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**LIMITED DISTRIBUTION - NOT TO BE FORWARDED
ISSUE: PATHFINDER PUBLICATION**

SENSITIVITY: A recent edition of the fortnightly Pathfinder newsletter published by the RAAF's Air Power Development Centre speculates about the comparative cross sections of modern western fighter aircraft.

KEY ISSUES:

- The actual radar cross sections of modern fighter aircraft are classified and closely protected.
- Edition 143 of the Pathfinder newsletter is written on the topic of stealth and suggests specific radar cross sections of the USAF F-15 (Eagle), F-35 (JSF) and F-22 (Raptor).
- Whilst stated as fact and not attributed, this information is from open sources, and specifically from a speculative Aviation Week article in 2008. The Air Power Development Centre, and the author of the Pathfinder article, do not have access to classified information related to radar cross sections.

- Inclusion in an Air Force publication in this way might give the impression that the information is authoritative. Pathfinder is widely distributed in electronic and physical form. The web version of the document has been removed.
- The US DoD (JSF Project Office and US DoD Acquisition Technology & Logistics) has been advised of this publication and has raised its concern with such information being presented as fact in an official publication.
- Actions are being taken to ensure any future such articles are reviewed by appropriate authorities prior to publication.

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**BACKGROUND
TEXT OF PATHFINDER ARTICLE**

What is Stealth

A majority of future airborne systems will incorporate the technology called low observability (LO), commonly known as 'stealth'. Stealth, in an air power context, primarily refers to special design features incorporated into military aircraft that permits it to fly deep into enemy territory and return, with reduced risk of detection and/or interception. Stealth is a complex design philosophy aimed at reducing the ability of an enemy's sensors (radar, laser, electromagnetic, infrared, ultraviolet, optical or acoustic) to detect, track and attack an aircraft. The intent is to reduce an aircraft's signature to such an extent that it can get close enough to an enemy's air defence system without being detected in order to attack it, or fly through the air defence system unharmed so that the high value targets being protected can be attacked.

The principle driver behind the development of stealth technology has been the necessity to improve an aircraft's chances of surviving in a hostile environment while undertaking a broad range of missions. The traditional means of improving aircraft survivability—increasing speed, operating altitude and manoeuvrability—became almost redundant with the advent of radar controlled high-speed, high-altitude surface-to-air missiles in the 1960s. By the mid-1970s radar and missile technology had evolved beyond the capability of an aircraft to evade, even with sophisticated onboard electronic countermeasure systems, thus reducing its chances of survival in a high-end warfare environment.

The quest to improve an aircraft's survivability examined both active and passive methods to reduce the air defence system's ability to detect and intercept an attacking aircraft. As radar continues to be the primary means of detecting aircraft, it was a logical starting point for the research. The initial proposal to minimise an aircraft's radar signature through design was articulated in a few theoretical papers published in Britain in 1941. By the 1960s this concept was being explored further. It was theorised that if an aircraft's shape returned less radar energy, the net effect would be to make the aircraft appear on the receiving radar later, thereby reducing the enemy's reaction time and improving the aircraft's chance of survival.

An aircraft's Radar Cross Section (RCS)—the area of the scattered wave field returned to the receiving radar—determines the amount of radar energy reflected back. Generally, the RCS of a conventional aircraft is much larger than its physical size and varies significantly with aspect.

Initial attempts at reducing RCS involved applying radar absorbent materials (RAM) to the aircraft's exterior. However, this provided only a minor reduction in RCS. It was realised that to make substantial reductions in RCS each part of the aircraft would have to be carefully designed to scatter radar energy away from its source. Early stealth aircraft such as the F-117 used faceted surfaces to achieve this at the cost of reduced manoeuvrability because of aerodynamic penalties. However, considerable improvements in computational modelling techniques are now permitting the use of blended surfaces, such as those on the F-22 'Raptor', which reduces RCS significantly without the accompanying loss of manoeuvrability. Other design features that aid stealth include positioning the engine deep within the aircraft, trapping radar energy within aircraft structural components, avoiding perpendicular corners and surface seams, and not having any external protuberances such as antennas or drainage pipes.

While the reduction of RCS is a major component of stealth, it is not the only one. Lowering RCS can make an aircraft's infrared, ultraviolet, electromagnetic, visual and acoustic signatures more pronounced to the extent that they can become the prime means of detecting stealth aircraft. Therefore, to be truly stealthy, these signatures also need to be reduced.

The key to reducing an aircraft's infrared signature is to cool the engine exhaust gases as much as possible before they are vented to the atmosphere. This cooling is achieved by mixing cold air into the exhaust plume before it leaves the engine and running the resultant exhaust over long heat absorbing ducts.

The purpose of designing and operating a stealth aircraft will be negated if it gives itself away through its own emissions. Therefore a stealth aircraft, at least during the attack phase, must turn off all transmitters such as radar, radio, laser rangefinders and some navigational and formation keeping devices. Further, it must also reduce its electromagnetic reflections, especially ultraviolet reflections off glass surfaces, through careful selection of shapes and materials. As a result, while in stealth mode, the aircraft cannot operate as an active node in a C2 network and is dependent upon its passive self-protection systems for survivability if engaged.

Visual stealth typically incorporates low glint surfaces and low visibility paint—grey for day operations and black for night. There are also research projects underway to design visual cloaking devices, though it will be many years before they enter operational service. In addition, stealth aircraft avoid operating at altitudes that create contrails (the white condensed water vapour trails seen behind high flying aircraft) and fuel additives are used to reduce visible smoke trails.

Acoustic signature reduction is achieved by a combination of flying at high altitudes, using high-bypass turbofan engines (besides being cooler they are also much quieter than turbojets), and flying at subsonic speeds to avoid sonic booms.

While stealth does provide substantial tactical advantages, it also has some limitations. Stealth technology is very expensive to build due to complex design requirements and the exotic materials required for fabrication. The designs also suffer from structural and weight compromises as stealth takes precedence over structural simplicity. The maintenance requirements of stealth aircraft are significant as any imperfection in the surface finish or alignment of access panels can compromise stealth capabilities. Finally, since the carriage of any external stores will compromise stealth characteristics, these aircraft have more limitations on their weapon and fuel loads as compared to non-stealth aircraft.

Like all military technological developments, there are counter-developments to stealth technology. One way to counter low RCS is to use very sensitive receivers coupled with very powerful radars to increase detection range. Another option is through a process called occlusion. Since stealth aircraft have significantly reduced signatures, they can be detected when they hide other objects, such as stars, as they pass in front of them. Another approach to counter stealth is to use bi-static or multi-static radars. Conventional mono-static radars place the transmitter and receiver in the same location. However, as stealth aircraft do reflect some radar energy, but away from the transmitter, bi-static or multi-static radars, which have their receivers located at a different location from the transmitter, could conceivably receive the reflected energy and detect stealth aircraft. Another possible countermeasure is to place sensors above the anticipated flight path of stealth aircraft as their stealth is optimised against sensors that are either at the same or lower altitude as themselves.

Although counter-measures are being developed, so far only one stealth aircraft has been lost to enemy action—the F-117 shot down over Serbia in Operation ALLIED FORCE in 1999. It is believed that this was made possible not through anti-stealth measures, but because of the regularity of the route being followed by the attacking aircraft that made it possible to locate surface-to-air missiles appropriately in advance.

Stealth is a leading edge technology and will continue to be researched and developed despite its current limitations and evolving countermeasures, to maximise the effectiveness and survivability of emerging weapons systems and their crews.