A

Seminar report

On

Stealth Technology

Submitted in partial fulfillment of the requirement for the award of degree
Of Civil

SUBMITTED TO: **SUBMITTED BY:**

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Preface

I have made this report file on the topic **Stealth Technology;** I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

Thirdly, I would like to thank my friends who helped me to make my work more organized and well-stacked till the end.

Next, I would thank Microsoft for developing such a wonderful tool like MS Word. It helped my work a lot to remain error-free.

Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

Contents:

INTRODUCTION:

Stealth technology also known as **LO technology** (**low observable technology**) is a sub-discipline of military tactics and passive electronic countermeasures, which cover a range of techniques used with personnel, aircraft, ships, submarines, and missiles, in order to make them less visible (ideally invisible) to radar, infrared,sonar and other detection methods.

Development in the United States occurred in 1958, where earlier attempts in preventing radar tracking of its U-2 spy planes during the Cold War by the Soviet Union had been unsuccessful. Designers turned to develop a particular shape for planes that tended to reduce detection, by redirecting electromagnetic waves from radars. Radar absorbent material was also tested and made to reduce or block radar signals that "bounced" off from the surface of planes. Such changes to shape and surface composition form stealth technology as currently deployed on the B-2 Spirit "Stealth Bomber".

Billions of dollars have also been spent in developing stealth over a number of decades but the U.S. has been the only country economically able to do this.

The concept of stealth is to operate or hide without giving enemy forces any indications as to the presence of friendly forces. This concept was first explored through camouflage by blending into the background visual clutter. As the potency of detection and interception technologies (radar, IRST, surface-to-air missiles etc.) have increased over time, so too has the extent to which the design and operation of military personnel and vehicles have been affected in response. Some military uniforms are treated with chemicals to reduce their infrared signature. A modern "stealth" vehicle will generally have been designed from the outset to have reduced or controlled signature. Varying degrees of stealth can be achieved. The exact level and nature of stealth embodied in a particular design is determined by the prediction of likely threat capabilities.

History

In England, irregular units of gamekeepers in the 17th century were the first to adopt drab colours (common in the 16th century Irish units) as a form of camouflage, following examples from the continent.

Yehudi lights were successfully employed in World War II by RAF Shorts Sunderland aircraft in attacks on U-boats.

In 1945 a Grumman Avenger with Yehudi lights got within 3,000 yards (2,700 m) of a ship before being sighted. This ability was rendered obsolete by the radar of the time.

One of the earliest stealth aircraft seems to have been the Horten Ho 229 flying wing. This included carbon powder in the glue to absorb radio waves. However, it was never deployed in any quantity.

In 1958, the CIA requested funding for a reconnaissance aircraft, to replace U-2 spy planes in which Lockheed secured contractual rights to produce the aircraft. "Kelly" Johnson and his team at Lockheed's Skunk Works were assigned to produce the A-12 or OXCART the first of the former top secret classified Blackbird series which operated at high altitude of 70000 to 80000 ft and speed of Mach 3.2 to avoid radar detection. Radar absorbent material had already been introduced on U-2 spy planes, and various plane shapes had been developed in earlier prototypes named A1 to A11 to reduce its detection from radar. Later in 1964, using previous models an optimal plane shape taking into account compactness was developed where another "Blackbird", the SR-71, was produced, surpassing previous models in both altitude of 90 000 ft and speed of Mach 3.3.

During 1970s, the U.S. Department of Defence then launched a project called Have Blue the project to develop a stealth fighter. Bidding between both Lockheed and Northrop for the tender was fierce to secure the multi billion dollar contract. Lockheed incorporated in its program paper written by a Soviet/Russian physicist Pyotr Ufimtsev in 1962 titled *Method of Edge Waves in the Physical Theory of Diffraction*, Soviet Radio, Moscow, 1962. In 1971 this book was translated into English with the same title by U.S. Air Force, Foreign Technology Division (National Air Intelligence Center) , Wright-Patterson AFB, OH, 1971. Technical Report AD 733203, Defense Technical Information Center of USA, Cameron Station, Alexandria , VA, 22304-6145, USA. This theory played a critical role in the design of American stealth-aircraft F-117 and B-2. The paper was able to find whether a plane's shape design would minimise its detection by radar or its radar cross-section (RCS) using a series of equations could be used to evaluate the radar cross section of any shape. Lockheed used it to design a shape they called the Hopeless Diamond, securing contractual rights to mass produce the F-117 Nighthawk.

The F-117 project began with a model called "The Hopeless Diamond" (wordplay on the Hope Diamond) in 1975 due to its bizarre appearance. In 1977 Lockheed produced two 60% scale models under the Have Blue contract. The Have Blue program was a stealth technology demonstrator that lasted from

1976 to 1979. The successes of Have Blue lead the Air Force to create the *Senior Trend* program which developed the F-117.

Stealth principles

Stealth technology (or LO for "low observability") is not a single technology. It is a combination of technologies that attempt to greatly reduce the distances at which a person or vehicle can be detected; in particular radar cross section reductions, but also acoustic, thermal, and other aspects:

Radar cross-section (RCS) reductions

Almost since the invention of radar, various techniques have been tried to minimize detection. Rapid development of radar during WWII led to equally rapid development of numerous counter radar measures during the period; a notable example of this was the use of chaff.

The term "stealth" in reference to reduced radar signature aircraft became popular during the late eighties when the Lockheed Martin F-117 stealth fighter became widely known. The first large scale (and public) use of the F-117 was during the Gulf War in 1991. However, F-117A stealth fighters were used for the first time in combat during Operation Just Cause, the United States invasion of Panama in 1989. Increased awareness of stealth vehicles and the technologies behind them is prompting the development of techniques for detecting stealth vehicles, such as passive radar arrays and low-frequency radars. Many countries nevertheless continue to develop low-RCS vehicles because they offer advantages in detection range reduction and amplify the effectiveness of on-board systems against active radar guidance threats.

Vehicle shape

The F-35 Lightning II offers better stealthy features (such as this landing gear door) than previous American fighters, such as the F-16 Fighting Falcon

The possibility of designing aircraft in such a manner as to reduce their radar cross-section was recognized in the late 1930s, when the first radar tracking systems were employed, and it has been known since at least the 1960s that aircraft shape makes a significant difference in detectability. The Avro Vulcan, a British bomber of the 1960s, had a remarkably small appearance on radar despite its large size, and occasionally disappeared from radar screens entirely.

It is now known that it had a fortuitously stealthy shape apart from the vertical element of the tail.

On the other hand, the Tupolev 95 Russian long range bomber (NATO reporting name 'Bear') appeared especially well on radar.

It is now known that propellers and jet turbine blades produce a bright radar image; the Bear had four pairs of large (5.6 meter diameter) contra-rotating propellers.

Another important factor is the internal construction. Behind the skin of some aircraft are structures known as re-entrant triangles. Radar waves penetrating the skin of the aircraft get trapped in these structures, bouncing off the internal faces and losing energy. This approach was first used on the F-117.

The most efficient way to reflect radar waves back to the transmitting radar is with orthogonal metal plates, forming a corner reflector consisting of either a dihedral (two plates) or a trihedral (three orthogonal plates). This configuration occurs in the tail of a conventional aircraft, where the vertical and horizontal components of the tail are set at right angles. Stealth aircraft such as the F-117 use a different arrangement, tilting the tail surfaces to reduce corner reflections formed between them. A more radical approach is to eliminate the tail completely, as in the B-2 Spirit.

In addition to altering the tail, stealth design must bury the engines within the wing or fuselage, or in some cases where stealth is applied to an existing aircraft, install baffles in the air intakes, so that the turbine blades are not visible to radar. A stealthy shape must be devoid of complex bumps or protrusions of any kind; meaning those weapons, fuel tanks, and other stores must not be carried externally. Any stealthy vehicle becomes un-stealthy when a door or hatch is opened.

Planform alignment is also often used in stealth designs. Planform alignment involves using a small number of surface orientations in the shape of the structure. For example, on the F-22A Raptor, the leading edges of the wing and the tail surfaces are set at the same angle.

Careful inspection shows that many small structures, such as the air intake bypass doors and the air refueling aperture, also use the same angles. The effect of planform alignment is to return a radar signal in a very specific direction away from the radar emitter rather than returning a diffuse signal detectable at many angles.

Stealth airframes sometimes display distinctive serrations on some exposed edges, such as the engine ports. The YF-23 has such serrations on the exhaust ports. This is another example in the use of re-entrant triangles and planform alignment, this time on the external airframe.

Shaping requirements have strong negative influence on the aircraft's aerodynamic properties. The F-117 has poor aerodynamics, is inherently unstable, and cannot be flown without a fly-by-wire control system.

The stealth ship, K32 HMS *Helsingborg*

Ships have also adopted similar techniques. The Visby corvette was the first stealth ship to enter service, though the earlier Arleigh Burke class destroyer incorporated some signature-reduction features.

Other examples are the French La Fayette class frigate, the USS *San Antonio* amphibious transport dock, and most modern warship designs.

Similarly, coating the cockpit canopy with a thin film transparent conductor (vapor-deposited gold or indium tin oxide) helps to reduce the aircraft's radar profile, because radar waves would normally enter the cockpit, bounce off an object (the inside of the cockpit has a complex shape, with the pilot's helmet itself providing a sizeable return), and possibly return to the radar, but the conductive coating creates a controlled shape that deflects the incoming radar waves away from the radar. The coating is thin enough that it has no adverse effect on the pilot's vision.

Non-metallic airframe

Dielectric composites are more transparent to radar, whereas electrically conductive materials such as metals and carbon fibers reflect electromagnetic energy incident on the material's surface. Composites may also contain ferrites to optimize the dielectric and magnetic properties of the material for its application.

Radar absorbing material

Radar absorbent material (RAM), often as paints, is used especially on the edges of metal surfaces. While the material and thickness of RAM coatings is classified, the material seeks to absorb radiated energy from a ground or air based radar station into the coating and converts it to heat rather than reflect it back.

Radar stealth countermeasures and limitations

Low frequency radar

Shaping does not offer stealth advantages against low-frequency radar. If the radar wavelength is roughly twice the size of the target, a half-wave resonance effect can still generate a significant return. However, low-frequency radar is limited by lack of available frequencies-many are heavily used by other systems, by lack of accuracy of the diffraction-limited systems given their long wavelengths, and by the radar's size, making it difficult to transport.

A Long-wave radar may detect a target and roughly locate it, but not identify it, and the location information lacks sufficient weapon targeting accuracy. Noise poses another problem, but that can be efficiently addressed using modern computer technology; Chinese "Nantsin" radar and much older Soviet-made long-range radar were modified this way. It has been said that "there's nothing invisible in the radar frequency range below 2 GHz".

Multiple transmitters

Much of the stealth comes from reflecting the transmissions in a different direction other than a direct return. Therefore detection can be better achieved if the sources are spaced from the receivers, known as bistatic radar, and proposals exist to use reflections from sources such as civilian radio transmitters, including cellular telephone radio towers.

Moore's law

By Moore's law the processing power behind radar systems is expected to improve over time, which will erode the ability of physical stealth to hide an aircraft, but that same level of improvement will boost the stealth aircraft's own electronic warfare equipment, which will always have a quieter return signal to mask than a non-stealth aircraft would return.

Acoustics

Acoustic stealth plays a primary role in submarine stealth as well as for ground vehicles. Submarines have extensive usage of rubber mountings to isolate and avoid mechanical noises that could reveal locations to underwater passive sonar arrays.

Early stealth observation aircraft used slow-turning propellers to avoid being heard by enemy troops below. Stealth aircraft that stay subsonic can avoid being tracked by sonic boom. The presence of supersonic and jet-powered stealth aircraft such as the SR-71 Blackbird indicates that acoustic signature is not always a major driver in aircraft design, although the Blackbird relied more on its extremely high speed and altitude.

Visibility

The simplest stealth technology is simply camouflage; the use of paint or other materials to color and break up the lines of the vehicle or person.

Most stealth aircraft use matte paint and dark colors, and operate only at night. Lately, interest on daylight Stealth (especially by the USAF) has emphasized the use of gray paint in disruptive schemes, and it is assumed that Yehudi lights could be used in the future to mask shadows in the airframe (in daylight, against the clear background of the sky, dark tones are easier to detect than light ones) or as a sort of active camouflage. The original B-2 design had wing tanks for a contrail-inhibiting chemical, alleged by some to be chlorofluorosulphonic acid, but this was replaced in the final design with a contrail sensor from Ophir that alerts the pilot when he should change altitudeand mission planning also considers altitudes where the probability of their formation is minimized.

Infrared

An exhaust plume contributes a significant infrared signature. One means of reducing the IR signature is to have a non-circular tail pipe (a slit shape) in order to minimize the exhaust cross-sectional volume and maximize the mixing of the hot exhaust with cool ambient air. Often, cool air is deliberately injected into the exhaust flow to boost this process. Sometimes, the jet exhaust is vented above the wing surface in order to shield it from observers below, as in the B-2 Spirit, and the unstealthy A-10 Thunderbolt II. To achieve infrared stealth, the exhaust gas is cooled to the temperatures where the brightest wavelengths it radiates on are absorbed by atmospheric carbon dioxide and water vapor, dramatically reducing the infrared visibility of the exhaust plume. Another way to reduce the exhaust temperature is to circulate coolant fluids such as fuel inside the exhaust pipe, where the fuel tanks serve as heat sinks cooled by the flow of air along the wings.

Reducing radio frequency (RF) emissions

In addition to reducing infrared and acoustic emissions, a stealth vehicle must avoid radiating any other detectable energy, such as from onboard radars, communications systems, or RF leakage from electronics enclosures. The F-117 uses passive infrared and low light level television sensor systems to aim its weapons and the F-22 Raptor has an advanced LPI radar which can illuminate enemy aircraft without triggering a radar warning receiver response.

Measuring stealth

The size of a target's image on radar is measured by the radar cross section or RCS, often represented by the symbol σ and expressed in square meters. This does not equal geometric area. A perfectly conducting sphere of projected cross sectional area 1 m^2 (i.e. a diameter of 1.13 m) will have an RCS of 1 m^2. Note that for radar wavelengths much less than the diameter of the sphere, RCS is independent of frequency. Conversely, a square flat plate of area 1 m^2 will have an RCS of $\sigma = 4\pi A^2 / \lambda^2$ (where A=area, λ=wavelength), or 13,982 m^2 at 10 GHz if the radar is perpendicular to the flat surface. At off-normal incident angles, energy is reflected away from the receiver, reducing the RCS. Modern stealth aircraft are said to have an RCS comparable with small birds or large insects, though this varies widely depending on aircraft and radarIf the RCS was directly related to the target's cross-sectional area, the only way to reduce it would be to make the physical profile smaller. Rather, by reflecting much of the radiation away or absorbing it altogether, the target achieves a smaller radar cross section.

Stealth tactics

Stealthy strike aircraft such as the F-117, designed by Lockheed Martin's famous Skunk Works, are usually used against heavily defended enemy sites such as Command and Control centers or surface-to-air missile (SAM) batteries. Enemy radar will cover the airspace around these sites with overlapping coverage, making undetected entry by conventional aircraft nearly impossible. Stealthy aircraft can also be detected, but only at short ranges around the radars, so that for a stealthy aircraft there are substantial gaps in the radar coverage.

Thus a stealthy aircraft flying an appropriate route can remain undetected by radar. Many ground-based radar exploit Doppler filter to improve sensitivity to objects having a radial velocity component with respect to the radar. Mission planners use their knowledge of the enemy radar locations and the RCS pattern of the aircraft to design a flight path that minimizes radial speed while presenting the lowest-RCS aspects of the aircraft to the threat radar. In order to be able to fly these "safe" routes, it is necessary to understand the enemy's radar coverage (see Electronic Intelligence). Airborne or mobile radar systems such as AWACS can complicate tactical strategy for stealth operation.

Stealth aircraft

An F-117 Nighthawk stealth strike aircraft

Stealth aircraft are aircraft that use stealth technologyto interfere with radar detection as well as means other than conventional aircraft by employing a combination of features to reduce visibility in the infrared, visual, audio, and radio frequency (RF) spectrum. Development of stealth technology likely began in Germany during WWII. Well-known modern examples of stealth aircraft include the United States' F-117 Nighthawk (1981–2008), the B-2 Spirit "Stealth Bomber", the F-22 Raptor, and the F-35 Lightning II. and the Indian/Russian Sukhoi PAK FA.

While no aircraft is totally invisible to radar, stealth aircraft prevent conventional radar from detecting or tracking the aircraft effectively, reducing the odds of an attack. Stealth 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.

Stealth is the combination of passive low observable (LO) features and active emitters such as Low Probability of Intercept Radars, radios and laser designators. These are usually combined with active defenses such as Chaff, Flares, and ECM.

Background

The first true "stealth" aircraft may have been the Horten Ho 229 flying wing fighter-bomber, developed in Germany during the last years of WWII. 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 Corporation established that this compound, along with the aircraft's shape, would have rendered the Ho 229 virtually invisible to Britain's Chain Home early warning radar, provided the aircraft was traveling at high speed (~550 mph) at extremely low altitude (50–100 feet).

In the closing weeks of WWII the US military initiated "Operation Paperclip", an effort by the US Army to capture as much advanced German weapons research as possible, and also to deny that research to advancing Soviet troops. A Horton glider and the Ho 229 number V3 were secured and sent to Northrop Aviation in the United States for evaluation, 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) based on photographs of the Horton'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 Horton wing-only glider are located in the Chino Air Museum in Southern California.

Modern stealth aircraft first became possible when Denys Overholser, a mathematician working for Lockheed Aircraft during the 1970s adopted a mathematical model developed by 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 found that an airplane 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". It was named that because it looked like a squat diamond and looked too hopeless to ever fly. But 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 that 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 in Panama. On December 20, 1989, two 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 in the opening phase of Operation Desert Storm and were the only jets allowed to operate inside

Limitations

B-2 Spirit stealth bomber of the U.S Air Force

Instability of design

Early stealth aircraft were designed with a focus on minimal radar cross section (RCS) rather than aerodynamic performance. Highly stealth aircraft like the F-117 Nighthawk and B-2 Spirit are aerodynamically unstable in all three axes and require constant flight corrections from a fly-by-wire system to maintain controlled flight. Most modern non-stealth fighter aircraft (F-16, Su-27, Gripen, Rafale) are unstable on one or two axes only. However, in the pursuit of increased maneuverability, most 4th and 5th-generation fighter aircraft have been designed with some degree of inherent instability that must be controlled by fly-by-wire computers.

Dogfighting ability

Earlier stealth aircraft (such as the F-117 and B-2) lack afterburners, 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 required in a 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 and F-35, 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 and Kolchuga, 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.

Vulnerable modes of flight

Stealth aircraft are still vulnerable to detection immediately during, and after using their weaponry. Since stealth payload (reduced RCS bombs and cruise missiles) 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 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 Lighting 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 stealthy, as the hardpoints and the weapons mounted on those hardpoints will show up on radar systems. This option therefore represents a trade off 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 near Point Mugu, California, a B-2 Spirit dropped forty-seven 500 lb (230 kg) class Mark 82 bombs, 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".

Cost of maintenance

Stealth aircraft are high-maintenance equipment, as their stealth capability requires detail-oriented care. The most obvious aspect is the aircraft's skin, that has a specific shape to reflect radar impulses away from the emission source, and a coating to absorb electromagnetic waves using materials such as radar absorbing paint. All openings and edges are electromagnetically shielded. The cockpit windows are shielded with metal trimmings.

By way of example, until the relatively recent introduction of improved sealing products, on the B-2 it would often take more hours of work to reseal access panels that were opened for maintenance, than the required maintenance itself. Stealth aircraft skin must also be protected from foreign object damage, as imperfections in the skin can dramatically increase the radar cross section.

In short, stealth depends on maintaining a high level of detail in every aspect of aircraft maintenance.

Sensitive skin

The B-2 Stealth Bomber has a skin made with highly specialized materials like Polygraphite.

Cost of operations

Stealth aircraft are typically more expensive to develop and manufacture. An example is the B-2 Spirit that is many times more expensive to manufacture and support than conventional bomber aircraft. The B-2 program costs the U.S. Air Force almost $45 billion.

Detection

Theoretically there are a number of methods to detect stealth aircraft at long range.

Reflected waves

Passive (multistatic) radar, bistatic radar and especially multistatic systems are believed to detect some stealth aircraft better than conventional monostatic radars, since first-generation stealth technology (such as the F117) reflects energy away from the transmitter's line of sight, effectively increasing the 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 with support of DARPA, have shown that it is possible to build a synthetic aperture radar image of an aircraft target using passive multistatic radar, possibly detailed enough to enable automatic target recognition (ATR).

In December 2007, SAAB researchers also 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 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 also provides a degree of protection against anti-radar (or anti-radiation) missiles or attacks.

Infrared (heat)

Some analysts claim 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 CO_2 (4.3 µm absorption maxima) detection possible, through difference comparing between the low and high channel. These analysts also point to the resurgence in such systems in several Russian designs in the 1980s, such as those fitted to the MiG-29 and Su-27. The latest version of the MiG-29, the MiG-35, is equipped with a new Optical Locator System that includes even more advanced IRST capabilities.

In air combat, the optronic suite allows:

- Detection of non-afterburning targets at 45 km range and more;
- Identification of those targets at 8 to 10 km range; and
- Estimates of aerial target range at up to 15 km.

For ground targets, the suite allows:

- A tank-effective detection range up to 15 km, and aircraft carrier detection at 60 to 80 km;
- Identification of the tank type on the 8 to 10 km range, and of an aircraft carrier at 40 to 60 km; and
- Estimates of ground target range of up to 20 km.

Wavelength match

The Dutch company Thales Nederland, formerly known as Holland Signaal, have developed a naval phased-array radar called SMART-L, which also is operated at L-Band and is claimed to offer counter stealth benefits. However, as with most claims of counter-stealth capability, these are unproven and untested. True resonant effects might be expected with HF sky wave radar systems, which have wavelengths of tens of metres. However, in this case, the accuracy of the radar systems is such that the detection is of limited value for engagement. Any radar which can successfully match the resonant frequency of a type of stealth aircraft should be able to detect its direction. In practice this is difficult because the resonant frequency changes depending on how the stealth aircraft is oriented with respect to the radar system.

OTH Radar (Over the Horizon Radar)

Over-the-horizon radar is a design concept that increases radar's effective range over conventional radar. It is claimed that the Australian JORN 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.

Use of stealth aircraft

USAF F-22 Raptor stealth fighter of the 27th Fighter Squadron

The F-35 Lightning II is developed by United States, United Kingdom, Italy, Canada, Australia, Netherlands, Norway, Denmark, and Turkey

To date, stealth aircraft have been used in several low- and moderate-intensity conflicts, including Operation Desert Storm, Operation Allied Force and the

2003 invasion of Iraq. In each case they were employed to strike high-value targets that were either out of range of conventional aircraft in the theater or were too heavily defended for conventional aircraft to strike without a high risk of loss. In addition, because the stealth aircraft do not have to evade surface-to-air missiles and anti-aircraft artillery over the target they can aim more carefully and thus are more likely to hit the target and cause less collateral damage. In many cases they were used to hit the high value targets early in the campaign, before other aircraft had the opportunity to degrade the opposing air defense to the point where other aircraft had a good chance of reaching those critical targets.

Stealth aircraft in future low- and moderate-intensity conflicts are likely to have similar roles. However, given the increasing prevalence of Russian-built surface-to-air missile systems on the open market (such as the SA-10, SA-12 and SA-20 (S-300P/V/PMU) and SA-15 (9K331/332)), stealth aircraft are likely to be very important in a high-intensity conflict in order to gain and maintain air supremacy, especially to the United States who is likely to face these types of systems. It is possible to cover one's airspace with so many air defences with such long range and capability that conventional aircraft would find it very difficult "clearing the way" for deeper strikes. For example, China license-builds all of the previously mentioned SAM systems in large quantities and would be able to heavily defend important strategic and tactical targets in the event of a conflict. Even if anti-radiation weapons are used in an attempt to destroy the SAM radars of such systems, or stand-off weapons are launched against them, these modern surface-to-air missile batteries are capable of shooting down weapons fired against them.

Stealth aircraft lost

The first (and to date only) case of a stealth aircraft being shot down happened on 27 March 1999, during Operation Allied Force. An Isayev S-125 'Neva-M' missile was fired at an American F-117 Nighthawk and successfully brought it down.

How does stealth technology work?

Stealth Technology

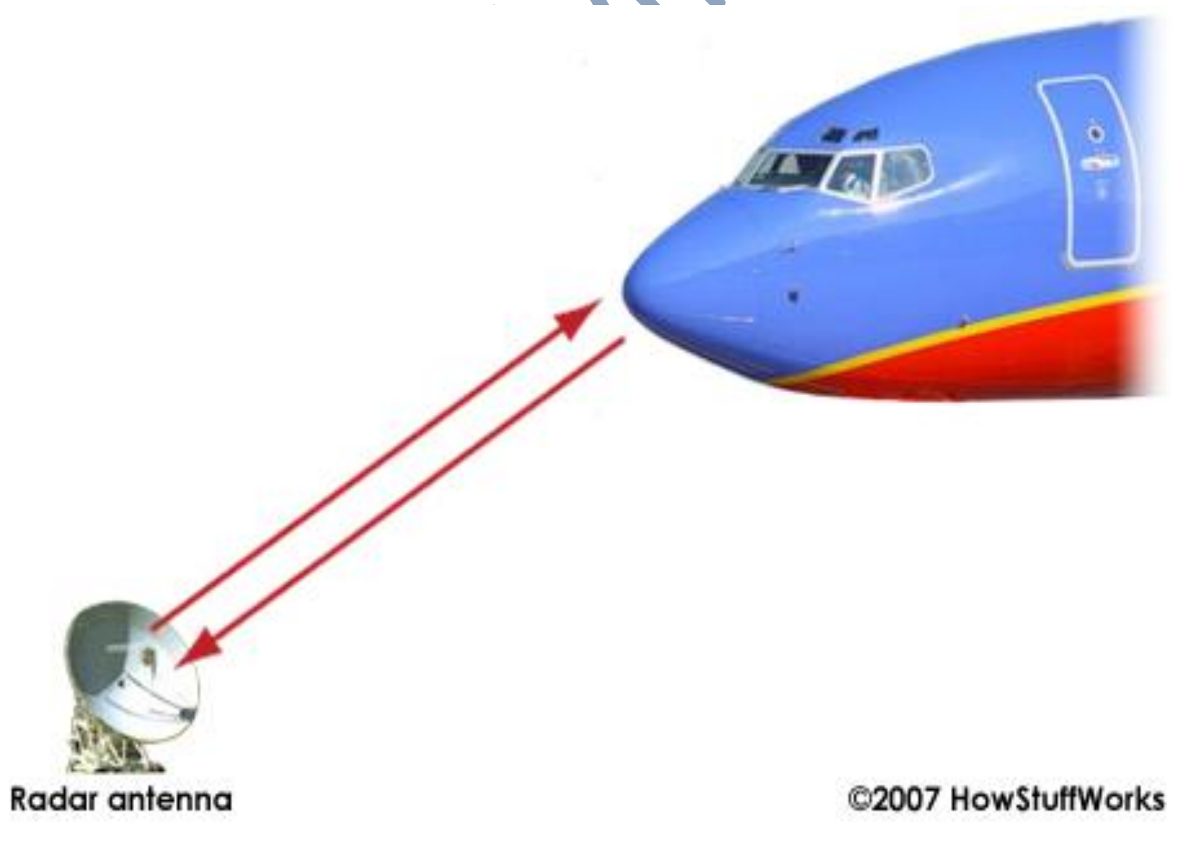
The article How Radar Works talks about the basic principles of a **radar system**. The idea is for the radar antenna to send out a burst of radio energy, which is then reflected back by any object it happens to encounter. The radar antenna measures the time it takes for the reflection to arrive, and with that information can tell how far away the object is.

The metal body of an airplane is very good at reflecting radar signals, and this makes it easy to find and track airplanes with radar equipment.

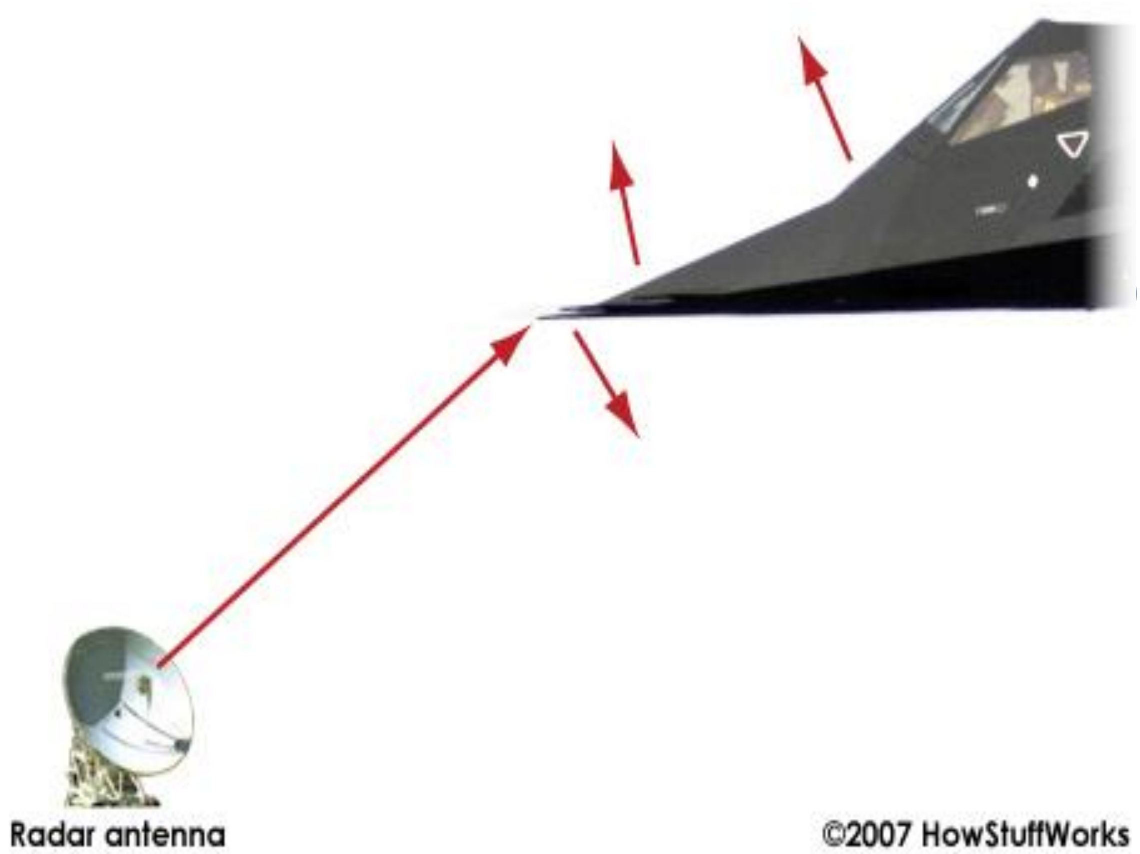
The goal of **stealth technology** is to make an airplane invisible to radar. There are two different ways to create invisibility:

- The airplane can be shaped so that any radar signals it reflects are reflected away from the radar equipment.
- The airplane can be covered in materials that absorb radar signals.

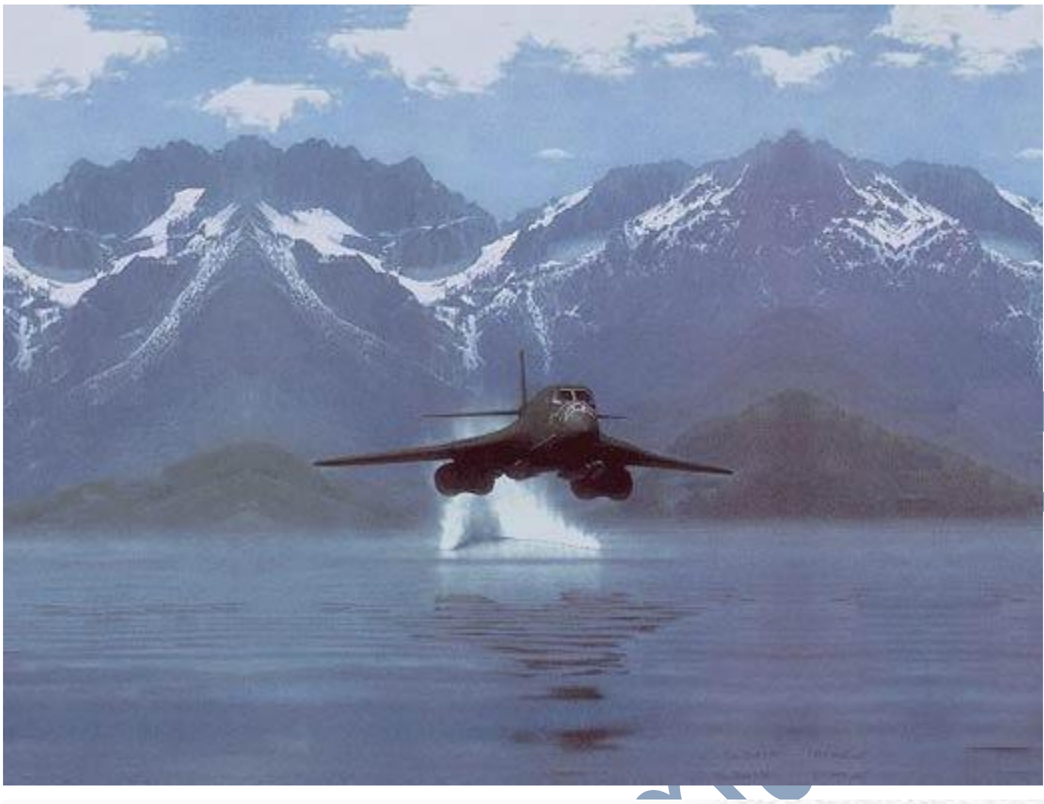
Most conventional aircraft have a rounded shape. This shape makes them aerodynamic, but it also creates a very efficient radar reflector. The round shape means that no matter where the radar signal hits the plane, some of the signal gets reflected back:



A stealth aircraft, on the other hand, is made up of completely **flat surfaces** and very **sharp edges**. When a radar signal hits a stealth plane, the signal reflects away at an angle, like this:



In addition, surfaces on a stealth aircraft can be treated so they **absorb radar energy** as well. The overall result is that a stealth aircraft like an F-117A can have the radar signature of a small bird rather than an airplane. The only exception is when the plane banks -- there will often be a moment when one of the panels of the plane will perfectly reflect a burst of radar ener gy back to the antenna.



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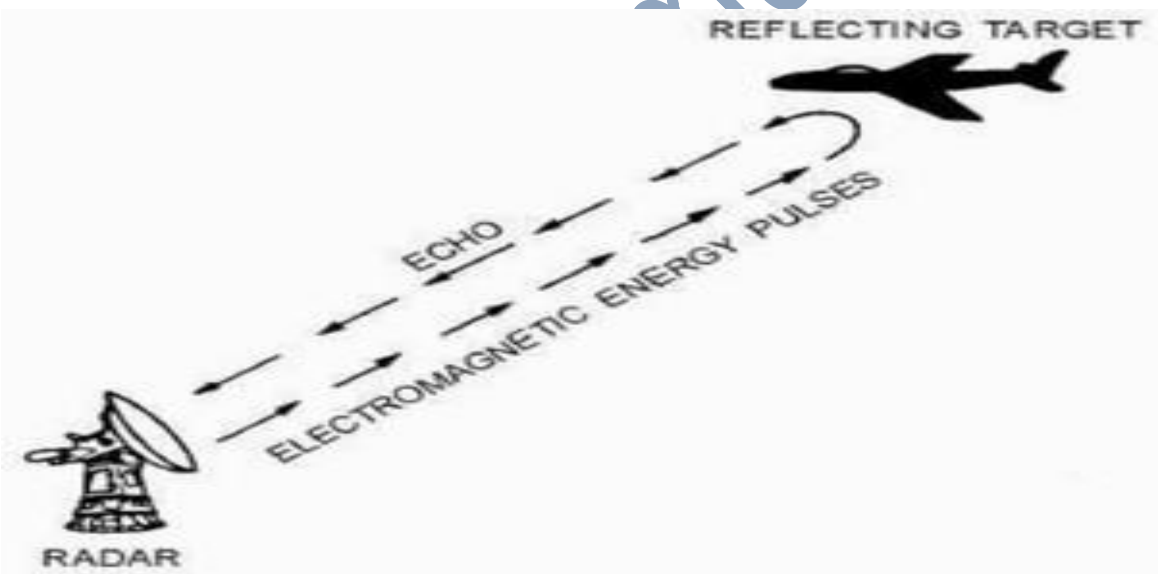

Methods of avoiding detection

There are some more methods by which planes can avoid detection. These methods do not need any hi-tech equipment to avoid detection. Some of them have been used for years together by pilots to avoid detection.

One of the main efforts taken by designers of the stealth aircraft of today is to carry the weapons payload of the aircraft internally. This has shown that carrying weapons internally can considerably decrease the radar cross-section of the aircraft. Bombs and Missiles have a tendency to reflect the incoming radar waves to a higher extent. Providing missiles with RAM and RAS is an impossible by the cost of these things. Thus the missiles are carried in internal bombays which are opened only when the weapons are released.

Aircraft has used another method of avoiding detection for a very long time. Radars can use the radar waves or electro-magnetic energy of planes radar and locate it. An aircraft can remain undetected just by turning the radar off.

In case of some of the modern stealth aircraft, it uses its wingman in tandem to track its target and destroy it. It is done in the following way. The fighter, which is going to attack moves forward, the wingman (the second aircraft) on the other hand remains at a safe distance from the target which the other fighter is approaching. The wingman provides the other fighter with the radar location of the enemy aircraft by a secured IFDL (In Flight Data Link). Thus the enemy radar is only able to detect the wingman while the attacking fighter approaches the enemy without making any sharp turns. This is done not to make any sudden variations in a stealth aircraft's radar signature. Thus the fighter, who moves forward, is able to attack the enemy without being detected.

Plasma Stealth

Plasma stealth technology is what can be called as "Active stealth technology" in scientific terms. This technology was first developed by the Russians. It is a milestone in the field of stealth technology. The technology behind this not at all new.

The plasma thrust technology was used in the Soviet / Russian space program. Later the same engine was used to power the American Deep Space 1 probe.

In plasma stealth, the aircraft injects a stream of plasma in front of the aircraft. The plasma will cover the entire body of the fighter and will absorb most of the electromagnetic energy of the radar waves, thus making the aircraft difficult to detect. The same method is used in Magneto Hydro Dynamics. Using Magneto Hydro Dynamics, an aircraft can propel itself to great speeds.

Plasma stealth will be incorporated in the MiG-35 "Super Fulcrum / Raptor Killer". This is a fighter which is an advanced derivative of the MiG-29 . Initial trials have been conducted on this technology, but most of the results have proved to be fruitful.

Detection methods for stealth aircraft

Whenever a technology is developed for military purposes, another technology is also developed to counter that technology. There are strong efforts to develop a system that can counter the low obervability of the fifth generation stealth aircraft. There are ways of detection and elimination of a low observable aircraft but this doesn't give a 100% success rage at present.

On a radar screen, aircraft will have their radar cross sections with respect to their size. This helps the radar to identify that the radar contact it has made is an aircraft. Conventional aircraft are visible on the radar screen because of its relative size. On the other hand, the relative size of a stealth aircraft on the radar screen will be that of a large bird. This is how stealth aircraft are ignored by radar and thus detection is avoided.

A proven method to detect and destroy stealth aircraft is to triangulate its location with a network of radar systems. This was done while the F-117 was shot down during the NATO offensive over Yugoslavia.

A new method of detecting low observable aircraft is just over the horizon. Scientists have found a method to detect stealth aircraft with the help of microwaves similar to the ones emitted by the cell phone towers. Nothing much is known about this technology, but the US military seems to be very keen about doing more research on this.

Disadvantages of stealth technology

Stealth technology has its own disadvantages like other technologies. Stealth aircraft cannot fly as fast or is not maneuverable like conventional aircraft. The F-22 and the aircraft of its category proved this wrong up to an extent. Though the F-22 may be fast or maneuverable or fast, it can't go beyond Mach 2 and cannot make turns like the Su-37.

Another serious disadvantage with the stealth aircraft is the reduced amount of payload it can carry. As most of the payload is carried internally in a stealth aircraft to reduce the radar signature, weapons can only occupy a less amount of space internally. On the other hand a conventional aircraft can carry much more payload than any stealth aircraft of its class.

Whatever may be the disadvantage a stealth aircraft can have, the biggest of all disadvantages that it faces is its sheer cost. Stealth aircraft literally costs its weight in gold.

Fighters in service and in development for the USAF like the B-2 ($2 billion), F-117 ($70 million) and the F-22 ($100 million) are the costliest planes in the world. After the cold war, the number of B-2 bombers was reduced sharply because of its staggering price tag and maintenance charges. There is a possible solution for this problem.

In the recent past the Russian design firms Sukhoi and Mikhoyan Gurevich (MiG) have developed fighters which will have a price tag similar to that of the Su-30MKI. This can be a positive step to make stealth technology affordable for third world countries.

Stealth aircraft of yesteryears, today and tomorrow

Stealth technology is a concept that is not at all new. During the Second World War, allied aircraft used tin and aluminum foils in huge numbers to confuse German radar installations. This acted as a cover for allied bombers to conduct air raids. This method was later used as chaffs by aircrafts to dodge radar guided missiles.

The first stealth aircraft was the F-117 developed by Lockheed Martin. It was a top-secret project developed by its Skunk Works unit. The F-117 was only revealed during the late 80s and then saw action in the Persian Gulf.

In due course of time the B-2 was developed as a successor to the B-2. Though both of them serve different purposes, the B-2 went a step ahead of the F-117. The B-2 was developed to deliver nuclear weapons and other guided and unguided bombs. On the other hand the F-117 was developed to deliver its precision laser guided bombs.

Another stealth aircraft, which made a lot of promises and in the end ended up in a trashcan, was the A-12. It was a fighter that was designed to replace the F-14 and F-18 in the future. The capabilities of this aircraft were boasted to such an extent that the project ended up in a big mess. Billions of dollars were wasted for nothing.

Stealth technology became famous with the ATF contest. The Boeing-Lockheed YF-22 and the McDonell Douglas-Grumman YF-23 fought for the milti-billion contract to build the fighter that would take the USAF into the fifth generation fighter era. The Boeing-Lockheed won the contract and the F-22 was approved to be the replacement for the F-15 "Eagle" interceptor.

America now has a competitors, Russia decided to respond to the development of the F-22 by making the Su-47 (S-37) "Berkut" and the MiG-35 "Super Fulcrum / Raptor Killer".

These fighters were developed by the two leading aviation firms in Russia Sukhoi and Mikhoyan Gurevich (MiG). The future of these projects totally depends on the funding which will be provided to the Russian defense sector. There are some hopes of increase in the funding to these projects as countries like India have started providing funds and technical assistance for these projects.

Another competition that soon came into the spotlight after the ATF competition was the JSF.

This time Boeing developed the X-32 and the Lockheed martinhttp://www.totalairdominance.50megs.com its X-35. With the experience gained from developing the F-22, they were tasked with making a replacement for the F-16. This saw great technological advances, as they had to make the first operational supersonic VSOL aircraft. Lockheed martin took the technical assistance of Russian scientists who developed the Yak-141. The Yak-141 is the first supersonic VSTOL aircraft. In the end the Lockheed team with its X-35 won the contract and the fighter was re-designated as the F-35.

Many projects remain over the horizon that will use stealth technology as its primary capability. They come from some of the most unlikely contenders.

These projects include the Euro JSF, which will be designed by the team that developed the EF-2000. Russia is stepping forward with its LFS project with the S-54 and other designs. Two new entries into this field will be India and China. India will be introducing its MCA, which is a twin engine fighter without vertical stabilizers. This fighter will use thrust vectoring instead of rudders. China will be introducing the J-12 (F-12/XXJ).

Conclusion:

Future of stealth technology

Stealth technology is clearly the future of air combat. In the future, as air defense systems grow more accurate and deadly, stealth technology can be a factor for a decisive by a country over the other. In the future, stealth technology will not only be incorporated in fighters and bombers but also in ships, helicopters, tanks and transport planes. These are evident from the RAH-66 "Comanche" and the Sea Shadow stealthttp://www.totalairdominance.50megs.comh ship. Ever since the Wright brothers flew the first powered flight, the advancements in this particular field of technology has seen staggering heights. Stealth technology is just one of the advancements that we have seen. In due course of time we can see many improvements in the field of military aviation which would one-day even make stealth technology obsolete.

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