

How F-15s Work



It didn't take long for the world to figure out the combat potential of [airplanes](#). In 1911, only eight years after the Wright brothers got their creation off the ground, the U.S. military started dropping test bombs from above. A few years later, World War I troops were battling it out in the sky with machine-gun-packing fighter planes.

Things moved pretty quickly from there. Only 60 years later, the early single-engine propeller planes had evolved into sleek, powerful fighter jets that could make sharp aerial turns at more than 600 miles per hour (970 kph).

In this article, we'll look at one of the most famous fighters, the F-15. This remarkable aircraft is getting up in years -- it has been around since the early '70s -- but it's still a crucial piece of the U.S. arsenal. According to the U.S. Air Force, it has a perfect combat record, with over 100 victories and zero defeats. As we'll see, its success is due to its phenomenal maneuverability, advanced electronic equipment and fearsome firepower.

What is an F-15?

The **F-15 Eagle** is a small, highly maneuverable jet plane designed to fly combat missions in all weather conditions. Its primary mission is maintaining **air superiority**. In other words, its ultimate purpose is to defeat other planes in aerial combat.



Photo courtesy [U.S. Air Force](#)
An F-15C Eagle prepares to refuel.

The United States Air Force commissioned the plane after they got a look at the MiG-25, a powerful fighter jet the Soviet Union unveiled in 1967. The MiG-25, commonly known as "the Foxbat," was far superior to the primary U.S. fighter jet at the time, the F-4 Phantom, and in the heart of the Cold War, the Air Force needed a comparable aircraft as soon as possible. McDonnell Douglas (now merged with Boeing) won the contract for the new project and delivered the finished F-15 a few years later. The company has introduced several variations on this plane since then, as technology and needs have changed (see below). The current combat F-15 Eagle is the **F-15C**.

The Strike Eagle

The original F-15 Eagle was designed to handle only air-to-air targets (other planes). It wasn't built to bomb targets on the ground because the Air Force knew that the extra equipment would compromise the plane's aerial combat abilities. But when the Air Force needed a fighter bomber to replace the aging **F-111** until the new stealth [F-117](#) was ready, they decided to modify the F-15 for air-to-ground missions. The result was the F-15 Strike Eagle, designated F-15E.



Photo courtesy [U.S. Department of Defense](#)



Photo courtesy [U.S. Department of Defense](#)
The F-15 Strike Eagle (bottom) carries a number of air-to-ground weapons in addition to the air-to-air weapons you'll find on an F-15C (top).

The Strike Eagle is not a replacement for the original F-15, but a supplementary bomber plane. Surprisingly, the Air Force's temporary solution turned out to be one of the best fighter bombers ever made. In Operation Desert Storm, the Strike Eagle proved it could successfully fight its way past enemy planes, hit several ground targets, and then fight its way out of enemy territory.

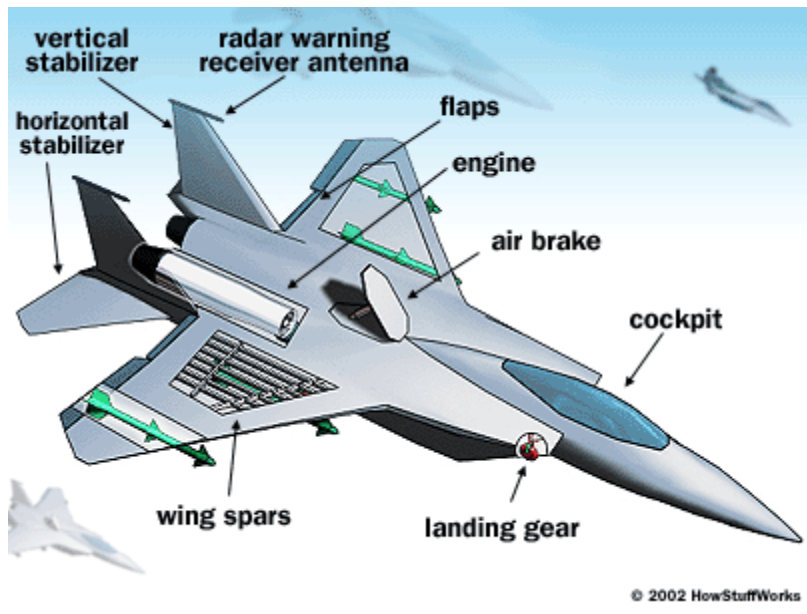
In the next section, we'll see how these two planes are put together and find out how they dive, climb and dodge so gracefully.

F-15 Models

- **F-15A** - The original F-15 combat plane, the F-15A first flew in July 1972. Like the current F-15C, this plane is designed for a single pilot.
- **F-15B** - The original F-15 training plane, the F-15B first flew in July 1973. This plane has two pilot stations -- one for an experienced instructor and one for a pilot in training.
- **F-15C** - An updated version of the F-15A, the Air Force added the F-15C in 1979. The F-15C has improved electronics, greater engine power and increased fuel capacity.
- **F-15D** - This is the two-seater training-plane counterpart to the F-15C.
- **F-15E** - A combination air-to-air fighter and air-to-ground bomber (also known as the F-15 Strike Eagle), the F-15E entered the Air Force arsenal in 1988. The biggest difference between the F-15C and the F-15E is the F-15E's extra cockpit station and its bombing capabilities. There are many smaller changes throughout the plane.
- **F-15I Thunder** - An Israeli variation on the F-15E
- **F-15S** - A Saudi variation on the F-15E
- **F-15J Peace Eagle** - A Japanese variation on the F-15C
- **F-15 ACTIVE** - The F-15 ACTIVE is a two-seater F-15 used in NASA research. ACTIVE stands for "advanced control technology for integrated vehicles."

Power and Flight

An F-15 has most of the elements you'll find on an ordinary jet plane. It has two wings that generate **lift**, it has rear vertical and horizontal stabilizers and rudders that balance and steer the plane, and it has twin [turbofan jet engines](#) at the rear of the plane that generate thrust.



The main difference between an F-15 and an ordinary jet is how these elements are balanced. The F-15's twin engines (Pratt & Whitney F-100-PW-220s or 229s) have a very high **thrust-to-weight ratio**, meaning they are relatively light for the amount of thrust they generate (they can generate almost eight times their own weight in thrust).



Photo courtesy [Department of Defense](#)
An Air Force maintenance squadron tests out a Pratt Whitney F100-PW-220e engine configured for the F-15.

The plane body is relatively light, too, though it is extremely strong. The wing spars (the support structures inside the wings) are made of titanium, which is lighter and stronger than [steel](#), and most of the skin is made of lightweight aluminum. According to the Air Force, each engine can generate between 25,000 and 29,000 pounds of thrust. The F-15C's normal weight is only 45,000 pounds, which means its thrust is actually greater than its weight! This lets it accelerate quickly, even while climbing in altitude.

The F-15 also has very low **wing loading**, meaning it has a lot of wing area for its weight. Greater wing area means greater lift, which makes the plane more agile. It can take off, ascend and turn much more quickly than an ordinary plane, which has much more weight per square foot of wing space.



Photo courtesy [U.S. Air Force](#)
An F-15's high thrust-to-weight ratio and low wing loading let it shoot off the ground at a sharp angle.

Afterburner, Tanks and Banks

The engines are outfitted with [afterburner nozzles](#), which can provide an extra kick of thrust when necessary. The afterburner simply injects fuel into the hot jet exhaust stream. It ignites, adding to the hot gases shooting out the back of the engine (see [this Question of the Day](#) for details on afterburners). At full force, the plane can get up to more than Mach 2.5 (approximately 1,854 mph / 2,984 kph).

The high engine power does come at a price -- poor fuel economy. Of course, the F-15 was designed with this limitation in mind. In order to extend its un-refueled range, it was built with large internal fuel tanks in the fuselage (the main body) and in the wings. It can also carry three external tanks, as well as a pair of aerodynamic form-fitting tanks under the wings that generate some lift of their own. Fully fueled, the F-15C can fly 3,450 miles (5,550 km), and the F-15E can fly 2,400 miles (3,860 km).



Photo courtesy [U.S. Air Force](#)
The F-15 can carry extra fuel in three external tanks. One mounts under each wing and one attaches to the fuselage.

The other problem with the engines is that they wear out pretty quickly. This is to be expected, given the amount of work they do. Fortunately, they're very easy to replace -- an Air Force ground crew can do it in less than an hour!

The F-15 doesn't just take off quickly, it stops quickly too. It has its own extendable **air-brake**, a hydraulically operated panel that dramatically increases the aircraft's drag to slow it down (just like a parachute).



Photo courtesy [U.S. Department of Defense](#)
An F-15 extends its air brake before landing.

Electronic Control

The main thing that sets the F-15 and other modern fighters apart from their predecessors are their electronic systems. Early fighter pilots controlled their planes mechanically, by moving linkages, and they mainly used their own eyes to target enemy planes. In stark contrast, nearly every aspect of the F-15 is computerized.



Photo courtesy [U.S. Department of Defense](#)

The plane is essentially a [robot](#). It has a central computer, which is connected to an array of advanced sensors. Based on input from the **inertial guidance system** (which contains highly sensitive [gyroscopic](#) sensors) and the pilot, the computer activates hydraulic actuators to adjust the wings and rear stabilizers. The pilot doesn't actually fly the plane directly: He or she gives instructions

and the computer decides how to carry them out. The computer is constantly making flight adjustments on its own to improve flight performance -- the computer artificially creates a relatively smooth ride. The F-15 computer can make necessary adjustments in milliseconds, about a hundred times faster than a human being.

Sensor Array

The plane's main "eye" is its computer-controlled [radar](#) system, mounted in the nose. The radar's job is to locate other aircraft and generate ground maps. The dish is mounted on moving gimbals, so it can pivot to scan different areas or follow a moving target. The radar figures out which way targets are moving using the pulse-Doppler system -- essentially, shifts in the reflected [radio wave](#) frequency indicate whether the target is moving toward the radar system or away from it (see [How Radar Works](#) for more information.)

The F-15 Strike Eagle has additional scanning equipment called the [low-altitude navigation and targeting infrared for night](#) (LANTIRN) system. The LANTIRN system is housed in two pods mounted to the bottom of the plane, near the engine inlets.

The **navigation pod** holds another radar unit that is optimized to map the ground terrain, and a [forward-looking-infrared \(FLIR\) night vision scanner](#) that picks up the infrared heat energy from surrounding objects.

Together, these sensors generate a detailed image of the ground below, allowing the pilot or computer to fly in total darkness.

If You're Shopping...

According to the Air Force, one F-15 Strike Eagle goes for \$31.1 million. The F-15D is a relative steal at only \$29.9 million, and a first generation plane will only cost you \$27.9 million. While this sounds like a lot to the average person, it's actually a pretty good deal in the military world. Airmen say it's a small price to pay for the F-15's extraordinary performance level.



Photo courtesy [U.S. Department of Defense](#)
One of the LANTIRN pods on an F-15 Strike Eagle

The **targeting pod** houses a powerful [laser](#) and another FLIR scanner, mounted to a swiveling turret. The laser works as a **range-finder**, calculating the distance to targets based on how long it takes a laser beam to bounce off of them, and also as a **target designator**, marking targets for [laser-guided missiles](#). The targeting system is designed to pick out ground targets, but it can also be used in air-to-air combat.

The central computer processes data from the radar and the LANTIRN system and presents targeting and navigation information to the crew. In the next section, we'll look inside the cockpit to see how the crew accesses this information, flies the plane and targets the enemy.

Inside the Cockpit

The original F-15 was designed for a single-person crew. The pilot flies the plane and targets enemy aircraft at the same time. The F-15 Strike Eagle has an additional station in the back of the cockpit for a **weapons systems officer**, or WSO (pronounced "wizzo"). In the Strike Eagle, the WSO is in charge of selecting and eliminating ground targets while the pilot concentrates on maneuvering the plane and fighting enemy aircraft. Both stations are housed in a sturdy "bubble" canopy on top of the plane. This canopy design gives the crew a full 360-degree view of their surroundings.



Photo courtesy [Department of Defense](#)

The F-15 bubble canopy gives the crew a wide view of the sky. This plane is preparing to refuel.

The pilot's station is designed to make flying and targeting as easy as possible. The computer presents most relevant information on the **heads-up display** (HUD), a monitor that projects an image onto a transparent screen at the front of the cockpit canopy. With the heads-up display, the pilot can monitor the flight data and the radar information while keeping an eye on the sky. This is crucial in combat -- a pilot can't keep looking down at gauges and instruments while evading or chasing enemy fighters. The Air Force is planning to eventually replace this system with a helmet-mounted monitor that projects flight data onto the pilot's visor.



Photo courtesy [U.S. Department of Defense](#)
An infrared terrain image displayed on an F-15's heads-up display

Controls

The pilot's controls are also fairly straightforward. The pilot steers the plane with a **control stick** located in the center of the cockpit, and controls the engine with the **throttle** on his or her left. Both controls have several buttons and switches that operate the radar equipment, select options on the heads-up display, and target and fire the weapons.

The controls are designed with the **hands-on throttle and stick (HOTAS)** system. In the HOTAS system, every switch and button on the controls has a different shape and texture. This way, the pilot can control all the major aspects of the plane without ever looking down into the cockpit.



Photo courtesy [U.S. Department of Defense](#)
The cockpit in the F-15 Strike Eagle (on the right) has an extra station for the weapons systems officer.

The WSO, by contrast, doesn't spend much time looking outside the cockpit. He or she monitors radar, LANTIRN and flight data on four multi-function displays (MFD) -- [cathode ray tube](#) monitors surrounded by buttons (sort of like the display on an [automatic teller machine](#)). The WSO position has a full set of flight controls, but this is only a back-up provision -- normally, the WSO doesn't help fly the plane. Both the pilot and the WSO sit in high-tech ACES II [ejection seats](#), which launch them clear of the plane in an emergency.

All of this expensive equipment serves one basic purpose: It is designed to deliver various missiles, bombs and bullets, known in military circles as **ordnance**, to enemy targets. In the next section, we'll find out what the F-15 is actually packing when it goes to war.

Missiles

The F-15 Eagle is loaded up with weaponry that can take out almost every aircraft in existence. It sports eight air-to-air missiles of different designs. It can carry various combinations of [AIM-120 advanced medium range air-to-air missiles](#) (AMRAAMs), [AIM-9L/M Sidewinder missiles](#), or [AIM-7F/M Sparrow missiles](#).



Photo courtesy [U.S. Department of Defense](#)
**Two F-15s launch AIM-7 Sparrow air-to-air missiles
in training exercises.**

All three missile types are designed to actively seek out their target. The AMRAAM and Sparrow missiles are both radar-guided. The AMRAAM has its own radar unit and flight control system. Before firing the missile, the F-15 computer transmits radar information specifying the intended target, and the missile's radar unit locks on. After the missile launches, its one goal is to steer itself (by adjusting flight fins) toward that target.

The Sparrow missile works on a similar principle, but it doesn't have its own radar transmitter. The pilot has to keep the plane's transmitter aimed at the target, to "paint" it for the missile.

The sidewinder missile uses an infrared sensor to pick up on an enemy plane's hot engine exhaust. The flight controls simply steer the missile toward the hottest area in sight.

Other Weapons

The F-15 also has a built-in [machine gun](#), an [M-61 20-mm 6-barrel cannon](#), mounted inside the starboard (right) wing. The gun has an efficient [Gatling gun](#) design that can fire about 6,000 rounds

per minute. It never gets the chance, however, because its magazine only holds 940 rounds. It can empty its entire magazine in less than 10 seconds!



Photo courtesy [U.S. Department of Defense](#)
Airmen load ammunition for the F-15's 20-mm cannon.

The pilot selects a different targeting display on the HUD for each weapon. The machine gun display, for example, consists of a funnel shape. The pilot maneuvers the plane so that the target is in the center of the funnel and then opens fire.

The F-15 Strike Eagle has everything the F-15 Eagle has, and it can also carry just about any air-to-ground missile in the Air Force arsenal. It often carries guided munitions, such as the [GBU-15 bomb](#). All in all, it can carry approximately 23,000 pounds (10,430 kg) of ordnance.



An F-15 Strike Eagle drops Mark 84 laser-guided bombs during a training exercise.

Both F-15 models also have a number of high-tech defenses. They have radar warning receivers, which detect enemy radar from ground stations, planes or guided missiles, and an advanced radar jammer to confuse these radar units. They also have a **chaff dispenser**, a device that shoots out a cloud of metal strips. Enemy radar picks up the chaff and temporarily loses its lock on the F-15.

The Future

The F-15's combination of high maneuverability, sophisticated electronics and powerful weaponry have made it a hugely successful weapon in the United States arsenal (and a number of other countries' arsenals, as well). But now it's approaching the end of its run. Boeing and Lockheed Martin have already developed its replacement, the [F-22 Raptor](#).



Photo courtesy [U.S. Air Force](#)
The F-22 Raptor, the F-15's high-tech replacement

The Raptor takes everything on the F-15 to a whole new level, with much greater acceleration, maneuverability and computer power. It's also designed for **stealth** flying, just like the F-117 and [B-2 bomber](#). When the F-22 enters service in 2005, the Air Force will phase out the F-15 Eagle. The F-15 Strike Eagle will keep flying for the foreseeable future.

For much more information about the F15, the F-22 and other military aircraft, check out the links on the next page.

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