**F35 Lightning II**

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*"Joint Strike Fighter" redirects here. For other uses, see* [*Joint Strike Fighter (disambiguation)*](http://en.wikipedia.org/wiki/Joint_Strike_Fighter_%28disambiguation%29)*.*

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| **F-35 Lightning II** |
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| An F-35A Lightning II, marked AA-1, lands at Edwards Air Force Base, California |
| **Role** | [Stealth](http://en.wikipedia.org/wiki/Stealth_aircraft) [multirole fighter](http://en.wikipedia.org/wiki/Multirole_combat_aircraft) |
| **National origin** | [United States](http://en.wikipedia.org/wiki/United_States) |
| **Manufacturer** | [Lockheed Martin Aeronautics](http://en.wikipedia.org/wiki/Lockheed_Martin_Aeronautics) |
| **First flight** | 15 December 2006 |
| **Introduction** | 2016-2018 |
| **Status** | In limited production, undergoing flight testing |
| **Produced** | 2006–present |
| **Number built** | 13 flight-test aircraft |
| **Unit cost** | F-35A: [US$](http://en.wikipedia.org/wiki/United_States_dollar)122 million ([flyaway cost](http://en.wikipedia.org/wiki/Flyaway_cost), 2011) F-35B: US$150M (avg. cost, 2011) F-35C: US$139.5M (avg. cost, 2011) Note: Average prices excludes development cost |
| **Developed from** | [Lockheed Martin X-35](http://en.wikipedia.org/wiki/Lockheed_Martin_X-35) |

The **Lockheed Martin F-35 Lightning II** is a family of single-seat, single-engine, [fifth generation](http://en.wikipedia.org/wiki/Fifth_generation_jet_fighter) [multirole fighters](http://en.wikipedia.org/wiki/Multirole_combat_aircraft) under development to perform [ground attack](http://en.wikipedia.org/wiki/Ground-attack_aircraft), [reconnaissance](http://en.wikipedia.org/wiki/Reconnaissance), and [air defense](http://en.wikipedia.org/wiki/Aerial_warfare) missions with [stealth](http://en.wikipedia.org/wiki/Stealth_aircraft) capability. The F-35 has three main models; one is a [conventional takeoff and landing](http://en.wikipedia.org/wiki/CTOL) variant, the second is a [short take off and vertical-landing](http://en.wikipedia.org/wiki/STOVL) variant, and the third is a [carrier](http://en.wikipedia.org/wiki/Aircraft_carrier)[-based](http://en.wikipedia.org/wiki/CATOBAR) variant.

The F-35 is descended from the [X-35](http://en.wikipedia.org/wiki/Lockheed_Martin_X-35), the product of the [Joint Strike Fighter](http://en.wikipedia.org/wiki/Joint_Strike_Fighter_Program) (JSF) program. JSF development is being principally funded by the [United States](http://en.wikipedia.org/wiki/United_States), with the [United Kingdom](http://en.wikipedia.org/wiki/United_Kingdom) and other partner governments providing additional funding. It is being designed and built by an aerospace industry team led by [Lockheed Martin](http://en.wikipedia.org/wiki/Lockheed_Martin). The F-35 took its [first flight](http://en.wikipedia.org/wiki/Maiden_flight) on 15 December 2006.

The United States intends to buy a total of 2,443 aircraft for an estimated US$323 billion, making it the most expensive defense program ever. The [United States Air Force](http://en.wikipedia.org/wiki/United_States_Air_Force) (USAF) budget data in 2010, along with other sources, projects the F-35 to have a [flyaway cost](http://en.wikipedia.org/wiki/Flyaway_cost) from US$89 million to US$200 million over the planned production of F-35s. Cost estimates have risen to $382 billion for 2,443 aircraft, at an average of $156 million each. The rising program cost estimates have cast doubt on the actual number to be produced for the U.S. In January 2011, the F-35B variant was placed on "probation" for two years because of development issues. In February 2011, the Pentagon put a price of $207.6 million for each of the 32 aircraft to be acquired in FY2012, rising to $304.15 million ($9,732.8/32) if its share of RDT&E spending is included.

**Development**

**JSF Program requirements and selection**

Main article: [Joint Strike Fighter Program](http://en.wikipedia.org/wiki/Joint_Strike_Fighter_Program)

The JSF program was designed to replace the United States military [F-16](http://en.wikipedia.org/wiki/General_Dynamics_F-16_Fighting_Falcon), [A-10](http://en.wikipedia.org/wiki/Fairchild_Republic_A-10_Thunderbolt_II), [F/A-18](http://en.wikipedia.org/wiki/McDonnell_Douglas_F/A-18_Hornet) (excluding newer [E/F "Super Hornet"](http://en.wikipedia.org/wiki/Boeing_F/A-18E/F_Super_Hornet) variants) and [AV-8B](http://en.wikipedia.org/wiki/McDonnell_Douglas_AV-8B_Harrier_II) tactical fighter aircraft. To keep development, production, and operating costs down, a common design was planned in three variants that share 80 [percent](http://en.wikipedia.org/wiki/Percent) of their parts:

* [F-35A](http://en.wikipedia.org/wiki/F-35A#F-35A#F-35A), conventional takeoff and landing ([CTOL](http://en.wikipedia.org/wiki/CTOL)) variant.
* [F-35B](http://en.wikipedia.org/wiki/F-35A#F-35B#F-35B), short-take off and vertical-landing ([STOVL](http://en.wikipedia.org/wiki/STOVL)) variant.
* [F-35C](http://en.wikipedia.org/wiki/F-35A#F-35C#F-35C), carrier-based [CATOBAR](http://en.wikipedia.org/wiki/CATOBAR) (CV) variant.

An F-35 wind tunnel testing model in the [Arnold Engineering Development Center](http://en.wikipedia.org/wiki/Arnold_Engineering_Development_Center)'s 16-foot transonic [wind tunnel](http://en.wikipedia.org/wiki/Wind_tunnel)

The F-35 is required to be four times more effective than legacy fighters in air-to-air combat, eight times more effective than legacy fighters in air-to-ground combat, and three times more effective than legacy fighters in reconnaissance and suppression of air defenses – while having better range and requiring less logistics support. Further, the design goals call for the F-35 to be the premier strike aircraft through 2040 and be second only to the F-22 in air superiority.

While the actual JSF development contract was signed on 16 November 1996, the contract for System Development and Demonstration (SDD) was awarded on 26 October 2001 to Lockheed Martin, whose X-35 beat the [Boeing X-32](http://en.wikipedia.org/wiki/Boeing_X-32). Although both aircraft met or exceeded requirements, the X-35 design was considered to have less risk and more growth potential. The designation of the new fighter as "F-35" is out-of-sequence with standard DoD aircraft numbering, by which it should have been "F-24". It came as a surprise even to Lockheed, which had been referring to the aircraft in-house by this expected designation.

**Design phase**

F-35 Lightning II [USAF](http://en.wikipedia.org/wiki/USAF) video

Based on wind tunnel testing, Lockheed Martin slightly enlarged its [X-35](http://en.wikipedia.org/wiki/Lockheed_Martin_X-35) design into the F-35. The forward fuselage is 5 inches (130 mm) longer to make room for avionics. Correspondingly, the horizontal [stabilators](http://en.wikipedia.org/wiki/Stabilator) were moved 2 inches (51 mm) rearward to retain balance and control. The top surface of the fuselage was raised by 1 inch (25 mm) along the center line. Also, it was decided to increase the size of the F-35B STOVL variant's weapons bay to be common with the other two variants. Manufacturing of parts for the first F-35 prototype airframe began in November 2003.

The F-35B STOVL variant was in danger of missing performance requirements in 2004 because it weighed too much; reportedly, by 2,200 lb. (1,000 kg) or 8 percent. In response, Lockheed Martin added engine thrust and thinned airframe members; reduced the size of the common weapons bay and vertical stabilizers; re-routed some thrust from the roll-post outlets to the main nozzle; and redesigned the wing-mate joint, portions of the electrical system, and the portion of the aircraft immediately behind the [cockpit](http://en.wikipedia.org/wiki/Cockpit_%28aviation%29). Many of the changes were applied to all three variants to maintain high levels of commonality. By September 2004, the weight reduction effort had reduced the aircraft's design weight by 2,700 pounds (1,200 kg).

On 7 July 2006, the US Air Force officially announced the name of the F-35: *Lightning II*, in honor of Lockheed's [World War II](http://en.wikipedia.org/wiki/World_War_II)-era twin-prop [Lockheed P-38 Lightning](http://en.wikipedia.org/wiki/Lockheed_P-38_Lightning) and the [Cold War](http://en.wikipedia.org/wiki/Cold_War)-era jet, the [English Electric Lightning](http://en.wikipedia.org/wiki/English_Electric_Lightning). [English Electric Company](http://en.wikipedia.org/wiki/English_Electric_Company)'s aircraft division was a predecessor of F-35 partner [BAE Systems](http://en.wikipedia.org/wiki/BAE_Systems). Lightning II was also an early company name for its fighter that was later named [F-22 Raptor](http://en.wikipedia.org/wiki/Lockheed_Martin_F-22_Raptor).

On 19 December 2008, Lockheed Martin rolled out the first weight-optimized F-35A (designated AF-1). It is the first F-35 to be produced at a full-rate production speed and is structurally identical to the production F-35As that will be delivered starting in 2010.

As of 5 January 2009, six F-35s were complete, including AF-1 and AG-1, and 17 were in production. "Thirteen of the 17 in production are pre-production test aircraft, and all of those will be finished in 2009," said John R. Kent, acting manager of F-35 Lightning II Communications at Lockheed Martin Aeronautics Company. "The other four are the first production-model planes, and the first of those will be delivered in 2010 to the U.S. Air Force, and will go to [Eglin Air Force Base](http://en.wikipedia.org/wiki/Eglin_Air_Force_Base)." On 6 April 2009, US Secretary of Defense [Robert Gates](http://en.wikipedia.org/wiki/Robert_Gates) proposed speeding up production for the US to buy 2,443 F-35s.

In August 2010, Lockheed Martin announced delays in resolving a "wing-at-mate overlap" production problem, which would slow initial production.

**Program cost increases and further delays**

On 21 April 2009, media reports, citing [Pentagon](http://en.wikipedia.org/wiki/Pentagon) sources, said that during 2007 and 2008, computer spies had managed to copy and siphon off several terabytes of data related to the F-35's design and electronics systems, potentially enabling the development of defense systems against the aircraft. However, Lockheed Martin has rejected suggestions that the project has been compromised, saying that it "does not believe any classified information had been stolen".

On 9 November 2009, Ashton Carter, under-secretary of defense for acquisition, technology and logistics, acknowledged that the Pentagon "joint estimate team" (JET) had found possible future cost and schedule overruns in the project and that he would be holding meetings to attempt to avoid these. On 1 February 2010, Gates removed JSF Program Manager U.S. Marine Major-General David Heinz and withheld $614 million in payments to Lockheed Martin because of program costs and delays.

On 11 March 2010, a report from the [Government Accountability Office](http://en.wikipedia.org/wiki/Government_Accountability_Office) to [United States Senate Committee on Armed Services](http://en.wikipedia.org/wiki/United_States_Senate_Committee_on_Armed_Services) projected the overall unit cost of an F-35A to be $112M in today's money. In 2010, Pentagon officials disclosed that the F-35 program has exceeded its original cost estimates by more than 50 percent. An internal Pentagon report critical of the JSF project states that "affordability is no longer embraced as a core pillar". On 24 March, Gates termed the recent cost overruns and delays as "unacceptable" in a testimony before the U.S. Congress. He characterized previous cost and schedule estimates for the project as "overly rosy". However, Gates insisted the F-35 would become "the backbone of U.S. air combat for the next generation" and informed the Congress that he had expanded the development period by an additional 13 months and budgeted $3 billion more for the testing program while slowing down production. Lockheed Martin expects to reduce government cost estimates by 20%.

In November 2010 as part of a cost-cutting measure, the co-chairs of the [National Commission on Fiscal Responsibility and Reform](http://en.wikipedia.org/wiki/National_Commission_on_Fiscal_Responsibility_and_Reform) suggested canceling procurement of the F-35B and halving orders of F-35As and F-35Cs. At the same time [*Air Force Magazine*](http://en.wikipedia.org/wiki/Air_Force_Magazine) reported that "Pentagon officials" are considering canceling the F-35B because its short range means that the bases or ships it operates from will be within range of hostile tactical ballistic missiles. However Lockheed Martin consultant Loren B. Thompson said that this rumor is merely a result of the usual tensions between the US Navy and Marine Corps, and there is no alternative to the F-35B as an [AV-8B](http://en.wikipedia.org/wiki/McDonnell_Douglas_AV-8B_Harrier_II) replacement. He also confirmed that there would be further delays and cost increases in the development process because of technical problems with the aircraft and software, but blamed most of the delays and extra costs on redundant flight test.

The [Center for Defense Information](http://en.wikipedia.org/wiki/Center_for_Defense_Information) estimated that the program would be restructured with an additional year of delay and $5 billion in additional costs. On 5 November 2010, the Block 1 software flew for the first time on BF-4 which included information fusion and initial weapons-release capability. As of the end of 2010, only 15% of the software remains to be written, but this includes the most difficult sections such as [data fusion](http://en.wikipedia.org/wiki/Data_fusion). But in 2011 it was revealed that only 50% of the eight million lines of code had actually been written and that it would take another six years and 110 additional software engineers in order to complete the software for this new schedule.

In January 2011 Defense Secretary [Robert Gates](http://en.wikipedia.org/wiki/Robert_Gates) expressed the Pentagon's frustration with the skyrocketing costs of the F-35 program when he said "The culture of endless money that has taken hold must be replaced by a culture of restraint." Focusing his attention on the troubled VTOL F-35B Gates ordered "a two-year probation", saying it "should be canceled" if corrections are unsuccessful. However, Gates has stated his support for the program. Some private analysts, such as Richard Aboulafia, of the Teal Group state that the whole F-35 program is becoming a money pit.

Former Pentagon manager Paul Kaminski has said that the lack of a complete test plan has added five years to the JSF program. As of February 2011, the main flaws with the aircraft are engine "screech", transonic wing roll-off and display flaws in the helmet mounted display.

The current schedule has the delivery of basic combat capability aircraft in late 2015, followed by full capability block three software in late 2016. The $56.4 billion development project for the aircraft should be completed in 2018 when the block five configuration is expected to be delivered, several years late and considerably over budget.

In November 2010, the GAO found that "Managing an extensive, still-maturing global network of suppliers adds another layer of complexity to producing aircraft efficiently and on-time" and that "However, due to the extensive amount of testing still to be completed, the program could be required to make alterations to its production processes, changes to its supplier base, and costly retrofits to produced and fielded aircraft, if problems are discovered."

**Design**

F-35A being towed to its inauguration ceremony on 7 July 2006

F-35B's thrust vectoring nozzle and lift fan

The F-35 appears to be a smaller, slightly more conventional, single-engine sibling of the sleeker, twin-engine [Lockheed Martin F-22 Raptor](http://en.wikipedia.org/wiki/Lockheed_Martin_F-22_Raptor), and indeed drew elements from it. The exhaust duct design was inspired by the [General Dynamics](http://en.wikipedia.org/wiki/General_Dynamics) Model 200 design, which was proposed for a 1972 supersonic VTOL fighter requirement for the [Sea Control Ship](http://en.wikipedia.org/wiki/Sea_Control_Ship). For specialized development of the F-35B STOVL variant, Lockheed consulted with the [Yakovlev Design Bureau](http://en.wikipedia.org/wiki/Yakovlev_Design_Bureau), purchasing design data from their development of the [Yakovlev Yak-141 "Freestyle"](http://en.wikipedia.org/wiki/Yakovlev_Yak-141). Although several experimental designs have been built and tested since the 1960s including the Navy's unsuccessful [Rockwell XFV-12](http://en.wikipedia.org/wiki/Rockwell_XFV-12), the F-35B is to be the first operational supersonic, STOVL stealth fighter.

The F-35 has a maximum speed of over Mach 1.6. With a maximum takeoff weight of 60,000 lb. (27,000 kg), the Lightning II is considerably heavier than the lightweight fighters it replaces. In empty and maximum gross weights, it more closely resembles the single-seat, single-engine [Republic F-105 Thunderchief](http://en.wikipedia.org/wiki/Republic_F-105_Thunderchief), which was the largest single-engine fighter of the [Vietnam war](http://en.wikipedia.org/wiki/Vietnam_war) era. However the F-35's modern engine delivers over 60 percent more thrust in an aircraft of the same weight so that in thrust to weight and wing loading it is much closer to a comparably equipped F-16.

Acquisition deputy to the assistant secretary of the Air Force, Lt. Gen. Mark D. "Shack" Shackelford has said that the F-35 is designed to be America's "premier surface-to-air missile killer and is uniquely equipped for this mission with cutting edge processing power, synthetic aperture radar integration techniques, and advanced target recognition."

Some improvements over current-generation fighter aircraft are:

* Durable, low-maintenance [stealth technology](http://en.wikipedia.org/wiki/Stealth_technology), using structural fiber mat instead of the high-maintenance coatings of legacy stealth platforms;
* Integrated avionics and sensor fusion that combine information from off- and on board sensors to increase the [pilot's](http://en.wikipedia.org/wiki/Aviator) situational awareness and improve target identification and weapon delivery, and to relay information quickly to other command and control (C2) nodes;
* High speed data networking including [IEEE 1394b](http://en.wikipedia.org/wiki/IEEE_1394_interface#FireWire_800_.28IEEE_1394b-2002.29) and [Fiber Channel](http://en.wikipedia.org/wiki/Fibre_Channel).
* The Autonomic Logistics Global Sustainment (ALGS), Autonomic Logistics Information System (ALIS) and Computerized Maintenance Management System (CMMS) help ensure aircraft uptime with minimal maintenance manpower.
* Electro hydrostatic actuators run by a power-by-wire flight-control system.

Lockheed Martin claims the F-35 is intended to have close and long-range air-to-air capability second only to that of the F-22 Raptor. The company has suggested that the F-35 could also replace the USAF's F-15C/D fighters in the air superiority role and the F-15E Strike Eagle in the ground attack role, but it does not have the range or payload of either F-15 model. The F-35A does carry a similar air-to-air armament as the [Boeing F-15SE Silent Eagle](http://en.wikipedia.org/wiki/Boeing_F-15SE_Silent_Eagle) when both aircraft are configured for low observable operations and has over 80 percent of the larger aircraft's combat radius.

The majority of the structural composites in the F-35 are made out of [bismaleimide (BMI)](http://en.wikipedia.org/wiki/Maleimide) and [composite epoxy material](http://en.wikipedia.org/wiki/Composite_epoxy_material).

The F-35 program has learned from the corrosion problems on the F-22. Compared to the F-22, the F-35 uses a gap filler that causes less [galvanic corrosion](http://en.wikipedia.org/wiki/Galvanic_corrosion) to the skin, is designed with fewer gaps in its skin that require gap filler, and has better drainage.

However, a United States Navy study found that the F-35 will cost 30 to 40 percent more to maintain than current jet fighters.

**Engines**

The F-35's main engine is the [Pratt & Whitney F135](http://en.wikipedia.org/wiki/Pratt_%26_Whitney_F135). The [General Electric/Rolls-Royce F136](http://en.wikipedia.org/wiki/General_Electric/Rolls-Royce_F136) is being developed as an alternative engine. The F135/F136 engines are not designed to [super cruise](http://en.wikipedia.org/wiki/Supercruise) in the F-35. The STOVL versions of both power plants use the [Rolls-Royce Lift System](http://en.wikipedia.org/wiki/Rolls-Royce_LiftSystem), patented by Lockheed Martin and built by Rolls-Royce. This system is more like the Russian [Yak-141](http://en.wikipedia.org/wiki/Yakovlev_Yak-141) and German [VJ 101D/E](http://en.wikipedia.org/wiki/EWR_VJ_101) than the preceding generation of STOVL designs, such as the [Harrier Jump Jet](http://en.wikipedia.org/wiki/Harrier_Jump_Jet) in which all of the lifting air went through the main fan of the [Rolls-Royce Pegasus](http://en.wikipedia.org/wiki/Rolls-Royce_Pegasus) engine.

The Lift System is composed of a lift fan, drive shaft, two roll posts and a "Three Bearing Swivel Module" (3BSM). The 3BSM is a [thrust vectoring](http://en.wikipedia.org/wiki/Thrust_vectoring) nozzle which allows the main engine exhaust to be deflected downward at the tail of the aircraft. The lift fan near the front of the aircraft provides a counter-balancing thrust. Somewhat like a vertically mounted [turbofan](http://en.wikipedia.org/wiki/Turbofan) within the forward fuselage, the lift fan is powered by the engine's low-pressure (LP) turbine via a drive shaft and gearbox. Roll control during slow flight is achieved by diverting unheated engine [bypass](http://en.wikipedia.org/wiki/Bypass_duct) air through wing mounted thrust nozzles called Roll Posts. Like lift engines, the added lift fan machinery is just dead weight during horizontal flight, but provides a net increase in payload capacity during vertical flight. The cool exhaust of the fan also reduces the amount of hot, high-velocity air that is projected downward during vertical takeoff, which can damage runways and aircraft carrier decks.

To date, F136 funding has come at the expense of other parts of the program, reducing the number of aircraft built and increasing their costs. The F136 team has claimed that their engine has a greater temperature margin which may prove critical for VTOL operations in hot, high altitude conditions.

Pratt & Whitney is also testing higher thrust versions of the F135, partly in response to GE's claims that the F136 is capable of producing more thrust than the 43,000 lbf (190 kN) supplied by early F135s. The F135 has demonstrated a maximum thrust of over 50,000 lbf (220 kN) during testing. The F-35's Pratt & Whitney F135 is the most powerful engine ever installed in a fighter aircraft.

The F135 is the second (radar) stealthy afterburning jet engine and like the [Pratt & Whitney F119](http://en.wikipedia.org/wiki/Pratt_%26_Whitney_F119) from which it was derived, has suffered from pressure pulsations in the afterburner at low altitude and high speed or "screech". In both cases this problem was fixed during development of the fighter program.

**Armament**

Weapons bay on a [mock-up](http://en.wikipedia.org/wiki/Mock-up) of the F-35

The F-35A includes a GAU-22/A, a four-barrel version of the [GAU-12 Equalizer](http://en.wikipedia.org/wiki/GAU-12_Equalizer) [25 mm](http://en.wikipedia.org/wiki/25_mm_caliber) cannon. The cannon will be mounted internally with 180 rounds in the F-35A and fitted as an external pod with 220 rounds in the F-35B and F-35C. The gun pod for the B and C variants will have stealth features. This pod could be used for different equipment in the future, such as EW, reconnaissance equipment, or possibly a rearward facing radar.

Internally, up to two 2,000 lb. (910 kg) air-to-ground bombs can be carried in A and C models (BRU-68) (two 1,000 lb. (450 kg) bombs in the B model (BRU-67)) along with two smaller weapons, normally expected to be air-to-air missiles. Lockheed Martin says on its website that the weapons load can also be configured as all-air-to-ground or all-air-to-air, and has suggested that a Block 5 version will be able to carry three internal weapons per bay instead of two, replacing the heavy bomb with two smaller weapons such as [AIM-120 AMRAAM](http://en.wikipedia.org/wiki/AIM-120_AMRAAM) air-to-air missiles. Missiles and bombs to be carried inside the weapon bays include [AIM-120 AMRAAM](http://en.wikipedia.org/wiki/AIM-120_AMRAAM), [AIM-132 ASRAAM](http://en.wikipedia.org/wiki/AIM-132_ASRAAM), the [Joint Direct Attack Munition](http://en.wikipedia.org/wiki/Joint_Direct_Attack_Munition) (JDAM) – up to 2,000 lb. (910 kg), the [Joint Standoff Weapon](http://en.wikipedia.org/wiki/AGM-154_Joint_Standoff_Weapon) (JSOW), [Small Diameter Bombs](http://en.wikipedia.org/wiki/GBU-39_Small_Diameter_Bomb) (SDB) – a maximum of four in each bay (three per bay in F-35B, or four [GBU-53/B](http://en.wikipedia.org/wiki/GBU-53/B) in each bay for all F-35 variants; a set of up to four [small diameter bombs](http://en.wikipedia.org/wiki/Small_diameter_bomb) takes the place of a single larger bomb), [Brimstone](http://en.wikipedia.org/wiki/Brimstone_missile) anti-armor missiles, and Cluster Munitions (WCMD). The [MBDA Meteor](http://en.wikipedia.org/wiki/MBDA_Meteor) air-to-air missile is currently being adapted to fit four internally in the missile spots and may be integrated into the F-35. A modified Meteor design with smaller tailfins for the F-35 was revealed in September 2010. The United Kingdom had originally planned to put up to four AIM-132 ASRAAM internally but this has been changed to carry 2 internal and 2 external ASRAAMs. The external ASRAAMs will add only an insignificant amount to the F-35's radar cross section and will allow attacks to slightly beyond visual range without using radar that might alert the target.

At the expense of being more detectable by radar, many more missiles, bombs and fuel tanks can be attached on four wing pylons and two near wingtip positions. The two wingtip locations can only carry [AIM-9X Sidewinder](http://en.wikipedia.org/wiki/AIM-9_Sidewinder#AIM-9X). The other pylons can carry the AIM-120 AMRAAM, [Storm Shadow](http://en.wikipedia.org/wiki/Storm_Shadow), [AGM-158 Joint Air to Surface Stand-off Missile](http://en.wikipedia.org/wiki/AGM-158_JASSM) (JASSM) cruise missiles, guided bombs, 480-gallon and 600-gallon fuel tanks. An air-to-air load of eight AIM-120s and two AIM-9s is conceivable using internal and external weapons stations, as well as a configuration of six 2,000 lb. (910 kg) bombs, two AIM-120s and two AIM-9s. With its payload capability, the F-35 can carry more weapons payload than the legacy fighters it is to replace as well as the F-22 Raptor. Solid-state lasers were being developed as optional weapons for the F-35 as of 2002. While the F-35 will take on the [Wild Weasel](http://en.wikipedia.org/wiki/Wild_Weasel) mission, it will lack the ability to carry an anti-radiation missile internally (and therefore stealthily) until the [JDRADM](http://en.wikipedia.org/wiki/JDRADM) is fielded in 2025.

Norway and Australia are funding a program to adapt the [Naval Strike Missile](http://en.wikipedia.org/wiki/Naval_Strike_Missile) (NSM) to fit the internal bays of the F-35. This will be a multirole version, named the Joint Strike Missile (JSM), and will be the only cruise missile to fit the internal bays. Studies have shown that the F-35 would be able to carry two of these internally, while four additional missiles could be carried externally. The missile has an expected range in excess of 150 nm. (278 km). On 12 April 2011 the Norwegian Ministry of Defense announced phase 2 of development with a cost estimate of 1029 MNOK.

The [B61 nuclear bomb](http://en.wikipedia.org/wiki/B61_nuclear_bomb) was scheduled for deployment in 2017, but delays in the F-35 program may delay this.

**Stealth and signatures**

Landing gear door of the F-35, showing its stealthy sawtooth design

The F-35 has been designed to have a low [radar cross section](http://en.wikipedia.org/wiki/Radar_cross_section) primarily due to [stealthy](http://en.wikipedia.org/wiki/Stealth_technology) materials used in construction, including fiber-mat. Unlike the previous generation of fighters, the F-35 was designed with a shape for low-observable characteristics.

The [Teen Series](http://en.wikipedia.org/wiki/Teen_Series) of fighters (F-15, F-16, F/A-18) were notable for always carrying large external fuel tanks, but in order to avoid negating its stealth characteristics the F-35 must fly most missions without external fuel tanks. Unlike the F-16 and F/A-18, the F-35 lacks [leading edge extensions](http://en.wikipedia.org/wiki/Leading_edge_extension) and instead uses stealth-friendly [chines](http://en.wikipedia.org/wiki/Leading_edge_extension#Chines) for vortex lift in the same fashion as the [SR-71 Blackbird](http://en.wikipedia.org/wiki/SR-71_Blackbird). The small bumps just forward of the engine air intakes form part of the [diverterless supersonic inlet (DSI)](http://en.wikipedia.org/wiki/Diverterless_supersonic_inlet) which is a simpler, lighter means to ensure high-quality airflow to the engine over a wide range of conditions. These inlets also crucially improve the aircraft's low-observable characteristics.

In spite of being smaller than the F-22, the F-35 has a larger radar cross section. It is said to be roughly equal to a metal golf ball rather than the F-22's metal marble. The F-22 was designed to be difficult to detect by all types of radars and from all directions. The F-35 on the other hand manifests its lowest radar signature from the frontal aspect because of compromises in design. Its surfaces are shaped to best defeat radars operating in the X and upper S band, which are typically found in fighters, surface-to-air missiles and their tracking radars, although the aircraft would be easier to detect using other radar frequencies. Ground crews require Repair Verification Radar (RVR) test sets in order to verify the RCS of the aircraft after performing repairs, which was not a concern for previous generations of non-stealth fighters.

Low observable aircraft must consider different types of detection and so the F-35 is not only radar stealthy, but it also has infrared and visual signature reduction incorporated.

In late 2008 the Air Force revealed that the F-35 would be about twice as loud at takeoff as the [McDonnell Douglas F-15 Eagle](http://en.wikipedia.org/wiki/McDonnell_Douglas_F-15_Eagle) and up to four times as loud during landing. As a result, residents near [Luke Air Force Base](http://en.wikipedia.org/wiki/Luke_Air_Force_Base), Arizona and [Eglin Air Force Base](http://en.wikipedia.org/wiki/Eglin_Air_Force_Base), Florida, possible home bases for the jet, requested that the Air Force conduct environmental impact studies concerning the F-35's noise levels. The city of [Valparaiso, Florida](http://en.wikipedia.org/wiki/Valparaiso%2C_Florida), adjacent to Eglin AFB, threatened in February 2009 to sue the Air Force over the impending arrival of the F-35s, but this lawsuit was settled in March 2010. Moreover, it was reported in March 2009 that testing by Lockheed Martin and the [Royal Australian Air Force](http://en.wikipedia.org/wiki/Royal_Australian_Air_Force) revealed that the F-35 was not as loud as first reported, being "only about as noisy as an [F-16](http://en.wikipedia.org/wiki/General_Dynamics_F-16_Fighting_Falcon) fitted with a Pratt & Whitney F100-PW-200 engine" and "quieter than the Lockheed Martin F-22 Raptor and the Boeing F/A-18E/F Super Hornet." However according to an acoustics study done by Lockheed Martin and the US Air Force, the noise levels of the F-35 are found to be comparable to the F-22 Raptor and F/A-18E/F Super Hornet.

**Cockpit**

F-35 cockpit and instrument panel mock-up

The F-35 features a full-panel-width "panoramic cockpit display" (PCD) [glass cockpit](http://en.wikipedia.org/wiki/Glass_cockpit), with dimensions of 20 by 8 inches (50 by 20 centimeters). A cockpit speech-recognition system ([Direct Voice Input](http://en.wikipedia.org/wiki/Direct_Voice_Input)) provided by [Adacel](http://en.wikipedia.org/wiki/Adacel) is planned to improve the pilot's ability to operate the aircraft over the current-generation interface. The F-35 will be the first US operational fixed-wing aircraft to use this system, although similar systems have been used in [AV-8B](http://en.wikipedia.org/wiki/McDonnell_Douglas_AV-8B_Harrier_II) and trailed in previous US jets, particularly the [F-16 VISTA](http://en.wikipedia.org/wiki/General_Dynamics_F-16_VISTA).

A helmet-mounted display system (HMDS) will be fitted to all models of the F-35. A helmet-mounted cueing system is already in service with the F-15s, F-16s and F/A-18s. While some fighters have offered HMDS along with a [head up display](http://en.wikipedia.org/wiki/Head_up_display) (HUD), this will be the first time in several decades that a front line tactical jet fighter has been designed without a HUD. The F-35 is equipped with a right-hand [side stick](http://en.wikipedia.org/wiki/Side-stick) controller in a standard Lockheed Martin [HOTAS](http://en.wikipedia.org/wiki/HOTAS) configuration.

The [Martin-Baker](http://en.wikipedia.org/wiki/Martin-Baker) US16E [ejection seat](http://en.wikipedia.org/wiki/Ejection_seat) is used in all F-35 variants. The US16E seat design balances major performance requirements, including safe-terrain-clearance limits, pilot-load limits, and pilot size. It uses a twin-catapult system that is housed in side rails.

The [General Dynamics F-16 Fighting Falcon](http://en.wikipedia.org/wiki/General_Dynamics_F-16_Fighting_Falcon) has a similarity in cockpit layout and so is being used to train pilots until training F-35s become available.

**Sensors and avionics**

Electro-optical target system (EOTS) under the nose of a mockup of the F-35

The F-35's sensor and communications suite is intended to facilitate [situational awareness](http://en.wikipedia.org/wiki/Situational_awareness), command-and-control and [network-centric warfare](http://en.wikipedia.org/wiki/Network-centric_warfare) capability. The main sensor on board the F-35 is it’s [AN/APG-81](http://en.wikipedia.org/wiki/APG-81) [AESA](http://en.wikipedia.org/wiki/AESA)-radar, designed by [Northrop Grumman Electronic Systems](http://en.wikipedia.org/wiki/Northrop_Grumman_Electronic_Systems). It is augmented by the Electro-Optical Targeting System (EOTS) mounted under the nose of the aircraft, designed by Lockheed Martin. This gives the same capabilities as the [Lockheed Martin Sniper XR](http://en.wikipedia.org/wiki/Lockheed_Martin_Sniper_XR) while avoiding making the plane more easily detectable.

Six additional passive infrared sensors are distributed over the aircraft as part of Northrop Grumman's AN/AAQ-37 distributed aperture system (DAS), which acts as a [missile warning system](http://en.wikipedia.org/wiki/Missile_Approach_Warning), reports missile launch locations, detects and tracks approaching aircraft spherically around the F-35, and replaces traditional night vision goggles for night operations and navigation. All DAS functions are performed simultaneously, in every direction, at all times. The F-35's AN/ASQ-239 (Barracuda) Electronic Warfare systems are designed by [BAE Systems](http://en.wikipedia.org/wiki/BAE_Systems) and include Northrop Grumman components. The communications, navigation and identification (CNI) suite is designed by Northrop Grumman and includes the [Multifunction Advanced Data Link](http://en.wikipedia.org/wiki/Multifunction_Advanced_Data_Link) (MADL). The F-35 will be the first jet fighter that has sensor fusion that combines both radio frequency and IR tracking for continuous target detection and identification in all directions which is shared via MADL to other platforms without compromising low observability.

The F-35 has been designed with synergy between sensors as a specific requirement, with the "senses" of the aircraft expected to provide a more cohesive picture of the reality around it, and be available in principle for use in any possible way, and any possible combination with one another. All of the sensors feed directly into the main processors to support the entire mission of the aircraft. For example the AN/APG-81 functions not just as a multi-mode radar, but also as part of the aircraft's electronic warfare system.

Unlike previous aircraft, such as the F-22, all software for the F-35 is written in [C++](http://en.wikipedia.org/wiki/C%2B%2B) for faster code development. The [Integrity DO-178B](http://en.wikipedia.org/wiki/Integrity_%28operating_system%29#INTEGRITY-178B) real-time operating system (RTOS) from [Green Hills Software](http://en.wikipedia.org/wiki/Green_Hills_Software) runs on [COTS](http://en.wikipedia.org/wiki/Commercial_off-the-shelf) Freescale PowerPC processors. The final Block 3 software for the F-35 is planned to have 8.6 million lines of software code. The scale of the program has led to a [software crisis](http://en.wikipedia.org/wiki/Software_crisis) as officials continue to discover that additional software needs to be written. General [Norton Schwartz](http://en.wikipedia.org/wiki/Norton_Schwartz) has said that the software is the biggest factor that might delay the USAF's initial operational capability which is now scheduled for April 2016. Michael Gilmore, Director of Operational Test & Evaluation, has written that, "the F-35 mission systems software development and test is tending towards familiar historical patterns of extended development, discovery in flight test, and deferrals to later increments."

The F-35's electronic warfare systems are intended to detect hostile aircraft first, which can then be scanned with the electro-optical system and action taken to engage or evade the opponent before the F-35 is detected.

The USAF has expressed interest in upgrading the F-22 fleet with F-35 style advanced sensors, but has yet to budget any funds for this.

The CATbird avionics testbed for the F-35 program has proved capable of detecting and jamming F-22 radars.

**Helmet-mounted display system**

Helmet-mounted display system

The F-35 need not be physically pointing at its target for weapons to be successful. This is possible because of sensors that can track and target a nearby aircraft from any orientation, provide the information to the pilot through his helmet (and therefore visible no matter which way they are looking), and provide the [seeker-head](http://en.wikipedia.org/w/index.php?title=Seeker-head&action=edit&redlink=1) of a missile with sufficient information. Recent missile types provide a much greater ability to pursue a target regardless of the launch orientation, called "High Off-Boresight" capability, although the speed and direction in which the munition is launched affect the effective range of the weapon. Sensors use combined radio frequency and infra-red (SAIRST) to continually track nearby aircraft while the pilot's [helmet-mounted display system](http://en.wikipedia.org/wiki/Head-mounted_display) (HMDS) displays and selects targets. The helmet system replaces the display suite-mounted head-up display used in earlier fighters.

The F-35's systems provide the edge in the "observe, orient, decide, and act" [OODA loop](http://en.wikipedia.org/wiki/OODA_loop); stealth and advanced sensors aid in observation (while being difficult to observe), automated target tracking helps in orientation, sensor fusion simplifies decision making, and the aircraft's controls allow action against targets without having to look away from them.

The problems with the current Vision Systems International helmet mounted display lead Lockheed Martin to issue a draft specification for proposals for an alternative on 1 March 2011.

**Manufacturing responsibilities**

[Lockheed Martin Aeronautics](http://en.wikipedia.org/wiki/Lockheed_Martin_Aeronautics) is the prime contractor and performs aircraft final assembly, overall system integration, mission system, and provides forward fuselage, wings and flight controls system. [Northrop Grumman](http://en.wikipedia.org/wiki/Northrop_Grumman) provides [Active Electronically Scanned Array](http://en.wikipedia.org/wiki/Active_Electronically_Scanned_Array) (AESA) radar, electro-optical Distributed Aperture System (DAS), Communications, Navigation, Identification (CNI), center fuselage, weapons bay, and arrestor gear. [BAE Systems](http://en.wikipedia.org/wiki/BAE_Systems) provides aft fuselage and empennages, horizontal and vertical tails, crew life support and escape systems, [Electronic warfare](http://en.wikipedia.org/wiki/Electronic_warfare) systems, fuel system, and Flight Control Software (FCS1). [Alenia](http://en.wikipedia.org/wiki/Alenia_Aeronautica) will perform final assembly for Italy and, according to an Alenia executive, assembly of all European aircraft with the exception of Turkey and the United Kingdom. As an international program, countries that help build the F-35 will form a competitive marketplace where parts and maintenance contracts are traded. On 24 November 2009, Jon Schreiber, head of F-35 international affairs program for the Pentagon, said that the United States will not share the software code for the F-35 with its allies. The F-35 program has seen a great deal of investment in automated production facilities. For example, Handling Specialty produced the wing assembly platforms for Lockheed Martin.

**RAND war games**

In 2008 it was reported that [RAND Corporation](http://en.wikipedia.org/wiki/RAND_Corporation) conducted simulated war games in which Russian [Sukhoi Su-35](http://en.wikipedia.org/wiki/Sukhoi_Su-35) fighters apparently defeated the F-35. As a result of these media reports, then Australian defense minister [Joel Fitzgibbon](http://en.wikipedia.org/wiki/Joel_Fitzgibbon) requested a formal briefing from the [Australian Department of Defense](http://en.wikipedia.org/wiki/Department_of_Defence_%28Australia%29) on the simulation. This briefing stated that the reports of the simulation were inaccurate and did not actually compare the F-35's flight performance against other aircraft.

The Pentagon and Lockheed Martin added that these simulations did not address air-to-air combat. A Lockheed Martin press-release points to USAF simulations regarding the F-35's air-to-air performance against potential adversaries described as "[4th generation](http://en.wikipedia.org/wiki/Fourth_generation_jet_fighter)" fighters, in which it claims the F-35 is "400 percent" more effective. Major General Charles R. Davis, USAF, the F-35 program executive officer, has stated that the "F-35 enjoys a significant Combat Loss Exchange Ratio advantage over the current and future air-to-air threats, to include Sukhois". The nature of the simulations, and the terms upon which the "400 percent" figure have been derived remains unclear. Regarding the original plan to fit the F-35 with only two air-to-air missiles, Major Richard Koch, chief of USAF Air Combat Command’s advanced air dominance branch is reported to have said that "I wake up in a cold sweat at the thought of the F-35 going in with only two air-dominance weapons."

**Concerns over performance and safety**

[Andrew Krepinevich](http://en.wikipedia.org/wiki/Andrew_Krepinevich) has questioned the reliance on "short range" aircraft like the F-35 or F-22 to 'manage' China in a future conflict and has suggested reducing the number of F-35s ordered in favor of a longer range platform like the [Next-Generation Bomber](http://en.wikipedia.org/wiki/Next-Generation_Bomber), but [Michael Wynne](http://en.wikipedia.org/wiki/Michael_Wynne), then [United States Secretary of the Air Force](http://en.wikipedia.org/wiki/United_States_Secretary_of_the_Air_Force) rejected this plan of action in 2007. However in 2011, the Center for Strategic and Budgetary Assessments (CSBA) pointed to the restructuring of the F-35 program and the return of the bomber project as a sign of their effectiveness, while [Rebecca Grant](http://en.wikipedia.org/wiki/Rebecca_Grant_%28political_expert%29) said that the restructuring was a "vote of confidence" in the F-35 and "there is no other stealthy, survivable new fighter program out there".

Former RAND author John Stillion has written of the F-35A's air-to-air combat performance that it “can’t turn, can’t climb, can’t run”, but Lockheed Martin test pilot Jon Beesley has countered that in an air-to-air configuration the F-35 has almost as much thrust as weight and a flight control system that allows it to be fully maneuverable even at a 50-degree [angle of attack](http://en.wikipedia.org/wiki/Angle_of_attack).

Chen Hu, editor-in-chief of [World Military Affairs](http://en.wikipedia.org/w/index.php?title=World_Military_Affairs&action=edit&redlink=1) magazine has said that the F-35 is too costly because it attempts to provide the capabilities needed for all three American services in a common airframe. [Dutch](http://en.wikipedia.org/wiki/Netherlands) news program NOVA show interviewed US defense specialist Winslow T. Wheeler and aircraft designer [Pierre Sprey](http://en.wikipedia.org/w/index.php?title=Pierre_Sprey&action=edit&redlink=1) who called the F-35 "heavy and sluggish" as well as having a "pitifully small load for all that money", and went on to criticize the value for money of the stealth measures as well as lacking fire safety measures. His final conclusion was that any air force would be better off maintaining its fleets of F-16s and F/A-18s compared to buying into the F-35 program. Lockheed spokesman John Kent has said that the missing fire-suppression systems would have offered "very small" improvements to survivability.

In the context of selling F-35s to Israel to match the F-15s that will be sold to Saudi Arabia, a senior U.S. defense official was quoted as saying that the F-35 will be "the most stealthy, sophisticated and lethal tactical fighter in the sky," and added "Quite simply, the F-15 will be no match for the F-35." After piloting the plane, RAF Squadron Leader Steve Long said that, over its existing planes, the F-35 will give "the RAF and Navy a quantum leap in airborne capability."

Consultant to Lockheed Martin [Loren B. Thompson](http://en.wikipedia.org/wiki/Lexington_Institute) has said that the "electronic edge F-35 enjoys over every other tactical aircraft in the world may prove to be more important in future missions than maneuverability".

In 2011, Canadian politicians raised the issue of the safety of the F-35's reliance on a single engine (as opposed to a twin-engine configuration, which provides a backup in case of an engine failure). Canada had previous experience with a high-accident rate with the single-engine [Lockheed CF-104 Starfighter](http://en.wikipedia.org/wiki/Lockheed_CF-104_Starfighter) with many accidents related to engine failures. Defense Minister Peter MacKay, when asked what would happen if the F-35’s single engine fails in the Far North, stated "It won’t".

**Next Generation Jammer**

The [United States Marine Corps](http://en.wikipedia.org/wiki/United_States_Marine_Corps) is considering replacing their [Northrop Grumman EA-6B Prowler](http://en.wikipedia.org/wiki/Northrop_Grumman_EA-6B_Prowler) electronic attack aircraft with F-35s that have stealthy jammer pods attached. On 30 September 2008, the United States Navy outlined the basic requirements of the NGJ and stated that the design must be modular and open. The Navy has selected four companies to submit designs for the Next Generation Jammer. The NGJ will also have cyber-attack capabilities where the AESA radar is used to insert tailored data streams into remote systems. The [ITT](http://en.wikipedia.org/wiki/ITT_Corporation)-[Boeing](http://en.wikipedia.org/wiki/Boeing) design for the NGJ includes six AESA arrays for all around coverage. The team has been awarded a $42 million contract to develop their design based on ITT's experience with broadband electronically steerable antenna arrays. At the same time contracts were also awarded to Raytheon, Northrop Grumman and BAE Systems.

**Operational history**

**Testing**

The first F-35A (designated AA-1) was rolled out in [Fort Worth, Texas](http://en.wikipedia.org/wiki/Fort_Worth%2C_Texas) on 19 February 2006. The aircraft underwent extensive ground testing at [Naval Air Station Joint Reserve Base Fort Worth](http://en.wikipedia.org/wiki/Naval_Air_Station_Joint_Reserve_Base_Fort_Worth) in late 2006. In September 2006 the first engine run of the [F135](http://en.wikipedia.org/wiki/Pratt_%26_Whitney_F135) afterburner turbofan in an airframe and tests were completed; the first time that the F-35 was completely functional on its own power systems. On 15 December 2006, the F-35A completed its maiden flight. A modified [Boeing 737-300](http://en.wikipedia.org/wiki/Boeing_737), the [Lockheed CATBird](http://en.wikipedia.org/wiki/Lockheed_CATBird) is used as an avionic test bed inside of which are racks holding all of F-35's avionics, as well as a complete F-35.

On 31 January 2008 at Fort Worth, Texas, Lt Col James "Flipper" Kromberg of the U.S. Air Force became the first military service pilot to evaluate the F-35, taking the aircraft through a series of maneuvers on its 26th flight. F-35 AA-1, on its 34th test flight, began [aerial refueling](http://en.wikipedia.org/wiki/Aerial_refueling) testing in March 2008. Another milestone was reached on 13 November 2008, when the AA-1 flew at supersonic speeds for the first time, reaching Mach 1.05 at 30,000 ft (9,144 m) making four transitions through the sound barrier, for a total of eight minutes of supersonic flight.

The first F-35B (designated BF-1) made its maiden flight on 11 June 2008. The flight, which featured a conventional takeoff, was piloted by BAE Systems' test pilot Graham Tomlinson. The BF-1 is the second of 19 System Development and Demonstration (SDD) F-35s, and the first to use new weight-optimized design features that will apply to all future F-35s. Testing of the STOVL propulsion system in flight began on 7 January 2010. The STOVL system was used for 14 minutes of the 48 minute test flight while the aircraft slowed from 210 knots (390 km/h) to 180 knots (330 km/h). The F-35B's first hover (full stop in mid-air) happened on 17 March 2010, followed by a STOVL landing, and on 18 March 2010 the first vertical landing was performed. During a test flight on 10 June 2010, the F-35B became the second STOVL aircraft to achieve supersonic speeds, the first being its ancestor, the [X-35B](http://en.wikipedia.org/wiki/Lockheed_Martin_X-35), which achieved the same feat on 20 July 2001. In January 2011, Lockheed Martin reported it had solved a problem with the aluminum bulkhead used only on the F-35B which had cracked during ground testing.

Although many of the initial flight test targets have been accomplished, the F-35 testing program completed "just under 100 sorties and about as many hours in 2.5 years" by June 2009 and was falling significantly behind schedule. A 2008 Pentagon Joint Estimate Team (JET I) estimated that the program was two years behind the latest public schedule, and a 2009 Joint Estimate Team (JET II) revised that estimate to predict a 30-month delay. Due to those delays in the testing program, production numbers will be reduced by 122 aircraft through 2015 in order to provide additional funds for development. Those additional funds will add $2.8 billion to the development funds and internal memos suggest that the official timeline will be extended by 13 months (not the 30 months the JET II team predicted the slip would be). The success of the Joint Estimate Team has led [Ashton Carter](http://en.wikipedia.org/wiki/Ashton_Carter) to call for more such teams for other poorly performing Pentagon projects.

Nearly 30 percent of all the test flights have required more than routine maintenance to get the aircraft flyable again. As of March 2010, the F-35 program had used a million more [man-hours](http://en.wikipedia.org/wiki/Man-hour) than predicted and flight testing is expected to result in further design changes. The United States Navy has projected that lifecycle costs over a fleet life of 65 years for all of the American F-35s will be $442 billion higher than the U.S. Air Force has projected. The delay in the F-35 program is expected to lead to a shortfall of around 100 jet fighters in the Navy/Marines team. Given careful management, service life extension of the Marines' legacy F/A-18s, and more burdens placed on Navy fighters, it may be possible to reduce this shortfall. The F-35C carrier variant's maiden flight took place on 7 June 2010, also at [NAS Fort Worth JRB](http://en.wikipedia.org/wiki/Naval_Air_Station_Joint_Reserve_Base_Fort_Worth). The 57 minute flight was executed by Lockheed test pilot Jeff "Slim" Knowles, who was the chief test pilot for the F-117 program. A total of 11 U.S. Air Force F-35s are to arrive in Fiscal Year 2011.

On 9 March 2011 all F-35s were grounded after a dual generator failure and oil leak in flight. This was the first significant flight failure since 2007. Seven of the ten test aircraft (which have an older model of generators, unlike the kind that failed in flight), were cleared to fly four days later. And this problem was found to be the result of faulty maintenance rather than a design or construction issue.

**International participation and procurement**

Main article: [Lockheed Martin F-35 Lightning II procurement](http://en.wikipedia.org/wiki/Lockheed_Martin_F-35_Lightning_II_procurement)

While the United States is the primary customer and financial backer, the United Kingdom, Italy, the Netherlands, Canada, Turkey, Australia, Norway and Denmark have agreed to contribute [US$](http://en.wikipedia.org/wiki/United_States_dollar)4.375 billion toward the development costs of the program. Total development costs are estimated at more than US$40 billion (underwritten largely by the United States), while the purchase of an estimated 2,400 planes is expected to cost an additional US$200 billion. The nine major partner nations plan to acquire over 3,100 F-35s through 2035. The F-35 is expected to lift the American share of the $16 billion fighter aircraft market from 58 percent to more than 67 percent as European competitors fall further behind.

There are three levels of international participation. The levels generally reflect the financial stake in the program, the amount of technology transfer and subcontracts open for bid by national companies, and the order in which countries can obtain production aircraft. The United Kingdom is the sole "Level 1" partner, contributing US$2.5 billion, which was about 10% of the planned development costs under the 1995 [Memorandum of Understanding](http://en.wikipedia.org/wiki/Memorandum_of_Understanding) that brought the UK into the project. Level 2 partners are [Italy](http://en.wikipedia.org/wiki/Italy), which is contributing US$1 billion; and the [Netherlands](http://en.wikipedia.org/wiki/Netherlands), US$800 million. Level 3 partners are [Turkey](http://en.wikipedia.org/wiki/Turkey), US$195 million; [Canada](http://en.wikipedia.org/wiki/Canada), US$160 million; [Australia](http://en.wikipedia.org/wiki/Australia), US$144 million; [Norway](http://en.wikipedia.org/wiki/Norway), US$122 million and [Denmark](http://en.wikipedia.org/wiki/Denmark), US$110 million. [Israel](http://en.wikipedia.org/wiki/Israel) and [Singapore](http://en.wikipedia.org/wiki/Singapore) have joined as Security Cooperative Participants (SCP).

**Variants**

Configuration of the three original F-35 variants

The F-35 is being built in three different main versions to suit various combat missions. A fourth variant, the F-35I is an export version for Israel.

**F-35A**

The F-35A is the conventional takeoff and landing ([CTOL](http://en.wikipedia.org/wiki/CTOL)) variant intended for the US Air Force and other air forces. It is the smallest, lightest F-35 version and is the only variant equipped with an internal cannon, the [GAU-22/A](http://en.wikipedia.org/wiki/GAU-12_Equalizer#GAU-22.2FA). This [25 mm](http://en.wikipedia.org/wiki/25_mm_caliber) cannon is a development of the [GAU-12](http://en.wikipedia.org/wiki/GAU-12_Equalizer) carried by the USMC's [AV-8B Harrier II](http://en.wikipedia.org/wiki/AV-8B_Harrier_II). It is designed for increased effectiveness against ground targets compared to the [20 mm](http://en.wikipedia.org/wiki/20_mm_caliber) [M61 Vulcan](http://en.wikipedia.org/wiki/M61_Vulcan) cannon carried by other USAF fighters.

The F-35A is expected to match the F-16 in maneuverability and instantaneous and sustained high-g performance, and outperform it in stealth, payload, range on internal fuel, avionics, operational effectiveness, supportability, and survivability. It is expected to match an F-16 that is carrying the usual external fuel tank in acceleration performance. It also has an internal laser designator and infrared sensors, equivalent to the Sniper XR pod carried by the F-16, but built in to reduce radar cross section.

The A variant is primarily intended to replace the USAF's [F-16 Fighting Falcon](http://en.wikipedia.org/wiki/General_Dynamics_F-16_Fighting_Falcon). It is also to replace the [A-10 Thunderbolt II](http://en.wikipedia.org/wiki/Fairchild_Republic_A-10_Thunderbolt_II) starting in 2028.

**F-35B**

The Pratt & Whitney F135 engine with [lift fan](http://en.wikipedia.org/wiki/Rolls-Royce_LiftSystem), roll posts, and rear vectoring nozzle, as designed for the F-35B, at the [Paris Air Show](http://en.wikipedia.org/wiki/Paris_Air_Show), 2007

The F-35B is the short takeoff and vertical landing ([STOVL](http://en.wikipedia.org/wiki/STOVL)) variant of the aircraft. Similar in size to the A variant, the B sacrifices about a third of the other versions fuel volume to make room for the [vertical flight system](http://en.wikipedia.org/wiki/Rolls-Royce_LiftSystem). Takeoffs and landing with vertical flight systems are by far the riskiest, and in the end, a decisive factor in design. Like the [AV-8B Harrier II](http://en.wikipedia.org/wiki/McDonnell_Douglas_AV-8B_Harrier_II), the B’s guns will be carried in a ventral pod. Whereas the F-35A is stressed to 9 g, the F-35B is stressed to 7 g. The F-35B was unveiled at Lockheed Martin's Fort Worth plant on 18 December 2007, and the first test flight was on 11 June 2008.

Unlike the other variants, because it can land vertically the F-35B has no landing hook. The "STOVL/HOOK" button in the cockpit initiates conversion instead of dropping the hook. The F-35B sends jet thrust directly downwards during vertical takeoffs and landing and the nozzle is being redesigned to spread the output out in an oval rather than a small circle so as to limit damage to asphalt and ship decks.

The [United States Marine Corps](http://en.wikipedia.org/wiki/United_States_Marine_Corps) plans to purchase 340 F-35Bs, to replace all current inventories of the [F/A-18 Hornet](http://en.wikipedia.org/wiki/McDonnell_Douglas_F/A-18_Hornet) (A, B, C and D-models), and AV-8B Harrier II in the [fighter](http://en.wikipedia.org/wiki/Fighter_aircraft), and [attack](http://en.wikipedia.org/wiki/Ground-attack_aircraft) roles.

The [Royal Air Force](http://en.wikipedia.org/wiki/Royal_Air_Force) and [Royal Navy](http://en.wikipedia.org/wiki/Royal_Navy) had planned to use the F-35B to replace their [Harrier GR9s](http://en.wikipedia.org/wiki/BAE_Harrier_II). One of the Royal Navy requirements was that the F-35B design should have a Shipborne Rolling and Vertical Landing (SRVL) mode so that wing lift could be added to powered lift to increase the maximum landing weight of carried weapons. This method of landing is slower than wire arrested landing and could disrupt regular carrier operations, as the landing method uses the same pattern of approach as wire arrested. With SRVL, the aircraft is able to "bring back" 2 × 1K JDAM, 2 × AIM-120 and reserve fuel. However, in October 2010, Prime Minister [David Cameron](http://en.wikipedia.org/wiki/David_Cameron) announced that the UK would change their F-35 order to the [CATOBAR](http://en.wikipedia.org/wiki/CATOBAR) F-35C variant.

Commandant of the Marine Corps, General [James Amos](http://en.wikipedia.org/wiki/James_Amos) has said that, in spite of its increasing costs and schedule delays, there is no plan B to substitute for the F-35B. The F-35B is larger than the aircraft it replaces, which required the [USS America (LHA-6)](http://en.wikipedia.org/wiki/USS_America_%28LHA-6%29) to be designed without needed well deck capabilities. In 2011, the USMC and USN signed an agreement that the USMC will purchase 340 F-35B and 80 F-35C while the USN will purchase 260 F-35C. The five squadrons of Marine Corps F-35Cs will be assigned to the Navy carriers while the Marine Corps F-35Bs will be used on Amphibious ships and ashore.

On 6 January 2011, Gates said that the 2012 budget would call for a two year pause in F-35B production during which the aircraft may be redesigned, or canceled if unsuccessful. Gates stated, "If we cannot fix this variant during this time frame, and get it back on track in terms of performance, cost and schedule, then I believe it should be canceled."

Lockheed Martin executive vice president Tom Burbage and former Pentagon director of operational testing Tom Christie have said that most of the delays in the total program have been due to issues with the F-35B, which forced massive redesigns on the other versions.

**F-35C**

The F-35C carrier variant features larger wings with foldable wingtip sections, larger wing and tail control surfaces for improved low-speed control, stronger landing gear for the stresses of [carrier](http://en.wikipedia.org/wiki/Aircraft_carrier) landings, and a stronger [tailhook](http://en.wikipedia.org/wiki/Tailhook) for use with [carrier](http://en.wikipedia.org/wiki/Aircraft_carrier) arrestor cables. The larger wing area allows for decreased landing speed while increasing both range and payload. With twice the range on internal fuel as the F/A-18C Hornet, the F-35C achieves much the same goal as the [F/A-18E/F Super Hornet](http://en.wikipedia.org/wiki/Boeing_F/A-18E/F_Super_Hornet).

The [United States Navy](http://en.wikipedia.org/wiki/United_States_Navy) will use the F-35C carrier variant. It intends to buy 480 F-35Cs to replace the F/A-18A, B, C, and D Hornets. The F-35C will also serve as a low-observable complement to the Super Hornet. On 27 June 2007, the carrier variant completed its Air System Critical Design Review (CDR). This allows the first two functional prototype F-35C units to be produced. The C variant is expected to be available beginning in 2014. The first F-35C was rolled out on 29 July 2009. On 6 November 2010, the first F-35C arrived at [Naval Air Station Patuxent River](http://en.wikipedia.org/wiki/Naval_Air_Station_Patuxent_River). The Marine Corps will also purchase 80 F-35Cs, enough for five squadrons, for use with Navy [carrier air wings](http://en.wikipedia.org/wiki/Carrier_air_wing) in a joint service agreement signed on March 14, 2011.

In October 2010, the United Kingdom decided to change its F-35B order to the F-35C, which will be used for both land and naval operations. The total number of F-35C aircraft to be procured has not been announced. However, it will be less than the 150 originally planned. The Royal Navy's new [Queen Elizabeth class aircraft carriers](http://en.wikipedia.org/wiki/Queen_Elizabeth_class_aircraft_carrier) are large enough to support non-STOVL operations and as a result, at least HMS *Queen Elizabeth* will have catapults and arrestor cables installed to allow F-35C and Allied naval aircraft operations. The carrier will typically carry 12 F-35Cs with the ability to deploy up to 36. The UK Strategic Defense & Security Review found that the F-35C's greater endurance in the air meant that fewer aircraft would be needed and that the F-35C has a 25 percent lower lifetime cost than the F-35B.

**F-35I**

Main article: [Lockheed Martin F-35 Lightning II procurement#Israel](http://en.wikipedia.org/wiki/Lockheed_Martin_F-35_Lightning_II_procurement#Israel)

F-35A with Israeli modifications. A senior Israel air force official stated "the aircraft will be designated F-35I, as there will be unique Israeli features installed in them". The United States will not allow for the integration of Israel's own electronic warfare systems into the aircraft’s built-in electronic suite. However, a plug-and-play feature added to the main computer will allow for use of Israeli electronics in an add-on fashion. Israel will be able to fit its own external jamming pod and plans to install its own air-to-air missiles and guided bombs in the F-35’s internal weapon bays.

**CF-35**

Main article: [Lockheed Martin F-35 Lightning II Canadian procurement](http://en.wikipedia.org/wiki/Lockheed_Martin_F-35_Lightning_II_Canadian_procurement)

The Canadian CF-35 will differ from the American F-35A through the addition of a drag chute and an F-35B/C style refueling probe. Norway may also use the drag chute option, as they also have icy runways.

**Specifications (F-35A)**

The first of 15 pre-production F-35s

F-35B cutaway with Lift Fan

*Data from* Lockheed Martin specifications, F-35 Program brief, F-35 JSF Statistics

**General characteristics**

* **Crew:** 1
* **Length:** 51.4 ft (15.67 m)
* [**Wingspan**](http://en.wikipedia.org/wiki/Wingspan)**:** 35 ft (10.7 m)
* **Height:** 14.2 ft (4.33 m)
* **Wing area:** 460 ft² (42.7 m²)
* [**Empty weight**](http://en.wikipedia.org/wiki/Manufacturer%27s_Weight_Empty)**:** 29,300 lb. (13,300 kg)
* **Loaded weight:** 49,540 lb. (22,470 kg)
* [**Max takeoff weight**](http://en.wikipedia.org/wiki/Maximum_Takeoff_Weight)**:** 70,000 lb. (31,800 kg)
* **Powerplant:** 1 × [Pratt & Whitney F135](http://en.wikipedia.org/wiki/Pratt_%26_Whitney_F135) afterburning [turbofan](http://en.wikipedia.org/wiki/Turbofan)
	+ **Dry thrust:** 28,000 lbf (125 kN)
	+ **Thrust with** [**afterburner**](http://en.wikipedia.org/wiki/Afterburner)**:** 43,000 [lbf](http://en.wikipedia.org/wiki/Pound-force) (191 kN)
* **Internal fuel capacity:** 18,480 lb. (8,382 kg)

**Performance**

* [**Maximum speed**](http://en.wikipedia.org/wiki/V_speeds#Vno)**:** [Mach](http://en.wikipedia.org/wiki/Mach_number) 1.6+ (1,200 mph, 1,930 km/h)
* [**Range**](http://en.wikipedia.org/wiki/Range_%28aircraft%29)**:** 1,200 [nm.](http://en.wikipedia.org/wiki/Nautical_mile) (2,220 km) on internal fuel
* [**Combat radius**](http://en.wikipedia.org/wiki/Combat_radius)**:** over 590 nm. (1,090 km) on internal fuel
* [**Service ceiling**](http://en.wikipedia.org/wiki/Ceiling_%28aeronautics%29)**:** 60,000 ft (18,288 m)
* [**Rate of climb**](http://en.wikipedia.org/wiki/Rate_of_climb)**:** [classified](http://en.wikipedia.org/wiki/Classified_information_in_the_United_States) (not publicly available)
* [**Wing loading**](http://en.wikipedia.org/wiki/Wing_loading)**:** 91.4 lb./ft² (446 kg/m²)
* [**Thrust/weight**](http://en.wikipedia.org/wiki/Thrust-to-weight_ratio)**:**
	+ **With full fuel:** 0.87
	+ **With 50% fuel:** 1.07
* ***g*-Limits:** 9 *g*

**Armament**

* **Guns:** 1 × [General Dynamics](http://en.wikipedia.org/wiki/General_Dynamics) [GAU-22/A Equalizer](http://en.wikipedia.org/wiki/GAU-12_Equalizer#GAU-22.2FA) [25 mm (0.984 in)](http://en.wikipedia.org/wiki/25_mm_caliber) [4-barreled gatling cannon](http://en.wikipedia.org/wiki/Gatling_gun#M61_Vulcan.2C_Minigun.2C_and_other_designs), internally mounted with 180 rounds
* [**Hardpoints**](http://en.wikipedia.org/wiki/Hardpoint)**:** 6 × external pylons on wings with a capacity of 15,000 lb. (6,800 kg) and 2 internal bays with 2 pylons each for a total weapons payload of 18,000 lb. (8,100 kg) and provisions to carry combinations of:
	+ **Missiles:**
		- [AIM-120 AMRAAM](http://en.wikipedia.org/wiki/AIM-120_AMRAAM)
		- [AIM-132 ASRAAM](http://en.wikipedia.org/wiki/AIM-132_ASRAAM)
		- [AIM-9X Sidewinder](http://en.wikipedia.org/wiki/AIM-9_Sidewinder#AIM-9X)
		- [IRIS-T](http://en.wikipedia.org/wiki/IRIS-T)
		- [JDRADM](http://en.wikipedia.org/wiki/JDRADM) (after 2020)
		- [AGM-154 JSOW](http://en.wikipedia.org/wiki/AGM-154_JSOW)
		- [AGM-158 JASSM](http://en.wikipedia.org/wiki/AGM-158_JASSM)
		- [JSM](http://en.wikipedia.org/wiki/Naval_Strike_Missile#Joint_Strike_Missile)
	+ **Bombs:**
		- [Mark 84](http://en.wikipedia.org/wiki/Mark_84_bomb), [Mark 83](http://en.wikipedia.org/wiki/Mark_83_bomb) and [Mark 82](http://en.wikipedia.org/wiki/Mark_82_bomb) GP bombs
		- [Mk.20 Rockeye II](http://en.wikipedia.org/wiki/CBU-100) cluster bomb
		- [Wind Corrected Munitions Dispenser](http://en.wikipedia.org/wiki/Wind_Corrected_Munitions_Dispenser) capable
		- [Paveway](http://en.wikipedia.org/wiki/Paveway)-series laser-guided bombs
		- [Small Diameter Bomb](http://en.wikipedia.org/wiki/Small_Diameter_Bomb) (SDB)
		- [JDAM](http://en.wikipedia.org/wiki/JDAM)-series
		- [B61 nuclear bomb](http://en.wikipedia.org/wiki/B61_nuclear_bomb)

**Avionics**

* [Northrop Grumman Electronic Systems](http://en.wikipedia.org/wiki/Northrop_Grumman_Electronic_Systems) [AN/APG-81](http://en.wikipedia.org/wiki/AN/APG-81) [AESA](http://en.wikipedia.org/wiki/Active_Electronically_Scanned_Array) radar
* Northrop Grumman Electronic Systems AN/AAQ-37 Distributed Aperture System (DAS) missile warning system
* [BAE Systems](http://en.wikipedia.org/wiki/BAE_Systems) [AN/ASQ-239](http://en.wikipedia.org/w/index.php?title=AN/ASQ-239&action=edit&redlink=1) (Barracuda) [electronic warfare](http://en.wikipedia.org/wiki/Electronic_warfare) system
* [Harris Corporation](http://en.wikipedia.org/wiki/Harris_Corporation) [Multifunction Advanced Data Link](http://en.wikipedia.org/wiki/Multifunction_Advanced_Data_Link) (MADL) communication system

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| --- |
| Differences between variants |
|  | **F-35ACTOL** | **F-35BSTOVL** | **F-35CCarrier version** |
| Length | 51.4 ft (15.7 m) | 51.3 ft (15.6 m) | 51.5 ft (15.7 m) |
| Wingspan | 35 ft (10.7 m) | 35 ft (10.7 m) | 43 ft (13.1 m) |
| Wing Area | 460 ft² (42.7 m²) | 460 ft² (42.7 m²) | 668 ft² (62.1 m²) |
| Empty weight | 29,300 lb. (13,300 kg) | 32,000 lb. (14,500 kg) | 34,800 lb. (15,800 kg) |
| Internal fuel | 18,500 lb. (8,390 kg) | 13,300 lb. (6,030 kg) | 19,600 lb. (8,890 kg) |
| Max takeoff weight | 70,000 lb. (31,800 kg) | 60,000 lb. (27,000 kg) | 70,000 lb. (31,800 kg) |
| Range | 1,200 nm. (2,220 km) | 900 nm. (1,670 km) | 1,400 nm. (2,520 km) |
| Combat radius oninternal fuel | 590 nm. (1,090 km) | 450 nm. (833 km) | 640 nm. (1,185 km) |
| Thrust/weightfull fuel50% fuel | 0.871.07 | 0.901.04 | 0.750.91 |

**See also**

|  |  |
| --- | --- |
|  | [***United States Air Force portal***](http://en.wikipedia.org/wiki/Portal%3AUnited_States_Air_Force) |
|  | [***United States Navy portal***](http://en.wikipedia.org/wiki/Portal%3AUnited_States_Navy) |
|  | [***United States Marine Corps portal***](http://en.wikipedia.org/wiki/Portal%3AUnited_States_Marine_Corps) |
|  | [***Aviation portal***](http://en.wikipedia.org/wiki/Portal%3AAviation) |

**Related development**

* [Lockheed Martin X-35](http://en.wikipedia.org/wiki/Lockheed_Martin_X-35)
* [Lockheed Martin F-22 Raptor](http://en.wikipedia.org/wiki/Lockheed_Martin_F-22_Raptor)

**Comparable aircraft**

* [Chengdu J-20](http://en.wikipedia.org/wiki/Chengdu_J-20)
* [Sukhoi PAK FA](http://en.wikipedia.org/wiki/Sukhoi_PAK_FA)
* [Advanced Medium Combat Aircraft](http://en.wikipedia.org/wiki/Advanced_Medium_Combat_Aircraft)

**Related lists**

* [List of fighter aircraft](http://en.wikipedia.org/wiki/List_of_fighter_aircraft)
* [List of active United States military aircraft](http://en.wikipedia.org/wiki/List_of_active_United_States_military_aircraft)
* [List of megaprojects, Aerospace](http://en.wikipedia.org/wiki/List_of_megaprojects#Aerospace_projects)