**Stealth Aircraft**

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An [F-117 Nighthawk](https://en.wikipedia.org/wiki/F-117_Nighthawk) stealth strike aircraft

**Stealth aircraft** use [stealth technology](https://en.wikipedia.org/wiki/Stealth_technology) to avoid detection by features to interfere with [radar](https://en.wikipedia.org/wiki/Radar), as well as to reduce visibility in the [infrared](https://en.wikipedia.org/wiki/Infrared), visual, audio, and [radio frequency (RF)](https://en.wikipedia.org/wiki/Radio_frequency) spectrum. Development of stealth technology likely began in [Germany during World War II](https://en.wikipedia.org/wiki/History_of_Germany_during_World_War_II). Well-known modern examples of stealth aircraft include the United States' [F-117 Nighthawk](https://en.wikipedia.org/wiki/F-117_Nighthawk) (1981–2008), the [B-2 Spirit](https://en.wikipedia.org/wiki/Northrop_Grumman_B-2_Spirit), the [F-22 Raptor](https://en.wikipedia.org/wiki/Lockheed_Martin_F-22_Raptor), and the [F-35 Lightning II](https://en.wikipedia.org/wiki/F-35_Lightning_II).

While no aircraft is totally invisible to radar, stealth aircraft make it difficult for conventional radar to detect or track the aircraft effectively, increasing the odds of a successful attack. Stealth is the combination of passive low observable (LO) features and active emitters such as [Low Probability of Intercept Radars](https://en.wikipedia.org/wiki/Low_Probability_of_Intercept_Radar), radios and laser designators. These are usually combined with active defenses such as [chaff](https://en.wikipedia.org/wiki/Chaff_(radar_countermeasure)), [flares](https://en.wikipedia.org/wiki/Flare_(countermeasure)), and [ECM](https://en.wikipedia.org/wiki/Electronic_countermeasures). It is accomplished by using a complex design philosophy to reduce the ability of an opponent's sensors to detect, track, or attack the stealth aircraft. This philosophy also takes into account the heat, sound, and other emissions of the aircraft as these can also be used to locate it.

Full-size stealth combat aircraft demonstrators have been flown by the United States (in 1977), Russia (in 2010) and China (in 2011), while the [US military](https://en.wikipedia.org/wiki/U.S._Armed_Forces) has adopted three stealth designs, and is preparing to adopt the [Lockheed Martin F-35 Lightning II](https://en.wikipedia.org/wiki/Lockheed_Martin_F-35_Lightning_II).

Most recent fighter designs will claim to have some sort of stealth, low observable, reduced RCS or radar jamming capability, but there has been no air to air combat experience against stealth aircraft.

**Background**

During the First World War, an attempt to reduce the visibility of military aircraft through the experimental use of "Cellon" plastic transparent covering material resulted in single examples of the [Fokker E.III](https://en.wikipedia.org/wiki/Fokker_E.III) *Eindecker* fighter monoplane, the [Albatros C.I](https://en.wikipedia.org/wiki/Albatros_C.I) two-seat observation biplane, and one German heavy bomber design, the [Linke-Hofmann R.I](https://en.wikipedia.org/wiki/Linke-Hofmann_R.I) all being covered with the "Cellon" material; the latter two aircraft had all-wooden structures covered with the "Cellon" material, which degraded rapidly in direct sunlight and were not proceeded with any further.

Nearly three decades later, a more serious attempt at "invisibility" was tried with the [Horten Ho 229](https://en.wikipedia.org/wiki/Horten_Ho_229) [flying wing](https://en.wikipedia.org/wiki/Flying_wing) fighter-bomber, developed in Germany during the last years of World War II. In addition to the aircraft's shape, which may not have been a deliberate attempt to affect radar deflection, the majority of the Ho 229's wooden skin was bonded together using carbon-impregnated plywood resins designed with the purported intention of absorbing radar waves. Testing performed in early 2009 by the [Northrop-Grumman](https://en.wikipedia.org/wiki/Northrop-Grumman) Corporation established that this compound, along with the aircraft's shape, would have rendered the Ho 229 virtually invisible to the top-end [HF](https://en.wikipedia.org/wiki/High_frequency)-band, 20-30 MHz primary signals of Britain's [Chain Home](https://en.wikipedia.org/wiki/Chain_Home) early warning radar, provided the aircraft was traveling at high speed (approximately 550 mph (890 km/h)) at extremely low altitude (50–100 feet).

In the closing weeks of WWII the US military initiated "[Operation Paperclip](https://en.wikipedia.org/wiki/Operation_Paperclip)", an effort by the [US Army](https://en.wikipedia.org/wiki/US_Army) to capture as much advanced German weapons research as possible, and also to deny that research to advancing Soviet troops. A Horten glider and the nearly complete Ho 229 V3 third prototype airframe were secured and sent to Northrop Aviation for evaluation in the United States, who much later used a flying wing design for the B-2 stealth bomber. During WWII Northrop had been commissioned to develop a large wing-only long-range bomber ([XB-35](https://en.wikipedia.org/wiki/XB-35)) based on photographs of the Horten's record-setting glider from the 1930s, but their initial designs suffered controllability issues that were not resolved until after the war. Northrop's small one-man prototype (N9M-B) and a Horten wing-only glider are located in the [Chino Air Museum](https://en.wikipedia.org/wiki/Planes_of_Fame) in Southern California.

Modern stealth aircraft first became possible when Denys Overholser, a mathematician working for [Lockheed](https://en.wikipedia.org/wiki/Lockheed_Corporation) Aircraft during the 1970s, adopted a mathematical model developed by [Petr Ufimtsev](https://en.wikipedia.org/wiki/Petr_Ufimtsev), a Russian scientist, to develop a computer program called Echo 1. Echo made it possible to predict the radar signature an aircraft made with flat panels, called facets. In 1975, engineers at Lockheed [Skunk Works](https://en.wikipedia.org/wiki/Skunk_Works) found that an aircraft made with faceted surfaces could have a very low radar signature because the surfaces would radiate almost all of the radar energy away from the receiver. Lockheed built a model called "the Hopeless Diamond", so-called because it resembled a squat diamond, and looked too hopeless to ever fly. Because advanced computers were available to control the flight of even a Hopeless Diamond, for the first time designers realized that it might be possible to make an aircraft that was virtually invisible to radar.

Reduced radar cross section is only one of five factors the designers addressed to create a truly stealthy design such as the F-22. The F-22 has also been designed to disguise its infrared emissions to make it harder to detect by infrared homing ("heat seeking") surface-to-air or air-to-air missiles. Designers also addressed making the aircraft less visible to the naked eye, controlling radio transmissions, and noise abatement.

The first combat use of purpose-designed stealth aircraft was in December 1989 during [Operation Just Cause](https://en.wikipedia.org/wiki/Operation_Just_Cause) in [Panama](https://en.wikipedia.org/wiki/Panama). On 20 December 1989, two [USAF](https://en.wikipedia.org/wiki/USAF) F-117s bombed a Panamanian Defense Force barracks in Rio Hato, Panama. In 1991, F-117s were tasked with attacking the most heavily fortified targets in [Iraq](https://en.wikipedia.org/wiki/Iraq) in the opening phase of [Operation Desert Storm](https://en.wikipedia.org/wiki/Operation_Desert_Storm) and were the only jets allowed to operate inside Baghdad's city limits.

**General design**

The general design of a stealth aircraft is always aimed at reducing radar and thermal detection. It is the designer's top priority to satisfy the following conditions; some of which are listed below, by using their skills, which ultimately decides the success of the aircraft:-

* Reducing thermal emission from thrust
* Reducing radar detection by altering some general configuration (like introducing the split rudder)
* Reducing radar detection when the aircraft opens its weapons bay
* Reducing infra-red and radar detection during adverse weather conditions

**Limitations**



[B-2 Spirit](https://en.wikipedia.org/wiki/Northrop_Grumman_B-2_Spirit) stealth bomber of the [U.S Air Force](https://en.wikipedia.org/wiki/United_States_Air_Force)

**Instability of design**

Early stealth aircraft were designed with a focus on minimal [radar cross section](https://en.wikipedia.org/wiki/Radar_cross_section) (RCS) rather than aerodynamic performance. Highly-stealth aircraft like the F-117 Nighthawk are aerodynamically unstable in all three axes and require constant flight corrections from a [fly-by-wire](https://en.wikipedia.org/wiki/Fly-by-wire) (FBW) flight system to maintain controlled flight. Most modern non-stealth fighter aircraft are unstable on one or two axes only. However, in the pursuit of increased maneuverability, most 4th and 5th-generation fighter aircraft are designed with some degree of inherent instability that must be controlled by fly-by-wire computers. As for the [B-2 Spirit](https://en.wikipedia.org/wiki/Northrop_Grumman_B-2_Spirit), based on the development of the flying wing aircraft by Jack Northrop since 1940, design allowed creating stable aircraft with sufficient yaw control, even without vertical surfaces such as rudders.

**Aerodynamic limitations**

Earlier stealth aircraft (such as the F-117 and B-2) lack [afterburners](https://en.wikipedia.org/wiki/Afterburner), because the hot exhaust would increase their infrared footprint, and breaking the sound barrier would produce an obvious sonic boom, as well as surface heating of the aircraft skin which also increased the infrared footprint. As a result their performance in [air combat maneuvering](https://en.wikipedia.org/wiki/Air_combat_maneuvering) required in a [dogfight](https://en.wikipedia.org/wiki/Dogfight) would never match that of a dedicated fighter aircraft. This was unimportant in the case of these two aircraft since both were designed to be bombers. More recent design techniques allow for stealthy designs such as the F-22 without compromising aerodynamic performance. Newer stealth aircraft, like the F-22, F-35 and the [Sukhoi T-50](https://en.wikipedia.org/wiki/Sukhoi_T-50), have performance characteristics that meet or exceed those of current front-line jet fighters due to advances in other technologies such as flight control systems, engines, airframe construction and materials.

**Electromagnetic emissions**

The high level of computerization and large amount of electronic equipment found inside stealth aircraft are often claimed to make them vulnerable to passive detection. This is highly unlikely and certainly systems such as [Tamara](https://en.wikipedia.org/wiki/Tamara_passive_sensor) and [Kolchuga](https://en.wikipedia.org/wiki/Kolchuga_passive_sensor), which are often described as counter-stealth radars, are not designed to detect stray electromagnetic fields of this type. Such systems are designed to detect intentional, higher power emissions such as radar and communication signals. Stealth aircraft are deliberately operated to avoid or reduce such emissions.

Current [Radar Warning Receivers](https://en.wikipedia.org/wiki/Radar_Warning_Receiver) look for the regular pings of energy from mechanically swept radars while fifth generation jet fighters use [Low Probability of Intercept Radars](https://en.wikipedia.org/wiki/Low_Probability_of_Intercept_Radar) with no regular repeat pattern.

**Vulnerable modes of flight**

Stealth aircraft are still vulnerable to detection during, and immediately after using their weaponry. Since stealth payload (reduced RCS bombs and [cruise missiles](https://en.wikipedia.org/wiki/Cruise_missile)) are not yet generally available, and ordnance mount points create a significant radar return, stealth aircraft carry all armament internally. As soon as weapons bay doors are opened, the plane's RCS will be multiplied and even older generation radar systems will be able to locate the stealth aircraft. While the aircraft will reacquire its stealth as soon as the bay doors are closed, a fast response defensive weapons system has a short opportunity to engage the aircraft.

This vulnerability is addressed by operating in a manner that reduces the risk and consequences of temporary acquisition. The B-2's operational altitude imposes a flight time for defensive weapons that makes it virtually impossible to engage the aircraft during its weapons deployment. All stealthy aircraft carry weapons in internal weapons bays. New stealth aircraft designs such as the F-22 and F-35 can open their bays, release munitions and return to stealthy flight in less than a second.

Some weapons require that the weapon's guidance system acquire the target while the weapon is still attached to the aircraft. This forces relatively extended operations with the bay doors open.

Also, such aircraft as the F-22 Raptor and F-35 Lightning II Joint Strike Fighter can also carry additional weapons and fuel on hardpoints below their wings. When operating in this mode the planes will not be nearly as stealthy, as the hardpoints and the weapons mounted on those hardpoints will show up on radar systems. This option therefore represents a tradeoff between stealth or range and payload. External stores allow those aircraft to attack more targets further away, but will not allow for stealth during that mission as compared to a shorter range mission flying on just internal fuel and using only the more limited space of the internal weapon bays for armaments.

**Reduced payload**



In a 1994 [live fire exercise](https://en.wikipedia.org/wiki/Live_fire_exercise) near [Point Mugu, California](https://en.wikipedia.org/wiki/Point_Mugu,_California), a [B-2 Spirit](https://en.wikipedia.org/wiki/Northrop_Grumman_B-2_Spirit) dropped forty-seven 500 lb. (230 kg) class [Mark 82 bombs](https://en.wikipedia.org/wiki/Mark_82_bomb), which represents about half of a B-2's total ordnance payload in Block 30 configuration

Fully stealth aircraft carry all fuel and armament internally, which limits the payload. By way of comparison, the F-117 carries only two laser or GPS guided bombs, while a non-stealth attack aircraft can carry several times more. This requires the deployment of additional aircraft to engage targets that would normally require a single non-stealth attack aircraft. This apparent disadvantage however is offset by the reduction in fewer supporting aircraft that are required to provide air cover, air-defense suppression and electronic counter measures, making stealth aircraft "[force multipliers](https://en.wikipedia.org/wiki/Force_multiplier)".

**Sensitive skin**

Stealth aircraft often have skins made with [Radar-absorbent materials](https://en.wikipedia.org/wiki/Radar-absorbent_material) or RAMs. Some of these contain [Carbon black](https://en.wikipedia.org/wiki/Carbon_black) particles, some contain tiny iron spheres. There are many materials used in RAMs, and some are classified, particularly the materials that specific aircraft use.

**Cost of operations**

Stealth aircraft are typically more expensive to develop and manufacture. An example is the [B-2 Spirit](https://en.wikipedia.org/wiki/Northrop_Grumman_B-2_Spirit) that is many times more expensive to manufacture and support than conventional bomber aircraft. The B-2 program cost the U.S. Air Force almost $45 billion.

**Reflected waves**

[Passive (multistatic) radar](https://en.wikipedia.org/wiki/Passive_radar), [bistatic radar](https://en.wikipedia.org/wiki/Bistatic_radar) and especially [multistatic radar](https://en.wikipedia.org/wiki/Multistatic_radar) systems detect some stealth aircraft better than conventional [monostatic radars](https://en.wikipedia.org/wiki/Monostatic_radar), since first-generation stealth technology (such as the F117) reflects energy away from the transmitter's [line of sight](https://en.wikipedia.org/wiki/Line-of-sight_propagation), effectively increasing the [radar cross section](https://en.wikipedia.org/wiki/Radar_cross_section) (RCS) in other directions, which the passive radars monitor. Such a system typically uses either low frequency broadcast TV and FM radio signals (at which frequencies controlling the aircraft's signature is more difficult). Later stealth approaches do not rely on controlling the specular reflections of radar energy and so the geometrical benefits are unlikely to be significant.

Researchers at the [University of Illinois at Urbana-Champaign](https://en.wikipedia.org/wiki/University_of_Illinois_at_Urbana-Champaign) with support of [DARPA](https://en.wikipedia.org/wiki/DARPA), have shown that it is possible to build a [synthetic aperture radar](https://en.wikipedia.org/wiki/Synthetic_aperture_radar) image of an aircraft target using passive multistatic radar, possibly detailed enough to enable [automatic target recognition](https://en.wikipedia.org/wiki/Automatic_target_recognition) ([ATR](http://www.ifp.uiuc.edu/%7Esmherman/darpa/)).

In December 2007, [SAAB](https://en.wikipedia.org/wiki/Saab_AB) researchers revealed details for a system called Associative Aperture Synthesis Radar (AASR) that would employ a large array of inexpensive and redundant transmitters and a few intelligent receivers to exploit [forward scatter](https://en.wikipedia.org/wiki/Bistatic_radar#Forward_scatter_radars) to detect low observable targets. The system was originally designed to detect stealthy cruise missiles and should be just as effective against aircraft. The large array of inexpensive transmitters provides a degree of protection against anti-radar (or anti-radiation) missiles or attacks.

**Infrared (heat)**

Some analysts claim [Infra-red search and track](https://en.wikipedia.org/wiki/Infra-red_search_and_track) systems (IRSTs) can be deployed against stealth aircraft, because any aircraft surface heats up due to air friction and with a two channel IRST is a CO2 (4.3 µm absorption maxima) detection possible, through difference comparing between the low and high channel. These analysts point to the resurgence in such systems in Russian designs in the 1980s, such as those fitted to the [MiG-29](https://en.wikipedia.org/wiki/Mikoyan_MiG-29) and [Su-27](https://en.wikipedia.org/wiki/Sukhoi_Su-27). The latest version of the MiG-29, the [MiG-35](https://en.wikipedia.org/wiki/Mikoyan_MiG-35), is equipped with a new Optical Locator System that includes more advanced IRST capabilities.

In air combat, the optronic suite allows:

* Detection of non-afterburning targets at 45-kilometre (28 mi) range and more;
* Identification of those targets at 8-to-10-kilometre (5.0 to 6.2 mi) range; and
* Estimates of aerial target range at up to 15 kilometers (9.3 mi).

For ground targets, the suite allows:

* A tank-effective detection range up to 15 kilometers (9.3 mi), and aircraft carrier detection at 60 to 80 kilometers (37 to 50 mi);
* Identification of the tank type on the 8-to-10-kilometre (5.0 to 6.2 mi) range, and of an aircraft carrier at 40 to 60 kilometers (25 to 37 mi); and
* Estimates of ground target range of up to 20 kilometers (12 mi).

**Longer Wavelength Radar**

VHF radar systems have wavelengths comparable to aircraft feature sizes and should exhibit scattering in the resonance region rather than the optical region, allowing most stealth aircraft to be detected. This has prompted Nizhniy Novgorod Research Institute of Radio Engineering (NNIIRT) to develop VHF [AESAs](https://en.wikipedia.org/wiki/AESA) such as the NEBO SVU, which is capable of performing target acquisition for SAM batteries. Despite the advantages offered by VHF radar, their longer wavelengths result in poor resolution compared to comparably sized X-band radar array. As a result, these systems must be very large before they can have the resolution for an engagement radar.

The Dutch company [Thales Nederland](https://en.wikipedia.org/wiki/Thales_Nederland), formerly known as [Holland Signaal](https://en.wikipedia.org/w/index.php?title=Holland_Signaal&action=edit&redlink=1), developed a naval phased-array radar called [SMART-L](https://en.wikipedia.org/wiki/SMART-L), which is operated at L-Band and has counter-stealth.

**OTH radar (over-the-horizon radar)**

[Over-the-horizon radar](https://en.wikipedia.org/wiki/Over-the-horizon_radar) is a concept increasing radar's effective range over conventional radar. The Australian JORN [Jindalee Operational Radar Network](https://en.wikipedia.org/wiki/Jindalee_Operational_Radar_Network) can overcome certain stealth characteristics. It is claimed that the HF frequency used and the method of bouncing radar from ionosphere overcomes the stealth characteristics of the F-117A. In other words, stealth aircraft are optimized for defeating much higher-frequency radar from front-on rather than low-frequency radars from above.

**Advancements in computational power**

The stealth platforms may have slower advances in materials technology and physical limits so that further advances in stealth become either impossible or unaffordable. This may force future stealth platforms to stand off from their targets and use active countermeasures and long range weaponry to strike targets.

However if the stealth aircraft are constantly upgraded they can hope to jam or evade emerging threats better than similarly equipped non-stealthy platforms could.

**Operational usage of stealth aircraft**



The [F-117 Nighthawk](https://en.wikipedia.org/wiki/Lockheed_F-117_Nighthawk) stealth attack aircraft.



The [B-2 Spirit](https://en.wikipedia.org/wiki/Northrop_Grumman_B-2_Spirit) strategic stealth bomber

The U.S. is the only country to use stealth aircraft in combat. These deployments include the [United States invasion of Panama](https://en.wikipedia.org/wiki/United_States_invasion_of_Panama), the [first Gulf War](https://en.wikipedia.org/wiki/Gulf_War), the [Kosovo Conflict](https://en.wikipedia.org/wiki/Kosovo_Conflict), the [War in Afghanistan](https://en.wikipedia.org/wiki/War_in_Afghanistan_(2001%E2%80%93present)) the [War in Iraq](https://en.wikipedia.org/wiki/War_in_Iraq) and the [2011 military intervention in Libya](https://en.wikipedia.org/wiki/2011_military_intervention_in_Libya). The first use of stealth aircraft was in the U.S. invasion of Panama, where [F-117 Nighthawk](https://en.wikipedia.org/wiki/F-117_Nighthawk) stealth attack aircraft were used to drop bombs on enemy airfields and positions while evading enemy radar.

In 1990 the F-117 Nighthawk was used in the First Gulf War, where F-117s flew 1,300 sorties and scored direct hits on 1,600 high-value targets in Iraqwhile accumulating 6,905 flight hours. Only 2.5% of the American aircraft in Iraq were F-117s, yet they struck 40% of the strategic targets, dropping 2,000 tons of precision-guided munitions and striking their targets with an 80% success rate.

In the [1999 NATO bombing of Yugoslavia](https://en.wikipedia.org/wiki/1999_NATO_bombing_of_Yugoslavia) two stealth aircraft were used by the United States, the veteran F-117 Nighthawk, and the newly introduced [B-2 Spirit](https://en.wikipedia.org/wiki/Northrop_Grumman_B-2_Spirit) strategic stealth bomber. The F-117 performed its usual role of striking precision high-value targets and performed well, although one F-117 was [shot down](https://en.wikipedia.org/wiki/Stealth_aircraft#Stealth_aircraft_lost#Stealth_aircraft_lost) by a Serbian [Isayev S-125](https://en.wikipedia.org/wiki/Isayev_S-125) 'Neva-M' missile commanded by Colonel [Zoltán Dani](https://en.wikipedia.org/wiki/Zolt%C3%A1n_Dani). The, then new, B-2 Spirit was highly successful, destroying 33% of selected Serbian bombing targets in the first eight weeks of U.S. involvement in the War. During this war, B-2s flew non-stop to Kosovo from their home base in Missouri and back.

In the 2003 invasion of Iraq, F-117 Nighthawks and B-2 Spirits were used, and this was the last time the F-117 would see combat. F-117s dropped satellite-guided strike munitions on selected targets, with high success. B-2 Spirits conducted 49 sorties in the invasion, releasing 1.5 million pounds of munitions.

During the May 2011 [operation to kill Osama bin Laden](https://en.wikipedia.org/wiki/Death_of_Osama_bin_Laden#Revelation_of_stealth_helicopter), one of the helicopters used to clandestinely insert US troops into Pakistan crashed in the bin Laden compound. From the wreckage it was revealed this helicopter had stealth characteristics, making this the first publicly known operational use of a [stealth helicopter](https://en.wikipedia.org/wiki/Stealth_helicopter).

A recent use of stealth aircraft was in the [2011 military intervention in Libya](https://en.wikipedia.org/wiki/2011_military_intervention_in_Libya), where B-2 Spirits dropped 40 bombs on a Libyan airfield with concentrated air defenses in support of the UN no-fly zone.



The [F-22 Raptor](https://en.wikipedia.org/wiki/Lockheed_Martin_F-22_Raptor) fifth generation stealth air superiority fighter



Naval variant of the [F-35 Lightning II](https://en.wikipedia.org/wiki/Lockheed_Martin_F-35_Lightning_II) fifth-generation stealth multi-role fighter



A [Sukhoi PAK FA](https://en.wikipedia.org/wiki/Sukhoi_PAK_FA) fifth-generation stealth multirole fighter

Stealth aircraft will continue to play a valuable role in air combat with the United States using the [F-22 Raptor](https://en.wikipedia.org/wiki/Lockheed_Martin_F-22_Raptor), B-2 Spirit, and the [F-35 Lightning II](https://en.wikipedia.org/wiki/Lockheed_Martin_F-35_Lightning_II) to perform a variety of operations.

The [Russian](https://en.wikipedia.org/wiki/Russia) [Sukhoi PAK FA](https://en.wikipedia.org/wiki/Sukhoi_PAK_FA) stealth multi-role fighter is scheduled to be introduced from 2015, to perform various missions.

The [Sukhoi/HAL FGFA](https://en.wikipedia.org/wiki/Sukhoi/HAL_FGFA), the [Indian](https://en.wikipedia.org/wiki/India) version of the [PAK FA](https://en.wikipedia.org/wiki/PAK_FA) is scheduled to be introduced from 2017 in higher numbers, also to perform various missions.

The [People's Republic of China](https://en.wikipedia.org/wiki/People%27s_Republic_of_China) plans to introduce the [Chengdu J-20](https://en.wikipedia.org/wiki/Chengdu_J-20) stealth multi-role fighter round 2018. A prototype was flown in early 2011.

**Stealth aircraft lost**

Main articles: [F-117 Nighthawk#Combat loss](https://en.wikipedia.org/wiki/F-117_Nighthawk#Combat_loss), [Andersen Air Force Base B-2 accident](https://en.wikipedia.org/wiki/Andersen_Air_Force_Base_B-2_accident) , and [RQ-170 Sentinel](https://en.wikipedia.org/wiki/RQ-170_Sentinel)

The first time that a stealth aircraft was shot down was on March 27, 1999, during [Operation Allied Force](https://en.wikipedia.org/wiki/Operation_Allied_Force) when an American [F-117 Nighthawk](https://en.wikipedia.org/wiki/F-117_Nighthawk) was brought down by an [Isayev S-125](https://en.wikipedia.org/wiki/Isayev_S-125) 'Neva-M' missile launched by a Serbian Air Defense crew who were operating their radars on unusually long wavelengths. The pilot ejected and was rescued and the aircraft remained relatively intact due to slowly striking the ground, inverted.

In December 2011, Iranian sources showed videos of a captured [US RQ-170 stealth drone](https://en.wikipedia.org/wiki/Lockheed_Martin_RQ-170_Sentinel) in a good shape with intact central controlling unit. The information was later confirmed by US sources. The analysts say that the drone might have been captured by electronic cyber-attack or jamming. There are reports that China and Russia asked Iran to inspect the drone less than a week after the Iranian video was released.

A B-2 crashed on February 23, 2008 shortly after takeoff from [Andersen Air Force Base](https://en.wikipedia.org/wiki/Andersen_Air_Force_Base) in [Guam](https://en.wikipedia.org/wiki/Guam). The investigation stated the B-2 crashed after "heavy, lashing rains" caused water to enter skin-flush air-data sensors, which feed [angle of attack](https://en.wikipedia.org/wiki/Angle_of_attack) and [yaw](https://en.wikipedia.org/wiki/Yaw_angle) data to the computerized flight-control system. The water distorted pre-flight readings in three of the plane's 24 sensors, causing the flight-control system to send an erroneous correction to the B-2 on takeoff. The B-2 quickly [stalled](https://en.wikipedia.org/wiki/Stall_(flight)), became unrecoverable, and crashed. The sensors measure environmental factors including air pressure and density, for data to calculate airspeed, altitude and attitude. Because of the faulty readings, the flight computers determined inaccurate airspeed readings and incorrectly indicated a downward angle for the aircraft, which contributed to an early rotation and an un-commanded 30-degree pitch up and left yaw, resulting in the stall.

**List of stealth aircraft**

**Dedicated reduced cross section designs**

In service

* [B-2 Spirit](https://en.wikipedia.org/wiki/Northrop_Grumman_B-2_Spirit) – [Northrop Grumman](https://en.wikipedia.org/wiki/Northrop_Grumman)



* [F-22 Raptor](https://en.wikipedia.org/wiki/Lockheed_Martin_F-22_Raptor) – [Lockheed Martin](https://en.wikipedia.org/wiki/Lockheed_Martin) / [Boeing](https://en.wikipedia.org/wiki/Boeing)



* [F-35 Lightning II](https://en.wikipedia.org/wiki/F-35_Lightning_II) – [Lockheed Martin](https://en.wikipedia.org/wiki/Lockheed_Martin) / [BAE Systems](https://en.wikipedia.org/wiki/BAE_Systems) / [Northrop Grumman](https://en.wikipedia.org/wiki/Northrop_Grumman)



Retired

* [F-117 Nighthawk](https://en.wikipedia.org/wiki/F-117_Nighthawk) – [Lockheed Martin](https://en.wikipedia.org/wiki/Lockheed_Martin)



Under development

* [PAK FA](https://en.wikipedia.org/wiki/PAK_FA) – [Sukhoi](https://en.wikipedia.org/wiki/Sukhoi)



* [FGFA](https://en.wikipedia.org/wiki/FGFA) – [Sukhoi](https://en.wikipedia.org/wiki/Sukhoi) / [HAL](https://en.wikipedia.org/wiki/Hindustan_Aeronautics_Limited)



* [Chengdu J-20](https://en.wikipedia.org/wiki/Chengdu_J-20) – [Chengdu Aircraft Corporation](https://en.wikipedia.org/wiki/Chengdu_Aircraft_Corporation)



* [Shenyang J-31](https://en.wikipedia.org/wiki/Shenyang_J-31) - [Shenyang Aircraft Corporation](https://en.wikipedia.org/wiki/Shenyang_Aircraft_Corporation)



* [AMCA](https://en.wikipedia.org/wiki/Advanced_Medium_Combat_Aircraft) – [ADA](https://en.wikipedia.org/wiki/Aeronautical_Development_Agency) / [HAL](https://en.wikipedia.org/wiki/Hindustan_Aeronautics_Limited)



* [TuAF TFX](https://en.wikipedia.org/wiki/TuAF_TFX) - [Turkish Aerospace Industries](https://en.wikipedia.org/wiki/Turkish_Aerospace_Industries" \o "Turkish Aerospace Industries)



* [KAI KF-X](https://en.wikipedia.org/wiki/KAI_KF-X) - [Korea Aerospace Industries](https://en.wikipedia.org/wiki/Korea_Aerospace_Industries" \o "Korea Aerospace Industries) / [Indonesian Aerospace](https://en.wikipedia.org/wiki/Indonesian_Aerospace)



* [Shafaq](https://en.wikipedia.org/wiki/Shafaq) - [HESA / IAMI](https://en.wikipedia.org/wiki/Iran_Aircraft_Manufacturing_Industrial_Company" \o "Iran Aircraft Manufacturing Industrial Company)



* [Qaher-313](https://en.wikipedia.org/wiki/Qaher-313)



Conceptual

* [Next-Generation Bomber](https://en.wikipedia.org/wiki/Next-Generation_Bomber) – [Lockheed Martin](https://en.wikipedia.org/wiki/Lockheed_Martin) / [Boeing](https://en.wikipedia.org/wiki/Boeing)



* [PAK DA](https://en.wikipedia.org/wiki/PAK_DA) – [Tupolev](https://en.wikipedia.org/wiki/Tupolev)



* [2037 Bomber](https://en.wikipedia.org/wiki/2037_Bomber)



Cancelled

* [A-12 Avenger II](https://en.wikipedia.org/wiki/A-12_Avenger_II) – [McDonnell-Douglas](https://en.wikipedia.org/wiki/McDonnell-Douglas) / [General Dynamics](https://en.wikipedia.org/wiki/General_Dynamics)



* [Boeing X-32](https://en.wikipedia.org/wiki/Boeing_X-32) – Boeing prototype



* [YF-23 Black Widow II](https://en.wikipedia.org/wiki/YF-23_Black_Widow_II) – Northrop / McDonnell Douglas prototype



* [MBB Lampyridae](https://en.wikipedia.org/wiki/MBB_Lampyridae) – West German stealth fighter prototype



* [RAH-66 Comanche](https://en.wikipedia.org/wiki/RAH-66_Comanche) – Boeing Sikorsky



* [Horten Ho 229](https://en.wikipedia.org/wiki/Horten_Ho_229) – Flying wing turbojet fighter only 10% detected on radar, prototype test in 1944. Project cancelled in 1945 due to the worsening war situation.



Technology demonstrators

* [BAE Replica](https://en.wikipedia.org/wiki/BAE_Replica) – BAE Systems



* [YF-22](https://en.wikipedia.org/wiki/YF-22) - Developed into [F22 Raptor](https://en.wikipedia.org/wiki/F22_Raptor" \o "F22 Raptor)



* [Boeing Bird of Prey](https://en.wikipedia.org/wiki/Boeing_Bird_of_Prey) – Boeing



* [Have Blue](https://en.wikipedia.org/wiki/Have_Blue) – [Lockheed](https://en.wikipedia.org/wiki/Lockheed_Corporation)



* [Mitsubishi ATD-X](https://en.wikipedia.org/wiki/Mitsubishi_ATD-X) – [Mitsubishi Heavy Industries](https://en.wikipedia.org/wiki/Mitsubishi_Heavy_Industries)



* [Northrop Tacit Blue](https://en.wikipedia.org/wiki/Northrop_Tacit_Blue) – [Northrop](https://en.wikipedia.org/wiki/Northrop_Corporation)



* [MiG 1.44](https://en.wikipedia.org/wiki/Mikoyan_Project_1.44) – Russian 5th generation fighter prototype



* [X-35](https://en.wikipedia.org/wiki/X-35) - [JSF](https://en.wikipedia.org/wiki/JSF" \o "JSF) winning contender developed into [F-35 Lightning II](https://en.wikipedia.org/wiki/F-35_Lightning_II" \o "F-35 Lightning II)



* [X-32](https://en.wikipedia.org/wiki/X-32) - [JSF](https://en.wikipedia.org/wiki/JSF" \o "JSF) losing contender



**Accidental or secondary function reduced cross section designs**

* [Avro Vulcan](https://en.wikipedia.org/wiki/Avro_Vulcan) – British strategic bomber with delta wing and buried engines that gave an unplanned low radar cross-section



* [B-1B Lancer](https://en.wikipedia.org/wiki/B-1B_Lancer) – RCS to about 10 m2



* [Dassault Rafale](https://en.wikipedia.org/wiki/Dassault_Rafale) – RCS to about 0.75 m2



* [Eurofighter Typhoon](https://en.wikipedia.org/wiki/Eurofighter_Typhoon) – RCS to about 0.25-0.75 m2



* [Chengdu J-10](https://en.wikipedia.org/wiki/Chengdu_J-10) - Incorporates [radar absorbent material](https://en.wikipedia.org/wiki/Radar_absorbent_material" \o "Radar absorbent material)



* [Shenyang J-11](https://en.wikipedia.org/wiki/Shenyang_J-11) - B variants incorporates [radar absorbent materials](https://en.wikipedia.org/wiki/Radar_absorbent_material" \o "Radar absorbent material)



* [Shenyang J-15](https://en.wikipedia.org/wiki/Shenyang_J-15) - Incorporates [radar absorbent material](https://en.wikipedia.org/wiki/Radar_absorbent_material" \o "Radar absorbent material)



* [Shenyang J-16](https://en.wikipedia.org/wiki/Shenyang_J-16) - Incorporates [radar absorbent material](https://en.wikipedia.org/wiki/Radar_absorbent_material" \o "Radar absorbent material)



* [JF-17 Thunder](https://en.wikipedia.org/wiki/JF-17_Thunder) - Incorporates DSI and Block II variants include [radar absorbent material](https://en.wikipedia.org/wiki/Radar_absorbent_material" \o "Radar absorbent material)



* [F-16C/D and E/F Fighting Falcon](https://en.wikipedia.org/wiki/General_Dynamics_F-16_Fighting_Falcon) – from Block 30 has got reduced RCS to about 1.2m2



* [F/A-18E/F Super Hornet](https://en.wikipedia.org/wiki/F/A-18E/F_Super_Hornet) – The F/A-18E/F's radar cross section was reduced greatly from some aspects, mainly the front and rear. RCS to about 20dB lower as a F18 C/D



* [Lockheed SR-71 Blackbird](https://en.wikipedia.org/wiki/Lockheed_SR-71_Blackbird) – Skunkworks Blackbirds were first production RCS aircraft; 1962 with CIA A-12, then later with SR-71, YF-12 and M-21 Blackbird series of aircraft



* [Mikoyan MiG-29K](https://en.wikipedia.org/wiki/Mikoyan_MiG-29K) – Due to special coatings Mig-29K radar reflecting surface is 4-5 times smaller than of basic MiG-29. RCS to about 0.60-0.75 m2



* [Sukhoi Su-47](https://en.wikipedia.org/wiki/Sukhoi_Su-47) – Russian technology demonstrator



* [Messerschmitt Me 163](https://en.wikipedia.org/wiki/Messerschmitt_Me_163)B – rocket-powered fighter aircraft.



* [PZL-230 Skorpion](https://en.wikipedia.org/wiki/PZL-230_Skorpion)



* [Novi Avion](https://en.wikipedia.org/wiki/Novi_Avion) – Yugoslav prototype, designed to have a features to lower its RADAR cross section



**Unmanned reduced RCS designs**

* [Sharp Sword](https://en.wikipedia.org/w/index.php?title=Sharp_Sword&action=edit&redlink=1) - Shenyang Aircraft Corporation



* [Wind Blade](https://en.wikipedia.org/w/index.php?title=Wind_Blade&action=edit&redlink=1) - Shenyang Aircraft Corporation



* [Boeing X-45](https://en.wikipedia.org/wiki/Boeing_X-45) – Boeing, based on the manned Boeing Bird of Prey demonstrator ( technology demonstrator)



* [BAE Taranis](https://en.wikipedia.org/wiki/BAE_Taranis) – [BAE Systems](https://en.wikipedia.org/wiki/BAE_Systems) ( UCAV Technology Demonstrator)



* [Dassault nEUROn](https://en.wikipedia.org/wiki/Dassault_Neuron) – technology demonstrator



* [EADS Barracuda](https://en.wikipedia.org/wiki/EADS_Barracuda) – [EADS](https://en.wikipedia.org/wiki/EADS) (technology demonstrator)



* [Rheinmetall KZO](https://en.wikipedia.org/wiki/Rheinmetall_KZO) – [Rheinmetall](https://en.wikipedia.org/wiki/Rheinmetall) (tactical UAV)



* [RQ-3 Dark Star](https://en.wikipedia.org/wiki/RQ-3_Dark_Star) – [Lockheed](https://en.wikipedia.org/wiki/Lockheed_Martin)/[Skunk Works](https://en.wikipedia.org/wiki/Skunk_Works#As_used_by_Lockheed) (cancelled)



* [Sofreh Mahi](https://en.wikipedia.org/wiki/Sofreh_Mahi) - [IAMI](https://en.wikipedia.org/wiki/Iran_Aircraft_Manufacturing_Industrial_Company) ([UCAV](https://en.wikipedia.org/wiki/UCAV))



* [Armstechno NITI](https://en.wikipedia.org/wiki/Armstechno_NITI) – [Armstechno](https://en.wikipedia.org/w/index.php?title=Armstechno&action=edit&redlink=1) (tactical UAV)



* [Lockheed Martin RQ-170 Sentinel](https://en.wikipedia.org/wiki/Lockheed_Martin_RQ-170_Sentinel) – [Lockheed Martin](https://en.wikipedia.org/wiki/Lockheed_Martin)



* [MiG Skat](https://en.wikipedia.org/wiki/MiG_Skat) – [Mikoyan](https://en.wikipedia.org/wiki/Mikoyan)



* [Northrop Grumman X-47B](https://en.wikipedia.org/wiki/Northrop_Grumman_X-47B) – [Northrop Grumman](https://en.wikipedia.org/wiki/Northrop_Grumman) (technology demonstrator)



* [DRDO AURA](https://en.wikipedia.org/wiki/DRDO_AURA)



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