 set up a “cost war room” in Arlington, Va.... A team of government and contractor representatives assigned to the cost war room are investigating 48 different ways to reduce expenses. They are also studying options for future repair and maintenance of F-35 aircraft in the United States and abroad.⁹⁷

The U.S. Air Force is looking to slash the number of locations where it will base F-35 Joint Strike Fighter squadrons to bring down the jet’s estimated trillion-dollar sustainment costs.... ‘When you reduce the number of bases from 40 to the low 30s, you end up reducing your footprint, making more efficient the long-term sustainment,’ David Van Buren, the service’s acquisition executive, said in a March 2 exit interview at the Pentagon.⁹⁸

More recently, “Lockheed, Northrop and BAE are also starting a ‘sustainment cost reduction initiative’ aimed at cutting operations and maintenance expenses by 10 percent during fiscal 2018 through fiscal 2022. The vendors will invest \$250 million and hope to reap at least \$1 billion in savings over five years.”⁹⁹

(...continued)

May Hinder Delivery of Expected Warfighting Capabilities, GAO-14-322, March 2014, p. 12.

⁹² Sandra I. Erwin, “Next Battle for F-35: Bring Down Operations Costs,” *National Defense* (nationaldefensemagazine.org), April 6, 2014.

⁹³ Marine Corps Assistant Commandant for Aviation LtGen. Terry Robling, cited in Andrea Shalal-Esa, “Lifetime cost to run F-35 fighter: about \$1 trillion,” *Reuters.com*, February 26, 2012.

⁹⁴ Graham Warwick, “Extending Service Life Pushes F-35 Sustainment Costs Up,” *Aerospace Daily and Defense Report*, March 28, 2016.

⁹⁵ Office of the Secretary of Defense, *Selected Acquisition Report (SAR): F-35*, March 21, 2016.

⁹⁶ Andrea Shalal, “U.S. focuses on cheaper, more reliable F-35 jet: Air Force official,” *Reuters.com*, April 1, 2014.

⁹⁷ Sandra I. Erwin, “Next Battle for F-35: Bring Down Operations Costs,” *National Defense* (nationaldefensemagazine.org), April 6, 2014.

⁹⁸ Marcus Weisgerber, “USAF Eyes Deep Cuts To F-35 Bases,” *Defense News*, March 3, 2012.

⁹⁹ Valerie Insinna, “Lockheed Extends F-35 Cost-Cutting Initiative To Save Billions,” *Defense News*, July 11, 2016.

Manufacturing Locations

The F-35 is manufactured in several locations. Lockheed Martin builds the aircraft's forward section in Fort Worth, TX. Northrop Grumman builds the mid-section in Palmdale, CA, and the tail is built by BAE Systems in the United Kingdom.¹⁰⁰ Final assembly of these components takes place in Fort Worth. Final assembly and checkout facilities have also been established in Cameri, Italy, and Nagoya, Japan.

The Pratt & Whitney F135 engine for the F-35 is produced in East Hartford and Middletown, CT. Rolls-Royce builds the F-35B lift system in Indianapolis, IN.

International Participation

In General

The F-35 program is DOD's largest international cooperative program. DOD has actively pursued allied participation as a way to defray some of the cost of developing and producing the aircraft, and to "prime the pump" for export sales of the aircraft.¹⁰¹ Allies in turn view participation the F-35 program as an affordable way to acquire a fifth-generation strike fighter, technical knowledge in areas such as stealth, and industrial opportunities for domestic firms.

Eight allied countries—the United Kingdom, Canada, Denmark, The Netherlands, Norway, Italy, Turkey, and Australia—are participating 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 various levels of participation in the program. International partners are also assisting with Initial Operational Test and Evaluation (IOT&E), a subset of SDD.¹⁰² The eight partner countries are expected to purchase hundreds of F-35s, with the United Kingdom's 138 being the largest anticipated foreign fleet.¹⁰³

Two additional countries—Israel and Singapore—are security cooperation participants outside the F-35 cooperative development partnership.¹⁰⁴ Israel has agreed to purchase 33 F-35s, and may want as many as 50.^{105 106} Japan chose the F-35 as its next fighter in October 2011,¹⁰⁷ and South

¹⁰⁰ CRS site visit to Palmdale, CA, March 10, 2016.

¹⁰¹ Congress insisted from the outset that the JAST program include ongoing efforts by DARPA to develop more advanced STOVL aircraft, opening the way for UK participation in the program.

¹⁰² Currently, the UK, Italy, and the Netherlands have agreed to participate in the IOT&E program. UK, the senior F-35 partner, will have the strongest participation in the IOT&E phase. Italy and the Netherlands are contributing a far smaller amount and will take part only in the coalition concept of operations (CONOPS) validation testing. (Telephone conversation with OSD/AT&L, October 3, 2007.) Other partner nations are still weighing their option to participate in the IOT&E program. The benefits to participation are expedited acquisition of aircraft, pilot training for the test cycle, and access to testing results.

¹⁰³ Gareth Jennings, "UK to approve bulk F-35B buy in 2017," *IHS Jane's 360*, February 6, 2014.

¹⁰⁴ DOD offers Foreign Military Sales (FMS)-level of participation in the F-35 program for countries unable to commit to partnership in the program's SDD phase. Israel and Singapore are believed to have contributed \$50 million each, and are "Security Cooperative Participants." (Selected Acquisition Report, Office of the Secretary of Defense for Acquisition. December 31, 2005.)

¹⁰⁵ Bob Cox, "Israeli government ok's F-35 buy," *Fort Worth Star-Telegram*, September 16, 2010. Yaakov Lappin, "Israel, US Sign F-35 Agreement," *Jerusalem Post*, October 8, 2010.

¹⁰⁶ Lara Seligman, "Israeli Air Chief Asks For 17 More F-35s," *Aerospace Daily & Defense Report*, June 23, 2016.

Korea committed to the F-35 in 2014.¹⁰⁸ Sales to additional countries are possible.¹⁰⁹ Some officials have speculated that foreign sales of F-35s might eventually surpass 2,000 or even 3,000 aircraft.¹¹⁰

The UK is the most significant international partner in terms of financial commitment, and the only Level 1 partner.¹¹¹ On December 20, 1995, the U.S. and UK governments signed an MOU on British participation in the JSF program as a collaborative partner in the definition of requirements and aircraft design. This MOU committed the British government to contribute \$200 million toward the cost of the 1997-2001 Concept Demonstration Phase.¹¹² On January 17, 2001, the U.S. and UK governments signed an MOU finalizing the UK's participation in the SDD phase, with the UK committing 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.¹¹³

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¹⁰⁷ Paul Kallender-Umez, "Japan F-X Competition Win Victory for JSF Program," *Defense News*, December 20, 2011.

¹⁰⁸ Choe Sang-hun, "South Korea Formally Announces Intent to Buy 40 Lockheed Fighter Jets," *The New York Times*, September 24, 2014.

¹⁰⁹ Viola Gienger, "Pentagon Awaits India's Interest in Lockheed Martin F-35 Fighter," *Bloomberg News*, November 2, 2011.

¹¹⁰ Andrea Shalal-Esa, "Pentagon sees 6,000 possible F-35 sales," *Reuters.com*, June 17, 2009. See also Marina Malenic, "F-35 Sales Could Double As Countries Look To Replace Aging Fleets, General Says," *Defense Daily*, June 18, 2009: 6, and Marcus Weisgerber, "JSF Program Anticipates Nearly 700 F-35 Buys [For International Customers] Between FY-09 and FY-23," *Inside the Air Force*, July 31, 2009.

¹¹¹ 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 voice with respect to 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 director level.

Level II partners consist of Italy and the Netherlands, contributing \$1 billion and \$800 million, respectively. On June 24, 2002, Italy became the senior Level II partner ("F-35 Joint Strike Fighter (JSF) Lightning II: International Partners," <http://www.globalsecurity.org/military/systems/aircraft/f-35-int.htm>). Italy wants to have its own F-35 final assembly line, which would be in addition to the existing F-35 maintenance and upgrade facility. The Netherlands signed on to the F-35 program on June 17, 2002, after it had conducted a 30-month analysis of potential alternatives.

Australia, Denmark, Norway, Canada, and Turkey joined the F-35 program as Level III partners, with contributions ranging from \$125 million to \$175 million. ("Australia, Belgium Enter Joint Strike Fighter Program as EMD Partners," *Inside the Air Force*, April 21, 2000.)

Unlike the SDD phase, PSFD phase does not make any distinction as to levels of participation. Also unlike the bilateral SDD MOUs, there is a single PSFD MOU for all partner nations. In signing the PSFD MOU, partner nations state their intentions to purchase the F-35, including quantity and variant, and a determination is made as to their delivery schedule. PSFD costs will be divided on a "fair-share" based on the programmed purchase amount of the respective nation. So-called "offset" arrangements, considered the norm in defense contracts with foreign nations, usually require additional incentives to compensate the purchasing nation for the agreement's impact to its local workforce. F-35 officials decided to take a different approach, in line with the program's goal to control costs, to avoid offset arrangements and promote competition as much as possible. Consequently, all partner nations have agreed to compete for work on a "best-value" basis and have signed the PSFD MOU.

¹¹² "U.S., U.K. Sign JAST Agreement," *Aerospace Daily*, December 21, 1995, p. 451.

¹¹³ BAE is a major partner to Lockheed Martin and is providing the aft fuselage, empennage, and electronic warfare suite for the aircraft. Rolls-Royce is partnered with GE on the F136 engine and is a subcontractor to Pratt and Whitney for producing components for the F-35B's STOVL lift system. In October 2009, Rolls Royce broke ground on a new plant in Virginia to make parts for the F136 engine. (Rolls Royce press release, "Rolls-Royce expands US capability; begins construction on new manufacturing facility in Virginia," October 19, 2009, available at http://www.rolls-royce.com/investors/news/2009/091019_manufacturing_virginia.jsp.) Rolls Royce's 2001 contract with Pratt and (continued...)

International Sales Quantities

The cost of F-35s for U.S. customers depends in part on the total quantity of F-35s produced. As the program has proceeded, some new customers have emerged, such as South Korea and Japan, mentioned above. Other countries have considered increasing their buys, while some have deferred previous plans to buy F-35s. It is perhaps noteworthy that the latest Selected Acquisition Report reduced the number of assumed international sales for cost purposes from 673 to 612.¹¹⁴ Recent updates to other countries' purchase plans are detailed in "Changes in International Orders," above.

Other international competitions in which the F-35 is or could be a candidate include the following:

Nation	Plans	Candidates
Belgium	Looking to purchase 34 new fighters. Selection is expected in 2018, with first deliveries expected in 2023.	Lockheed Martin F-35, Boeing F/A-18 Super Hornet, Dassault Rafale, Eurofighter Typhoon, Saab Gripen
Finland	Studying options to replace early model F/A-18 Hornets. Type selection could be made in 2020, and officials have said only Western fighters are being considered.	Gripen believed to have an edge.
Poland	Considering what to do with its Russian-built Su-22 attack aircraft and MiG-29 fighters. Has already taken delivery of 48 F-16s. A selection for more could be made in 2022.	Light attack version of the Leonardo-Finmeccanica M346, F-35, Typhoon
Spain	Operating Eurofighter and F/A-18 Hornet for the foreseeable future. Spain wants to replace its Hornets with an unmanned combat aircraft in the late 2020s or 2030s.	May also have to consider F-35B to maintain a fixed-wing fast jet from its small carrier.
Turkey	Replacing F-4 Phantoms with F-35As and F-16s with a new, indigenous aircraft, the TFX, first expected to fly in 2023. BAE Systems has been selected as co-partner to develop TFX.	Turkey also has ambitions to fly F-35Bs from its new amphibious warfare ships.

Source: Tony Osborne, "Fighter Aircraft Procurement Plans Of 19 European Countries," *Aviation Week*, June 29, 2016, <http://aviationweek.com/defense/fighter-aircraft-procurement-plans-19-european-countries-0>. Edited and supplemented by CRS.

As noted, a significant question remains over whether Canada will continue as an F-35 partner. The Trudeau government repudiated the previously announced purchase of 65 (which had originally been 80.) No plan for replacement of Canada's existing F-18s has been announced, and speculation varies as to whether the F-35 will be allowed to compete. Lockheed Martin has stated that if Canada withdraws as a customer, Canadian work share will suffer.¹¹⁵

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Whitney for design and development of the STOVL lift components is valued at \$1 billion over 10 years. ("Rolls-Royce Finishes First JSF Propulsion System Flight Hardware," Rolls-Royce Media Room, available at http://www.rolls-royce.com/media/showPR.jsp?PR_ID=40243.) All F-35Bs, regardless of what engine they use, are to employ Rolls Royce components in their STOVL lift systems.

¹¹⁴ Office of the Secretary of Defense, *Selected Acquisition Report (SAR): F-35 Joint Strike Fighter Aircraft (F-35)*, March 21, 2016.

¹¹⁵ Aaron Mehta, "No System in Place To Strip Canadian F-35 Participation," *Defense News*, July 11, 2016.

Friction over Work Shares and Technology Transfer

DOD and foreign partners in the JSF program have occasionally disagreed over the issues of work shares and proprietary technology. Most recently, the United States rejected a South Korean request for transfer of four F-35 technologies that could assist in the development of a Korean indigenous fighter program (although 21 other technologies were approved.)^{116 117}

The governments of Italy and the United Kingdom have lobbied for F-35 assembly facilities to be established in their countries. In July 2010, Lockheed and the Italian firm Alenia Aeronautica reached an agreement to establish an F-35 final assembly and checkout facility at Cameri Air base, Italy, to deliver aircraft for Italy and the Netherlands beginning in 2014. The facility opened in July, 2013.¹¹⁸ A similar facility has opened in Nagoya, Japan, with the first aircraft scheduled for delivery in 2017.^{119 120}

Proposed FY2017 Budget

Table 6 shows the Administration's FY2017 request for Air Force and Navy research and development and procurement funding for the F-35 program, along with FY2015 and FY2016 funding levels.

Table 6. FY2017 Funding Request for F-35 Program

(Figures in millions of then-year dollars)

	FY2015		FY2016		FY2017 (request)	
	Funding	Quantity	Funding	Quantity	Funding	Quantity
RDT&E funding						
Dept. of Navy	995.3	—	1,084.6	—	1,197.8	
Air Force	606.2	—	640.9	—	603.5	
Subtotal	1,601.5	—	1,725.5	—	1,801.3	
Procurement funding						
Dept. of Navy	2,442.6	10	3,685.5	21	3,309.9	20
Air Force	4,232.4	28	5,790.2	47	4,982.2	43
Subtotal	6,674.9	38	9,475.8	68	8,286.1	63
Spares	324.4		401.1		417.1	
TOTAL	8,600.9	38	11,602.4	68	10,504.5	63

Source: *Program Acquisition Costs by Weapons System*, Office of the Under Secretary of Defense (Comptroller)/Chief Financial Officer, February, 2016.

Note: Figures shown do not include funding for MilCon funding or research and development funding provided by other countries.

According to the February, 2016 DOD justification books, procurement cost of the 43 F-35As requested for FY2017 in the Air Force budget is estimated at \$4,862.2 million, or an average of

¹¹⁶ Jung Sung-ki, "Tech Transfer Hobbles South Korea's Fighter Program," *Defense News*, September 27, 2015.

¹¹⁷ Jon Grevatt, "US approves F-35 offset technology transfer to South Korea," *IHS Jane's Defence Industry*, December 21, 2016.

¹¹⁸ Craig Hoyle, "An Italian view on the F-35," *Flightglobal.com/DEW Line blog*, August 7, 2013.

¹¹⁹ Amy Butler, "First F-35 Assembled In Italy To Roll Out Early Next Year," *Aerospace Daily and Defense Report*, December 10, 2014.

¹²⁰ Amy Hillis, "Japan Begins Assembling First F-35A at Nagoya FACO," *Aerospace Daily and Defense Report*, December 12, 2015.

\$113.1 million each. These aircraft have received \$460.3 million in prior-year advance procurement (AP) funding, leaving another \$4,401.9 million to be funded in FY2017 to complete their estimated procurement cost. The FY2017 Air Force request also includes \$404.5 million in advance procurement funding for F-35As to be procured in future years, and \$267.8 million for F-35A initial spares, bringing the total FY2017 Air Force procurement funding request for the program to \$4,806.4 million.

The 16 F-35Bs requested for FY2017 in the Department of the Navy budget have a combined estimated procurement cost of \$2,240.8 million, or an average of \$140.1 million each. These aircraft have received \$203.1 million in prior-year AP funding, leaving another \$2,037.8 million to be funded in FY2017 to complete their estimated procurement cost. The FY2017 Department of the Navy request also includes \$233.6 million in advance procurement funding for F-35Bs to be procured in future years, and \$123.3 million funding for initial spares, bringing the total FY2017 Navy procurement funding request for the F-35B to \$2,271.4 million.

The 4 F-35Cs requested for FY2017 in the Department of the Navy budget have a combined estimated procurement cost of \$939.3 million, or an average of \$234.8 million each. These aircraft have received \$48.6 million in prior-year AP funding, leaving another \$890.7 million to be funded in FY2017 to complete their estimated procurement cost. The FY2017 Department of the Navy request also includes \$80.9 million in advance procurement funding for F-35Cs to be procured in future years, and \$26.1 million funding for initial spares, bringing the total FY2017 Navy procurement funding request for the F-35C to \$971.6 million.

Issues for Congress

Overall Need for F-35

The F-35's cutting-edge capabilities are accompanied by significant costs. Some analysts have suggested that upgrading existing aircraft might offer sufficient capability at a lower cost, and that such an approach makes more sense in a budget-constrained environment. Others have produced or endorsed studies proposing a mix of F-35s and upgraded older platforms; yet others have called for terminating the F-35 program entirely. Congress has considered the requirement for F-35s on many occasions and has held hearings, revised funding, and added oversight language to defense bills. As the arguments for and against the F-35 change, the program matures, and/or the budgetary situation changes, Congress may wish to consider the value of possible alternatives, keeping in mind the program progress thus far, funds expended, evolving world air environment, and the value of potential capabilities unique to the F-35.

Planned Total Procurement Quantities

A potential issue for Congress concerns the total number of F-35s to be procured. As mentioned above, planned production totals for the various versions of the F-35 we left unchanged by the 2010 Quadrennial Defense Review (QDR). Since then, considerable new information has appeared regarding cost growth that may challenge the ability to maintain the expected procurement quantities. “I think we are to the point in our budgetary situation where, if there is unanticipated cost growth, we will have to accommodate it by reducing the buy,” said Undersecretary of Defense Robert Hale, the Pentagon comptroller.”¹²¹

¹²¹ Marina Malenic, “DoD Comptroller: Further F-35 Cost Growth Jeopardizes Buy Quantity,” *Defense Daily*, March (continued...)

Some observers, noting potential limits on future U.S. defense budgets, potential changes in adversary capabilities, and competing defense-spending priorities, have suggested reducing planned total procurement quantities for the F-35. A September 2009 report on future Air Force strategy, force structure, and procurement by the Center for Strategic and Budgetary Assessments (CSBA), for example, states that

[A]t some point over the next two decades, short-range, non-stealthy strike aircraft will likely have lost any meaningful deterrent and operational value as anti-access/area denial systems proliferate. They will also face major limitations in both irregular warfare and operations against nuclear-armed regional adversaries due to the increasing threat to forward air bases and the proliferation of modern air defenses. At the same time, such systems will remain over-designed – and far too expensive to operate – for low-end threats....

Reducing the Air Force plan to buy 1,763 F-35As through 2034 by just over half, to 858 F-35As, and increasing the [annual F-35A] procurement rate to end [F-35A procurement] in 2020 would be a prudent alternative. This would provide 540 combat-coded F-35As on the ramp, or thirty squadrons of F-35s[,] by 2021[, which would be] in time to allow the Air Force budget to absorb other program ramp ups[,] like NGB [the next-generation bomber].¹²²

Block 4 as a Separate Program

Development of the F-35 Block 4 software is expected to cost as much as \$3 billion over the next six years, and \$8 billion in total. Some in Congress argue that a program of that size should part with traditional procurement practice for an upgrade and be run as a separate Major Defense Acquisition Program (MDAP), with its own budget line and the concomitant reporting requirements. At a March 23, 2016, hearing of a House Armed Services subcommittee,

Government Accountability Office (GAO) Director of Acquisition and Sourcing Management Michael Sullivan argued that the Block 4 estimated cost justifies its management as a separate program, but F-35 Program Executive Officer (PEO) Air Force Lt. Gen. Christopher Bogdan countered that breaking it off would create an administrative burden and add to the program's price tag and schedule.¹²³

Section 1087 of the Senate's version of the FY2017 National Defense Authorization Act (S. 2943) would require the Department of Defense to treat the F-35 follow-on modernization program (Block 4 development) as a separate MDAP. An amendment to the House version of the FY2017 NDAA (H.R. 4909) to do likewise failed in markup by a vote of 28-41.¹²⁴

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4, 2010.

¹²² Thomas P. Ehrhard, *An Air Force Strategy for the Long Haul*, Washington, Center for Strategic and Budgetary Assessments, 2009, pp. xii and xiv. The report was released on September 17, 2009, according to CSBA's website, and is available at http://www.csbaonline.org/4Publications/PubLibrary/R.20090917.An_Air_Force_Strat/R.20090917.An_Air_Force_Strat.pdf. Subsequent to writing this report, the author became a special assistant to the Air Force Chief of Staff.

¹²³ Valerie Insinna, "Bogdan: Separate Program For F-35 Block 4 Mods Would Increase Cost, Schedule Difficulties," *Defense Daily*, March 24, 2016.

¹²⁴ Markup of H.R. 4909, roll call vote no. 1, April 27, 2016.

Joint Program Office

Section 1086 of the Senate’s version of the FY2017 National Defense Authorization Act (S. 2943) would disestablish the F-35 Joint Program Office (JPO) at the end of the development phase and turn procurement responsibility over to the individual military services. The Senate argues that the overhead structure of a joint office, even if needed for development of a joint aircraft, is not needed once production has been established, and further that the F-35 is functionally three separate aircraft, with much less commonality than earlier envisioned. “[E]ven the Program Executive Officer of the F-35 Joint Program Office, General Christopher Bogdan, recently admitted the variants are only 20–25 percent common.”¹²⁵ The language includes a waiver provision that would allow the Secretary of Defense “to avert the disbandment of the F-35 joint program office if he or she certifies that the office is indeed needed.”¹²⁶ Supporters cite the requirement by the United States to support international customers and to oversee further software and other upgrades as reasons to keep the JPO in place.

The Joint Program Office employs 2,590 people, and the annual cost to operate it is on the order of about \$70 million a year.¹²⁷

Competition

Lt. Gen. Bogdan’s comments regarding the difficulty of cost control in a sole-source environment (see “Engine Costs,” above) reflect a broader issue affecting defense programs as industry consolidates and fewer sources of supply are available for advanced systems.¹²⁸ Congress may wish to consider the merits of maintaining competition when overseeing system procurements (for example, the use of competition to maintain cost pressure was a principal argument in favor of the F-35 alternate engine program).¹²⁹

Engine Cost Transparency

In the specific case of the F-35, Pratt & Whitney and the Joint Program Office have declined to reveal the cost per engine in each LRIP contract, replacing dollar costs with percentage savings and aggregate contract values that include items other than the engines themselves. Congress may wish to consider whether this approach is sufficient to provide useful oversight, and weigh that value against a contractor’s right to protect competition-sensitive data. A possible analogue can be found in the debate over whether public disclosure of the contract value for the B-21 bomber might reveal more data than prudent, or whether that is a reasonable cost to allow proper program oversight.

¹²⁵ S.Rept. 114-255, p. 280.

¹²⁶ Sandra I. Irwin, “Political Turbulence Hits F-35 Joint Strike Fighter,” *National Defense Magazine*, May 25, 2016.

¹²⁷ Testimony of Lt. Gen. Christopher Bogdan, U.S. Congress, Senate Committee on Armed Services, *F-35 Joint Strike Fighter Program*, 114th Cong., 2nd sess., April 26, 2016.

¹²⁸ See testimony of (name redacted), CRS Specialist in Defense Acquisition, U.S. Congress, House Committee on Armed Services, *Twenty-five years of Acquisition Reform: Where do we go from here?*, 113th Cong., 2nd sess., October 29, 2013.

¹²⁹ For more on this issue, see CRS Report R41131, *F-35 Alternate Engine Program: Background and Issues for Congress*.

Affordability and Projected Fighter Shortfalls

An additional potential issue for Congress for the F-35 program concerns the affordability of the F-35, particularly in the context of projected shortfalls in both Air Force fighters and Navy and Marine Corps strike fighters.

Although the F-35 was conceived as a relatively affordable strike fighter, some observers are concerned that in a situation of constrained DOD resources, F-35s might not be affordable in the annual quantities planned by DOD, at least not without reducing funding for other DOD programs. As the annual production rate of the F-35 increases, the program will require more than \$10 billion per year in acquisition funding at the same time that DOD will face other budgetary challenges. The issue of F-35 affordability is part of a larger and long-standing issue concerning the overall affordability of DOD's tactical aircraft modernization effort, which also includes procurement of F/A-18E/Fs (through FY2012, at least).¹³⁰ Some observers who are concerned about the affordability of DOD's desired numbers of F-35s have suggested procuring upgraded F-16s as complements or substitutes for F-35As for the Air Force, and F/A-18E/Fs as complements or substitutes for F-35Cs for the Navy.¹³¹ F-35 supporters argue that F-16s and F/A-18E/Fs are less capable than the F-35, and that the F-35 is designed to have reduced life-cycle costs.

The issue of F-35 affordability occurs in the context of a projected shortfall of up to 800 Air Force fighters that was mentioned by Air Force officials in 2008,¹³² and a projected shortfall of more than 100 (and perhaps more than 200) Navy and Marine Corps strike fighters.¹³³ In the interim, "in light of delays with the F-35 Lightning II Joint Strike Fighter, the U.S. Air Force is set to begin looking at which of its newer F-16s will receive structural refurbishments, avionics updates, sensor upgrades or all three."¹³⁴

Implications for Industrial Base

Another potential issue for Congress regarding the F-35 program concerns its potential impact on the U.S. tactical aircraft industrial base. The award of the F-35 SDD contract to a single company (Lockheed Martin) raised concerns in Congress and elsewhere that excluding Boeing from this program would reduce that company's ability to continue designing and manufacturing fighter aircraft.¹³⁵

Similar concerns regarding engine-making firms have been raised since 2006, when DOD first proposed (as part of the FY2007 budget submission) terminating the F136 alternate engine program. Some observers are concerned that if the F136 were cancelled, General Electric would not have enough business designing and manufacturing fighter jet engines to continue competing in the future with Pratt & Whitney (the manufacturer of the F135 engine). Others

¹³⁰ For more on this issue, see CRS Report RL33543, *Tactical Aircraft Modernization: Issues for Congress*.

¹³¹ See, inter alia, George Wilson, "Kill the F-35?" *CongressDaily AM*, March 22, 2010.

¹³² Testimony of Lieutenant General Daniel Darnell, Deputy Chief of Staff, Air, Space and Information Operations, Plans and Requirements, before an April 9, 2008, hearing on Air Force and Navy aviation programs before the Airland subcommittee of the Senate Armed Services Committee.

¹³³ For more on the projected Navy-Marine Corps strike fighter shortfall, see CRS Report RL30624, *Navy F/A-18E/F and EA-18G Aircraft Program*.

¹³⁴ John Reed, "JSF Woes Push AF to F-16s," *DoD Buzz*, November 4, 2010.

¹³⁵ For more information, see CRS Report RL31360, *Joint Strike Fighter (JSF): Potential National Security Questions Pertaining to a Single Production Line*, by (name redacted) and (name redacted).

argued that General Electric's considerable business in both commercial and military engines was sufficient to sustain General Electric's ability to produce this class of engine in the future.

Exports of the F-35 could also have a strong impact on the U.S. tactical aircraft industrial base through export. Most observers believe that the F-35 could potentially dominate the combat aircraft export market, much as the F-16 has. Like the F-16, the F-35 appears to be attractive because of its relatively low cost, flexible design, and promise of high performance. Competing fighters and strike fighters, including France's Rafale, Sweden's JAS Gripen, and the Eurofighter Typhoon, are positioned to challenge the F-35 in the fighter export market.

Some observers are concerned that by allowing foreign companies to participate in the F-35 program, DOD may be inadvertently opening up U.S. markets to foreign competitors who enjoy direct government subsidies. A May 2004 GAO report found that the F-35 program could "significantly impact" the U.S. and global industrial base.¹³⁶ GAO found that two laws designed to protect segments of the U.S. defense industry—the Buy American Act and the Preference for Domestic Specialty Metals clause—would have no impact on decisions regarding which foreign companies would participate in the F-35 program, because DOD has decided that foreign companies that participate in the F-35 program, and which have signed reciprocal procurement agreements with DOD to promote defense cooperation, are eligible for a waiver.

Future Joint Fighter Programs

DOD states that the F-35 program "was structured from the beginning to be a model of acquisition reform, with an emphasis on jointness, technology maturation and concept demonstrations, and early cost and performance trades integral to the weapon system requirements definition process."¹³⁷ A subsequent RAND Corporation study found that the fundamental concept behind the F-35 program—that of making one basic airframe serve multiple services' requirements—may have been flawed.¹³⁸ Congress may wish to consider how the advantages and/or disadvantages merits of joint programs may have changed as a consequence of evolutions in warfighting technology, doctrine, and tactics.

¹³⁶ General Accounting Office, *Joint Strike Fighter Acquisition: Observations on the Supplier Base*, GAO-04-554, May 2004.

¹³⁷ Department of Defense. *Selected Acquisition Report (SAR)[for] F-35 (JSF)*, December 31, 2007, p. 4.

¹³⁸ Mark A. Lorell, Michael Kennedy, Robert S. Leonard, Ken Munson, Shmuel Abramzon, David L. An, Robert A. Guffey, *Do Joint Fighter Programs Save Money?*, RAND Project Air Force, Santa Monica, CA, 2013, <http://www.rand.org/pubs/monographs/MG1225.html>.

Appendix. F-35 Key Performance Parameters

Table A-1 summarizes key performance parameters for the three versions of the F-35.

Table A-1. F-35 Key Performance Parameters (KPPs)

Source of KPP	KPP	F-35A Air Force CTOL version	F-35B Marine Corps STOVL version	F-35C Navy carrier- suitable version
Joint	Radio frequency signature	Very low observable	Very low observable	Very low observable
	Combat radius	590 nm Air Force mission profile	450 nm Marine Corps mission profile	600 nm Navy mission profile
	Sortie generation	3 surge / 2 sustained	4 surge / 3 sustained	3 surge / 2 sustained
	Logistics footprint	< 8 C-17 equivalent loads (24 PAA)	< 8 C-17 equivalent loads (20 PAA)	< 46,000 cubic feet, 243 short tons
	Mission reliability	93%	95%	95%
	Interoperability	Meet 100% of critical, top-level information exchange requirements; secure voice and data		
Marine Corps	STOVL mission performance – short-takeoff distance	n/a	550 feet	n/a
	STOVL mission performance – vertical lift bring-back	n/a	2 x 1K JDAM, 2 x AIM-120, with reserve fuel	n/a
Navy	Maximum approach speed	n/a	n/a	145 knots

Source: F-35 program office, October 11, 2007.

Notes: PAA is primary authorized aircraft (per squadron); vertical lift bring back is the amount of weapons with which plane can safely land.

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