Sensors, Weapons and Systems for a 21st Century Counter-Air Campaign

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ABSTRACT

Sensors, weapons and systems are some of the key determinants of success in counter-air warfare. This paper explores the growth potential in many of the basic technologies used to implement sensors, weapons and systems in the coming generation of fighters. Conclusions are drawn about potential performance and capability growth resulting from improvements in basic technology in the coming two decades.

The turn of the millennium is a critical junction point in the evolutionary process of fighter development. Indeed, it is a junction point not unlike that seen in the late nineteen forties. Evolutionary and revolutionary improvements in a number of key supporting technologies will transform the capabilities of the coming generation of fighters.

Pivotal to this transformation are the sensors, weapons and onboard systems of future fighter aircraft. This paper will explore these issues and attempt to place them in the context of modern fighter design[2].

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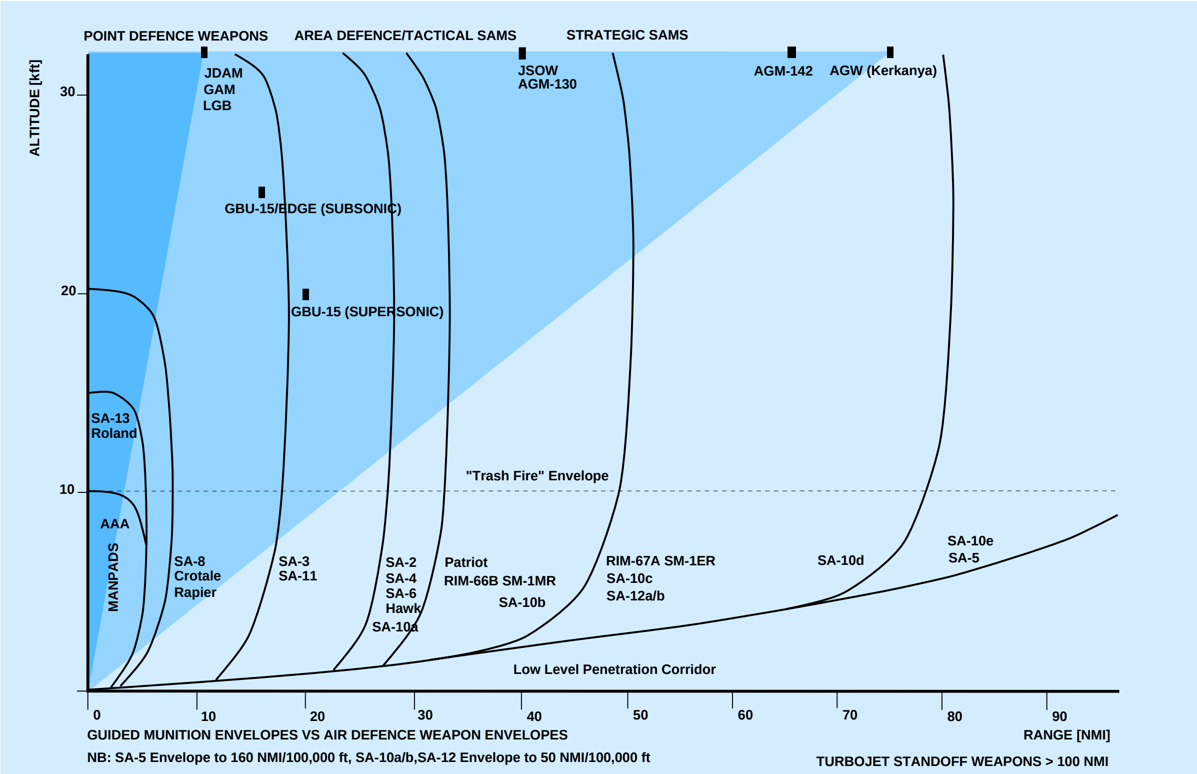
[2] This paper is derived from two series of papers published in Australian Aviation and Air Power International, between 1996 and 1999.



AIR DEFENCE WEAPON ENVELOPES VS WEAPON DELIVERY ENVELOPES

The Counter-Air Campaign and Capabilities

The essential starting point for any such discussion is the definition of a frame of reference. For the Counter-Air Campaign and required capabilities, this essentially amounts to identifying the objectives of the campaign and the categories of mission to be performed in order to attain campaign objectives.

The Counter-Air Campaign is a series of coordinated operations performed to achieve and maintain control of the air. Traditionally, control of the air was achieved by defeating an opponent's fighter force. In recent decades we have seen an increasing shift toward Integrated Air Defence Systems. In such systems an opponent's defence is based upon an interlocking and mutually supporting arsenal of fighters, Surface to Air Missiles and surface based sensors, primarily radar. The latest trend is to incorporate airborne and even orbital sensors into this defensive package.

Control of the Air therefore requires that a decisive defeat be inflicted upon an integrated and complex system of airborne and surface based systems.

To achieve this objective, an attacking force must be capable of prevailing in a number of roles:

- Offensive Counter Air combat between fighters.

- Offensive Counter Air strike against air bases.
- Defensive Counter Air combat against opposing counter-attack.
- Suppression or Destruction of Enemy Air Defences (SEAD/DEAD).
- Surveillance and Reconnaissance.
- Information Warfare / Electronic Combat (IW/EC).

Including the last role in this brief taxonomy may be questioned by some. It is, however, an essential component of the campaign and amounts to having the ability to deny the opponent the use of sensors and C3I resources, while preventing the opponent from doing the same.

The first observation we can make is that accommodating such a diverse package of roles is demanding in terms of fighter capabilities. Indeed, even a decade ago specialised types of fighters were required for many of these roles.

Will specialisation continue ? To some degree, yes. The incorporation of some of these capabilities across every aircraft in a fleet will continue to incur a prohibitive expense in machinery and aircrew training. However, advances in technology have already led to multirole fighters capable of covering a large proportion of the capability spectrum by exploiting specialised podded sensors and role specific weapons. Budgetary pressures and the possibilities inherent in the technology of the day will see this trend continue, with future multirole fighters capable of addressing increasing proportions of the capability spectrum.

Distilling the demands of the role spectrum into a capability spectrum yields, for a modern fighter, the following capabilities:

- the ability to defeat an opponent in BVR missile combat, which requires superior aerodynamic performance, superior sensors, lower signatures and superior reaction times.
- the ability to defeat an opponent in WVR combat, using missiles or other weapons, which requires superior aerodynamic performance, superior sensors, effective countermeasures, lower signatures and superior reaction times.
- the ability to destroy an opponent's air assets on the ground, and destroy supporting base infrastructure, which requires the ability to penetrate defenses and precisely deliver bombs or guided munitions.
- the ability to defeat an opponent's surface based air defences, by reduced signatures, jamming and lethal attack.

The ability to implement these capabilities depends quite critically upon the available basic technology. The better the technology, the more capability can be packaged into a single aircraft, in turn yielding greater lethality and operational flexibility.

It must be noted that in recent decades the driving requirements for aerodynamic performance and signatures have resulted from improvements in an opponent's sensors, weapons and systems. The current paradigm shift initiated by the United States, with the introduction of stealth and sustained dry supercruise, is a direct response to the increasing performance of widely available airborne and surface based radar, infrared sensors, passive electronic sensors, guided missile seekers and airborne system integration.

Basic Technology and Evolution

The importance of basic technology lies in the fact that it imposes fundamental bounds upon the capabilities, and potential growth in capabilities, achievable in any given platform, sensor, weapon or system.

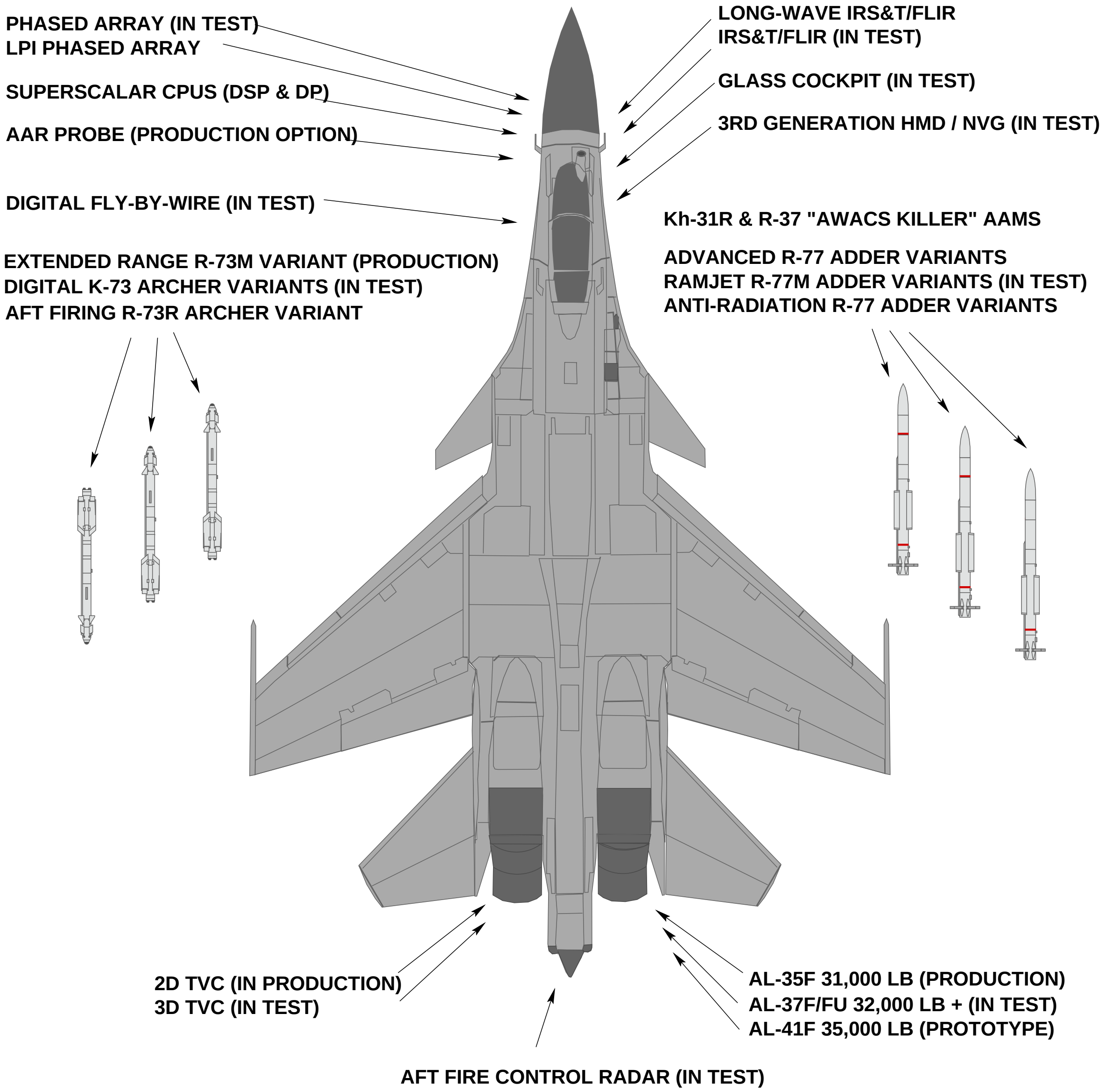
The design of any aircraft, weapon, sensor or system of such, is ultimately constrained by the basic technology from which it is implemented, and its useful operational life is limited by the same.

It is fashionable to see every platform, weapon, sensor or system to be "upgradable" through its service life. In practice, the level of such upgrades, their scope, and the utility of the package are all ultimately limited by the available basic technology.

The nineties have been characterised by significant evolutionary growth in several key areas of basic technology:

- Computing
- High Density Semiconductors
- Microwave Semiconductors
- Phased Arrays
- Radar Imaging Algorithms
- Passive Microwave Targeting
- GPS and Navigation
- Infra Red and Optical Focal Plane Arrays
- Flat Panel Displays
- Helmet Mounted Displays
- High Energy Lasers and Adaptive Optics
- High Power Microwave Technology
- Supercruising Turbofan Propulsion

- Solid Ramjet Propulsion
- Radar Signature Control (Stealth)
- Sensor Fusion



FLANKER CAPABILITY GROWTH

All of these will have important implications for counter-air campaigns in coming decades. They will not only shift the bounds of what extant and planned platforms, weapons, sensors and systems can achieve, but they will also allow for entirely new capabilities.

In technologically oriented forms of warfare the ability to evolve capabilities faster than an opponent is one of the key ingredients for success. He who evolves faster, all else being equal, shall prevail. The biological analogy holds exceptionally well, and every air war of this past century substantiates this argument.

Therefore the assets which will be the most successful in coming decades will be those which by fundamental design are best equipped to evolve rapidly. A fighter or missile airframe, or system design which cannot readily absorb infusions of new technology through its life cycle will be discarded by its users in favour of those which can.

There is no risk in predicting that "evolvability" will be one of the key ingredients for the success of fighter, sensor, weapon and system designs in coming decades.

We are already accustomed to the idea of swapping out engines for higher thrust models, swapping out computers for faster models, and tweaking various black boxes in a similar manner. We must now think in terms of aircraft and weapons which are designed from the very outset to be continually upgraded, year by year, with faster computer chips, more refined software, and ultimately, other more exotic components. Replacing nose cones and leading edges with the latest and stealthiest variants is likely to become the norm.

To understand better the growing pressure toward "evolvability" it is useful to look at anticipated growth trends in several areas of basic technology.

Computers

Computing is of central importance since it is subsuming, to an ever increasing degree, what used to be the hardwired functions of many components and subsystems in established military technology.

In computer hardware, Moore's Law remains valid for the forseeable future. Moore's Law predicts a doubling of available computing power per dollar every eighteen months. Current processor chips are implemented in 0.18 micron technology and execute at several hundred MegaHertz, using Superscalar internal architectures. We can expect this trend to hold for the next 1-2 decades, as X-ray lithography pushes chip geometries down to 0.7 microns or less. On-chip interconnection speeds will continue to improve with the shift toward copper metallisation, from aluminium. Should we consider the impending shift from established Superscalar architectures, which provide parallelism of the order of 2-4, to Very Large Instruction Word (VLIW) architectures with potentially much higher parallelism, much headroom for processor performance growth remains.

The increasing performance of such commercial chip designs will almost certainly result in a complete shift from the established military standard 1750A, AYK-14, i960 architectures to the higher volume commercial architectures, within the coming decade.

The USAF's F-22A ATF employs a pair of CIP multi-processors, built around the JIAWG backplane bus. This allows most of the functions traditionally performed by hardware to be implemented as software running on the CIPs. The CIPs employ liquid cooled variants of the Intel i960 chip and VHSIC digital signal processing chipsets (Lockheed-Martin/Boeing).

In terms of system architectures, the trend is clearly toward using redundant large central processors, typified by the JIAWG/PI architecture Common Integrated Processor (CIP) used in the F-22, and the IEEE SCI based architecture proposed for the JSF. In such systems, all sensor, system, and cockpit display processing will be performed in the central processors. High speed busses connect sensors to the central processors. The technology of federated architectures we see in the teen series fighters, and their European and Russian equivalents, is for all practical purposes a "legacy" technology.

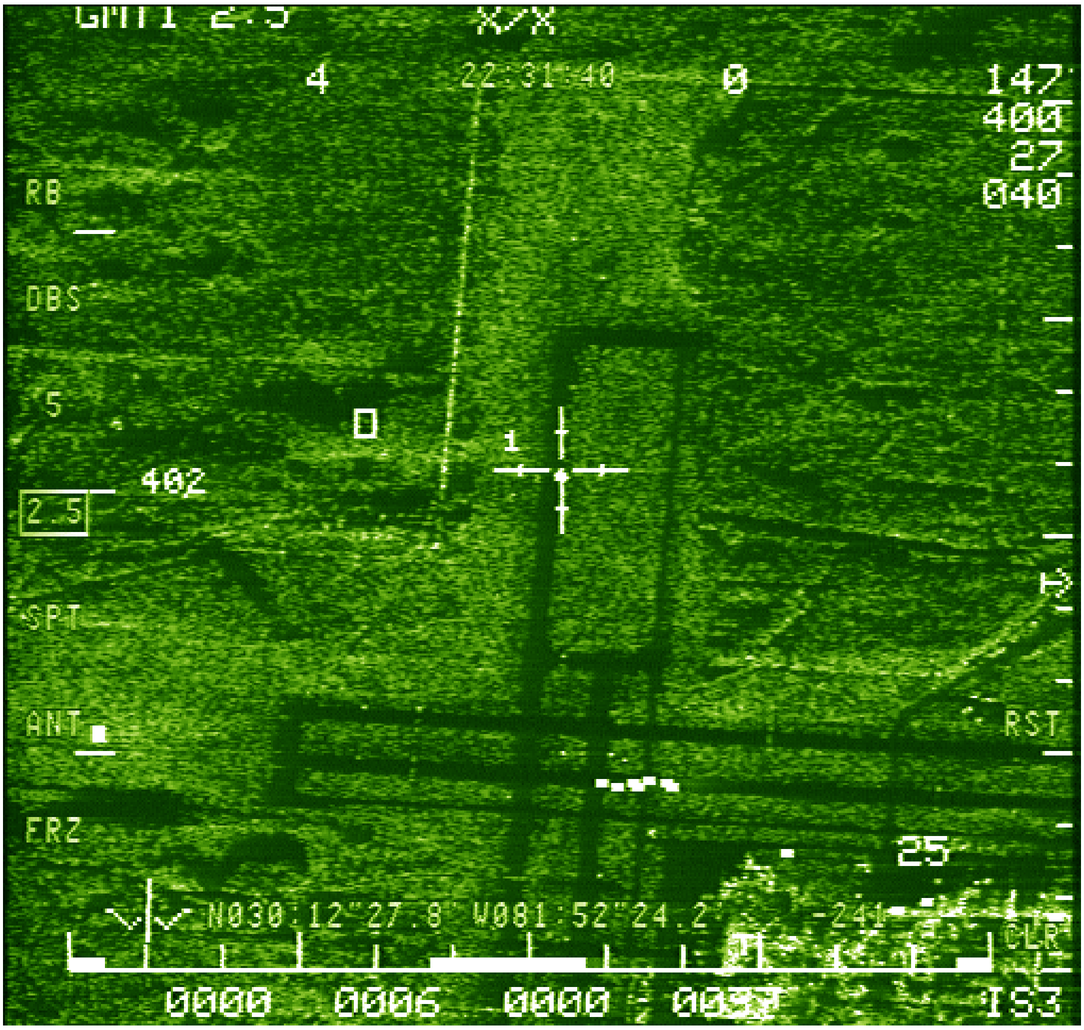
The Joint Strike Fighter is intended to use the commercial IEEE SCI bus to provide unprecedented bandwidth between internal subsystems (Lockheed-Martin, Boeing).

The density and speed growth we anticipate in processors will be paralleled by similar growth in custom chips and commodity components. The application of Moore's Law to computer memory chips yields a quadrupling of chip capacity per dollar every 3 years. By 2010 it is expected that the basic DRAM chip will have a capacity of about 10 Gigabytes.

Microwave Devices and Radar

In microwave semiconductors, the nineties have seen the large scale commercial and military use of Monolithic Microwave Integrated Circuits. These are microwave circuits on a single chip.

The most important near term use of the MMIC is in Transmit Receive Modules for phased arrays. While such modules are still no cheaper than hundreds of dollars per unit, the expected proliferation of the MMICs they use into commercial products will see costs plummet in the coming decade.

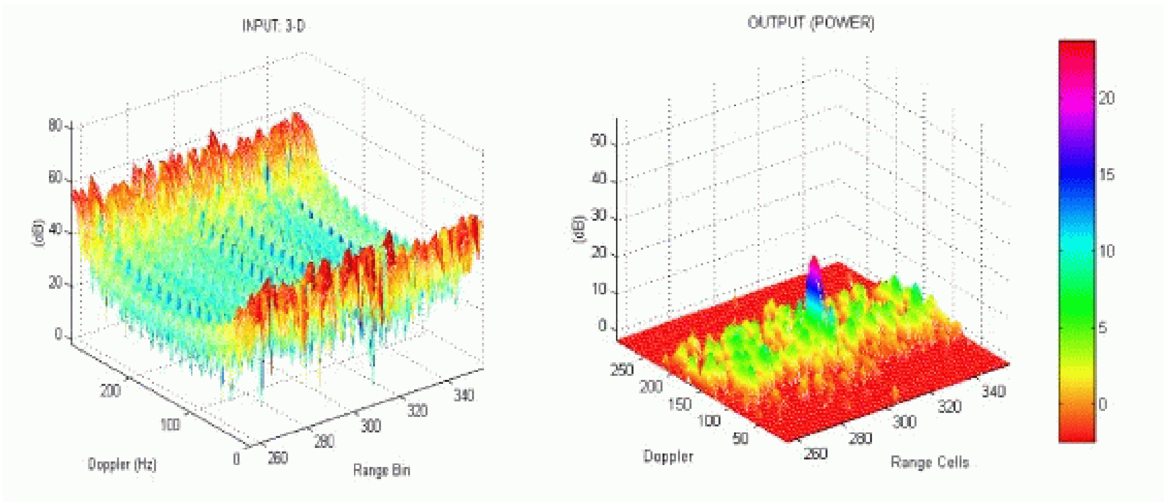


High resolution Synthetic Aperture imagery produced by the APG-76 radar (Northrop-Grumman ESSD).

Current GaAs MMICs used in X-band TR modules suitable for fighter radars and missile seekers are still relatively limited in achievable power output. Even so, a fighter radar with 2000 TR modules will deliver several times the average output power of typical Travelling Wave Tube based radars. With improvements in TR module packaging and cooling, this will further improve.

The phased array, or more properly Electronically Steered Array, is about to see large scale use in fighters. Active arrays, which employ GaAs MMIC TR modules, offer revolutionary capabilities in the coming generation of fighter radars. The F-22, JSF, F-16 Block 60 and growth versions of the Typhoon will all employ such arrays.

This technology enables the design of genuine Low Probability of Intercept radars, with very low structural Radar Cross Section.



Space Time Adaptive Processing (STAP) will significantly improve the look-down performance of pulse Doppler radars (USN NRL).

In terms of sidelobe performance, contemporary arrays can be built with sidelobes 40 to 50 dBs below the mainlobe. This is by no means a hard limit, insofar as TR module designs with 6, 7, or 8 bits of phase and amplitude control can push this even lower.

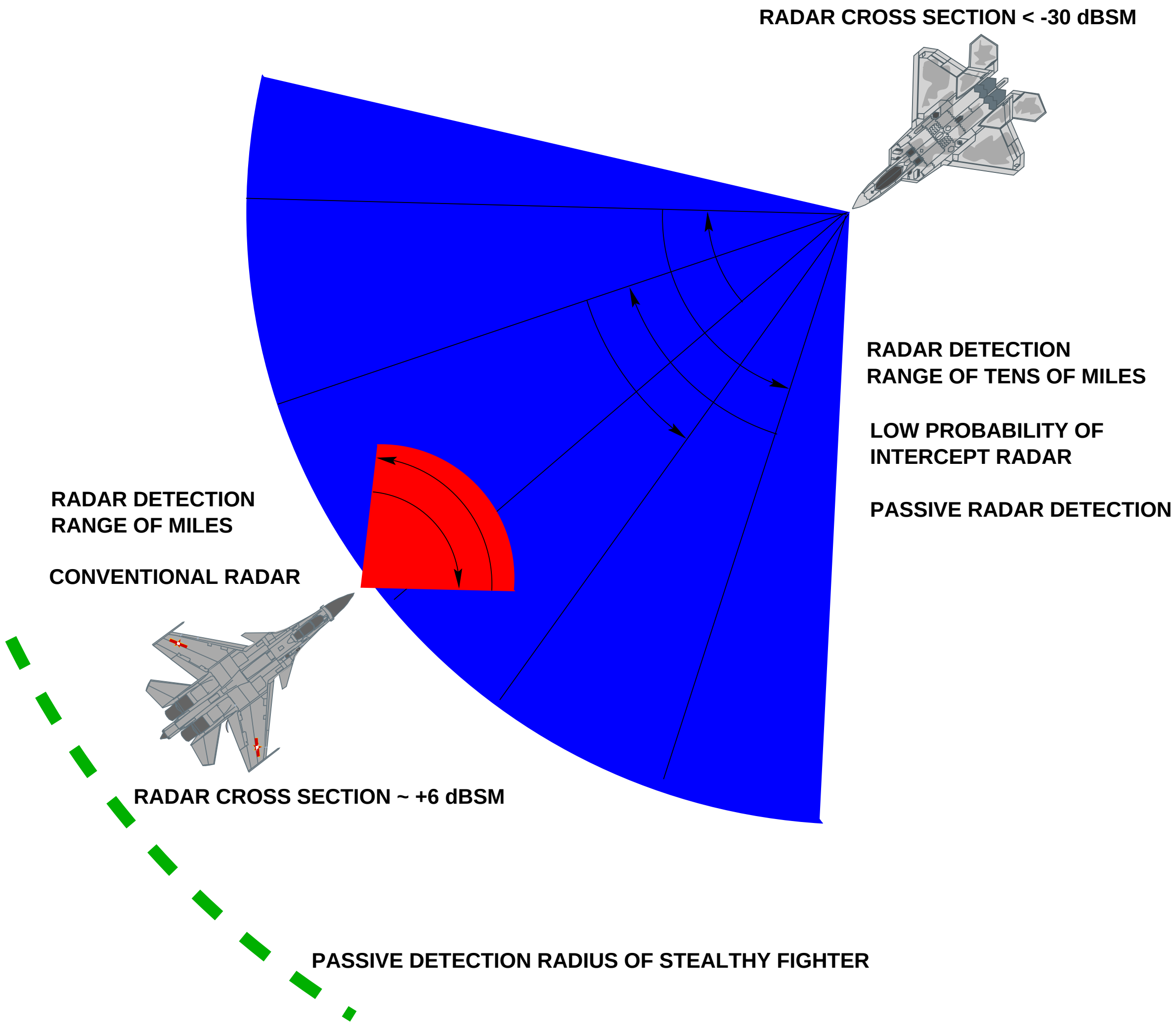
Electronically Steered Arrays also provide the revolutionary capability of interleaving multiple radar modes transparently to the user. Current arrays are relatively lethargic, taking milliseconds to change antenna configuration. Appropriate TR module design has the potential to improve this by a factor of a thousand.

The reliability of an Active Electronically Steered Array is many orders of magnitude better than that of a mechanically steered antenna. Because it degrades gracefully, the catastrophic failure of the system is almost impossible.

The phased array when used as a datalink antenna has the potential to send data at hundreds of Megabits/s over hundreds of kilometres. Therefore BVR missiles can be guided over significant ranges.

The mechanically steered radar antenna is yet another "legacy" technology in the 21st century.

The availability of increasingly cheap high performance computing will enable the use of increasingly powerful radar processing algorithms. Already fighter sized Synthetic Aperture Radars can map with resolutions of about one foot at tens of miles of standoff range. This is by no means the limit of what is achievable with this technology.



CONVENTIONAL AIR SUPERIORITY FIGHTER VS STEALTHY AIR SUPERIORITY FIGHTER

A number of SARs used for mapping now incorporate interferometric 3D imaging. Such radars can produce an accurate terrain elevation map, measuring local elevation with very high accuracy. Therefore the quality of reconnaissance imagery is set to improve further. The accuracy of weapons targeted off such imagery will also much improve over current technology. Weather is no obstacle to such radars.

It is entirely feasible that a fighter radar two decades hence will have the capability to not only produce an accurate 3D surface map with a resolution of inches, but to also shift through this image to find shapes associated with military equipment like SAM systems, AAA platforms, tanks, trucks and other vehicles.

Inverse Synthetic Aperture techniques allow the measurement of the shape of a moving target. Abundant computing power raises the prospect of a fighter being able to recognise an airborne target from its measured shape with a high level of confidence.

Space Time Adaptive Processing (STAP) algorithms currently being researched have the potential to strip away any remaining cover provided by low altitude radar clutter. STAP techniques can also allow very effective rejection of jammers.

A future fighter radar using an Active Electronically Steered Array, and supported by the huge computing power available in coming decades, will be a formidable sensor. It will be extremely difficult to detect, and will be capable of locating and identifying air and surface targets hitherto difficult, if not impossible, to locate and identify.

Passive Microwave Targeting

The established Crystal Video Receiver technology used in Radar Warning Equipment is very much a legacy technology. In the last decade progress in MMIC technology has made highly sensitive channelised receivers a viable proposition for combat aircraft.

Combined with interferometric antenna technology, such receivers will allow combat aircraft to measure the bearing and elevation to a threat emitter with accuracies of the order of a degree of arc or better.

An important related development during this decade is the refinement of passive rangefinding techniques, such as Phase Rate of Change (PRC), Differential Doppler (DD) and Differential Time of Arrival (DTOA) techniques.

Receivers using these technologies can measure within seconds the range, bearing and elevation to a fixed or moving threat emitter, by analysing the behaviour of the emitter signal.

This will allow a combat aircraft to engage an emitting target from standoff ranges without emitting any signal of its own.

The deployment of the Russian R-27 AAM variant with a passive anti-radiation seeker, indicates that a conventional fighter radar lacking Low Probability of Intercept technology will become a genuine liability in the coming decades.

The combination of passive microwave targeting systems on fighters, and anti-radiation AAM seekers will make any aircraft producing easily detectable microwave emissions extremely vulnerable to attack.

Focal Plane Arrays

Another technology which has seen its first large scale use in the nineties is the Focal Plane Array. Such arrays form, in effect, single chip cameras or thermal imagers. An FPA based imager is smaller, lighter, less demanding of cooling, vastly more reliable and potentially cheaper than the electromechanical contraptions in most current aircraft.

The ASRAAM and the AIM-9X are the first AAMs to exploit this technology, using an InSb array. The ongoing improvement of longwave imaging HgCdTe arrays promises to increase further detection ranges. For low cost short wavelength applications, PtSi arrays are another alternative.

The outlook is for improved production yields, lower cost and larger array sizes in the coming decades. We have yet to see the best this technology can offer.

In practical terms, this technology has the potential to provide every fighter with a highly sensitive Infra Red Search & Track set which doubles as a thermal imager for navigation and target identification. Combined with suitable optics and processing algorithms, such FPA imagers have the potential to detect targets at ranges of hundreds of kilometres.

Embedding an FPA imager into a pilot's helmet provides a low cost helmet steered FLIR, without many of the encumbrances of contemporary NVG technology.

GPS and Navigation

The nineties have seen massive improvements in the accuracy of differential GPS techniques. Wide Area Differential GPS techniques pioneered by the USAF now have the ability to locate platforms with accuracies of mere inches, in three dimensions. The incremental cost of incorporating WADGPS techniques into extant GPS technology is very low. Therefore, we can expect this capability to proliferate rapidly over the coming decade.

The availability of extremely accurate WADGPS techniques translates into a potentially huge improvement in the lethality of guided weapons used against fixed targets. It also enables significant improvements in areas such as Synthetic Aperture Radar, since the resolution and accuracy limits of such equipment depend on the positional accuracy of the carrying aircraft.

Important developments in digital beamforming antennas have largely overcome the susceptibility to jamming which was characteristic of early generation GPS receivers. Planned improvements to replacement GPS satellites, in power output and signal formats, will further extend the margin against jamming.

Other technologies will further accelerate the ongoing reduction in navigation system costs. The solid state Silicon gyro, coupled with solid state Silicon accelerometers, will allow the production of highly accurate GPS/inertial navigation packages at costs of hundreds of dollars. Therefore GPS guided bombs will further decline in cost, making electro-optically guided bombs and missiles uncompetitive in the coming decade.

Flat Panel Displays

The nineties have seen the Active Matrix Liquid Crystal Display panel displace the Cathode Ray Tube as the primary technology for cockpit displays. Providing full colour, high resolution, low power consumption and low volume, they are a cockpit designer's dream come true.

Current market pressures resulting from the introduction of High Definition TV will see further increases in AMLCD panel resolution and size, and major decreases in cost.

Another technology is now set to displace the AMLCD. It is the Light Emitting Polymer or LEP. The LEP is an organic semiconductor, which can be screen printed onto a substrate and actively emits light when current passes through it. Integrated with the thin film technology used in the AMLCD, it promises further reductions in cost, while improving reliability, contrast and viewing angles.

The Plasma Discharge Panel (PDP) is another technology which is maturing, and driven by the HDTV market, has the potential to compete with the LEP for the leading position held by the incumbent AMLCD.

Supported by the massive computing power of the coming generation of processor hardware, very elaborate and fast graphics displays will be both technically feasible and affordable.

A future cockpit exploiting this technology will be limited only by the available space and the need to find places to put the buttons and controls !

Helmet Mounted Displays

Helmet Mounted Display technology has also progressed dramatically, with strong pressures resulting from the proliferation of 4th generation WVR AAMs. At this time we have no less than 5 families of Helmet Mounted Display emerging in the marketplace. The Israeli DASH III and US/Israeli JHMCS, the French Topsight/Topnight, the UK/Dutch Viper family, the Pilkington Optronics Eurofighter Helmet and the Russian HMDs are the first step in this major area of technology.

The first displays which use lasers to project images directly onto the user's retina are now beginning to appear in the commercial market, driven by the computer games industry.

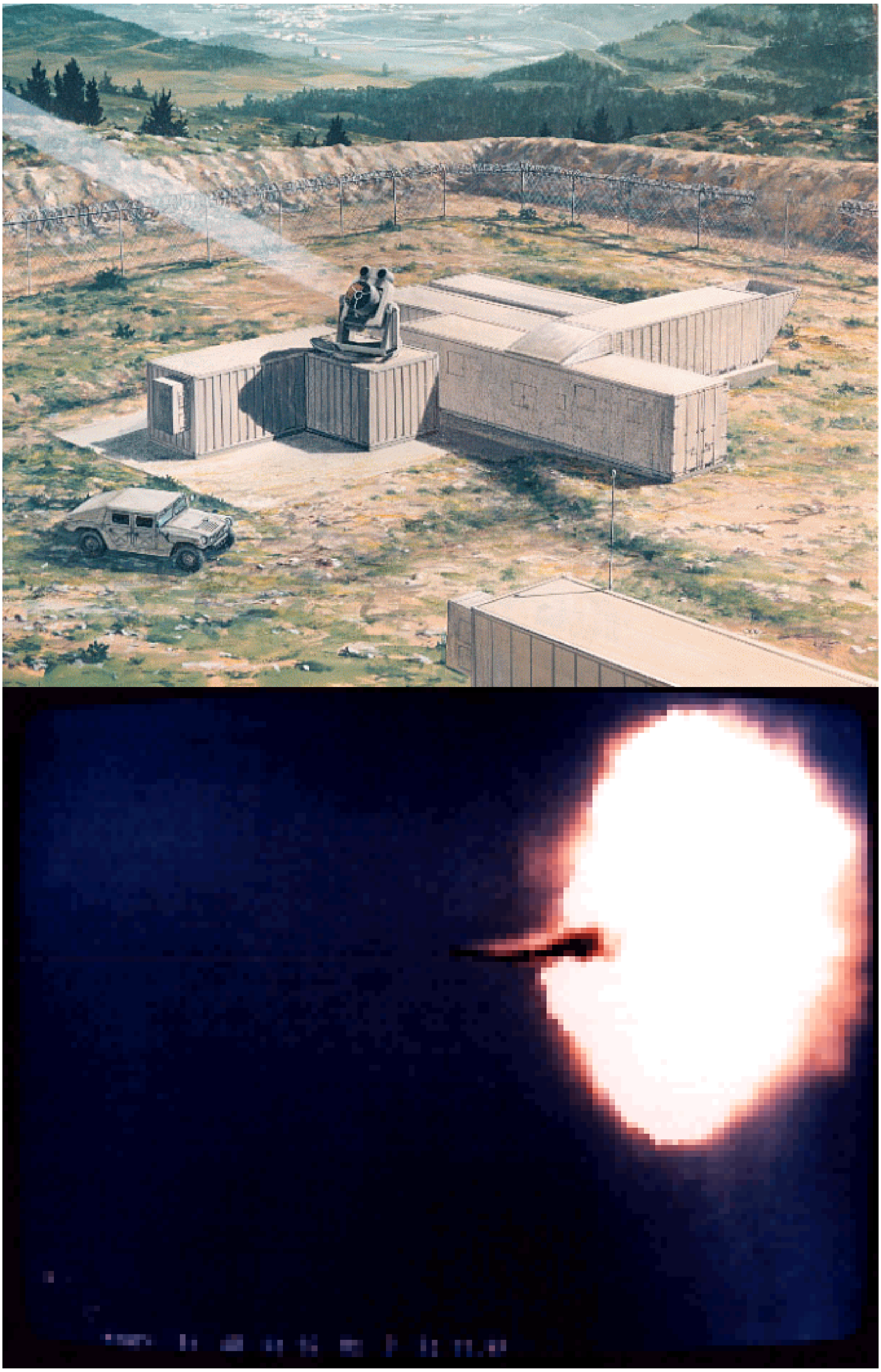
Micro-mechanical mirror technology used in commercial projectors is another potential basic technology for HMDs.

A commercial inertial head tracker has been recently patented, and a number of manufacturers now supply commercial eye tracking technology.

A future HMD incorporating these technologies is likely to project directly onto the pilot's visor a combination of colour synthetic symbology, and imagery from helmet mounted FPA imagers or NVG tubes. Using eye tracking and inertial head tracking, such a HMD is likely to be more accurate, much cheaper, and free of the "head pointing" clumsiness of current technology.

Supported by ample computing power, such HMDs raise the prospect of a completely synthetic cockpit environment, where the functions of the HUD and other cockpit displays are subsumed by the HMD.

Even older aircraft with cockpits which are too difficult to retrofit with flat panel displays could acquire many of the same capabilities, by using such HMDs.



US Army THEL installation and target kill (US Army).

High Energy Lasers

The impending test program and planned deployment of the USAF's YAL-1A/AL-1A airborne Anti-Ballistic Laser (ABL) weapon, and the US Army's Tactical High Energy Laser (THEL) herald the emergence of Directed Energy Weapons (DEW) on the modern battlefield.

Laser beams travel at the speed of light and deposit hundreds of kiloWatts or MegaWatts of power on their targets, causing structural failure of load bearing skins and ignition of fuel.

Two key developments in basic technology have enabled these devices to become viable.

The first is the development of the Chemical Oxygen Iodine Laser (COIL), the second is the development of adaptive optics. Adaptive optics or "flexible mirrors" allow the beam wavefront to be "pre-distorted" to compensate for atmospheric effects which would otherwise diffuse the beam.

Infra-red lasers such as the COIL, other halogen lasers, and the venerable carbon dioxide Gas-Dynamic Laser (GDL) are weather limited and do not penetrate cloud effectively. However, they are capable of covering large distances at the speed of light and can only be defeated robustly by defeating the weapon targeting and tracking subsystems. Reports in the trade press indicate that solid state lasers may also become viable prospects for weaponisation in the coming decade.

The US currently holds the monopoly on adaptive optics and weapon class HEL technology, but as history indicates it is only a matter of time before the technology is copied and it proliferates.

Large surface based lasers will therefore become an air defence threat in the coming decades.

It is not infeasible that further miniaturisation of such lasers and their optics will allow their incorporation into fighter aircraft. Such a laser could be employed as a close-in weapon, supplanting or supplementing the gun and WVR AAM with a virtually instantaneous capability to damage or destroy another aircraft at shorter ranges.

No less importantly, such a laser could be used to destroy inbound AAMs and SAMs.

HELs perform best at medium to high altitudes, conditions where passive optical and infra-red targeting works best. In such an environment, the signature performance of a fighter will be vital to its survivability.

High Power Microwaves

The dependency of modern weapon systems upon their onboard avionics, as well as the dependency of much of civil and military infrastructure upon computers has created an exploitable vulnerability to High Power Microwave (HPM) weapons.

Using GigaWatt class reusable pulsed sources such as Backward Wave Oscillators or single shot sources such as Vircators, it is now feasible to construct airborne and surface based microwave beam weapons and expendable microwave bombs.

Several warhead programs have been reported in the US, specifically involving the AGM-86C CALCM and AGM-154 JSOW glide weapon. Such weapons will be capable of disrupting, disabling or electrically killing a range of surface targets. These could include C3 systems, computing and communications infrastructure, air defence systems and aircraft on the ground.

HPM weapons are also a candidate for combat aircraft, providing that suitable antenna designs can be produced. A HPM weapon carried on a fighter could be used to disable opposing aircraft and inbound AAMs and SAMs. A hit by such a weapon could be fatal to a victim aircraft, by damaging the flight controls, engine controls and causing arcing effects in the fuel ullage and wiring. Weapon fuses could also be initiated under the right conditions.

As with laser weapons, HPM weapons will perform best at high altitudes, and can be effectively targeted by passive means. The best defence is also denial of targeting information by signature control.

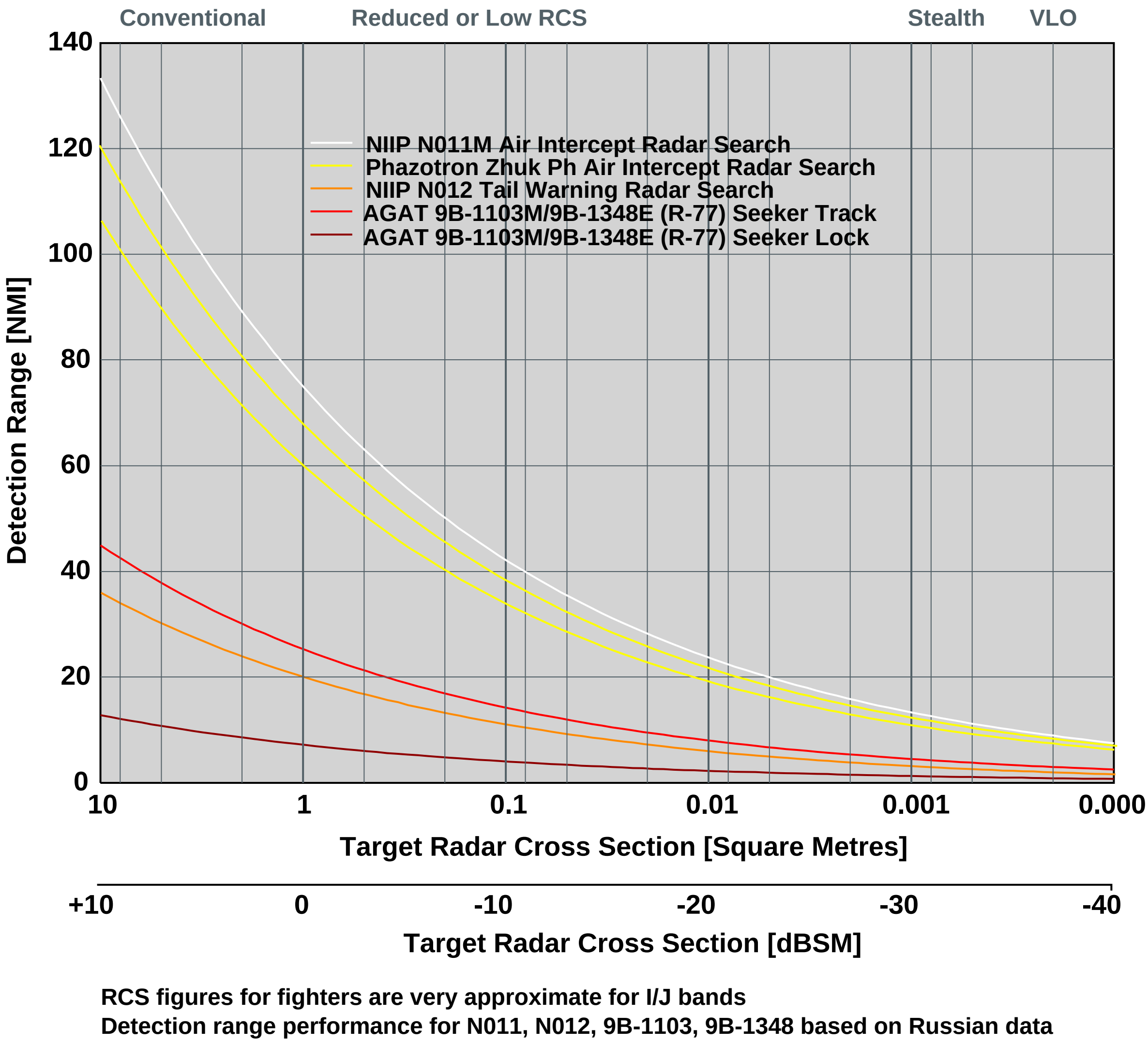
Fighter and Missile Propulsion

Powerplant technology has seen two important advances in this last decade, both of which will have important implications for air combat.

The first of these is the development and impending production of turbofans designed for sustained dry supersonic cruise operation. This is a demanding regime of operation which requires that the engine be designed from the ground up for a much higher temperature profile than established fighter turbofans. Materials and cooling techniques are critical to success, and incremental improvements to older engine technology are not a viable solution to the problem.

The US have tested the YF120 and the F119 engine, with the latter intended to power the F-22 and the JSF.

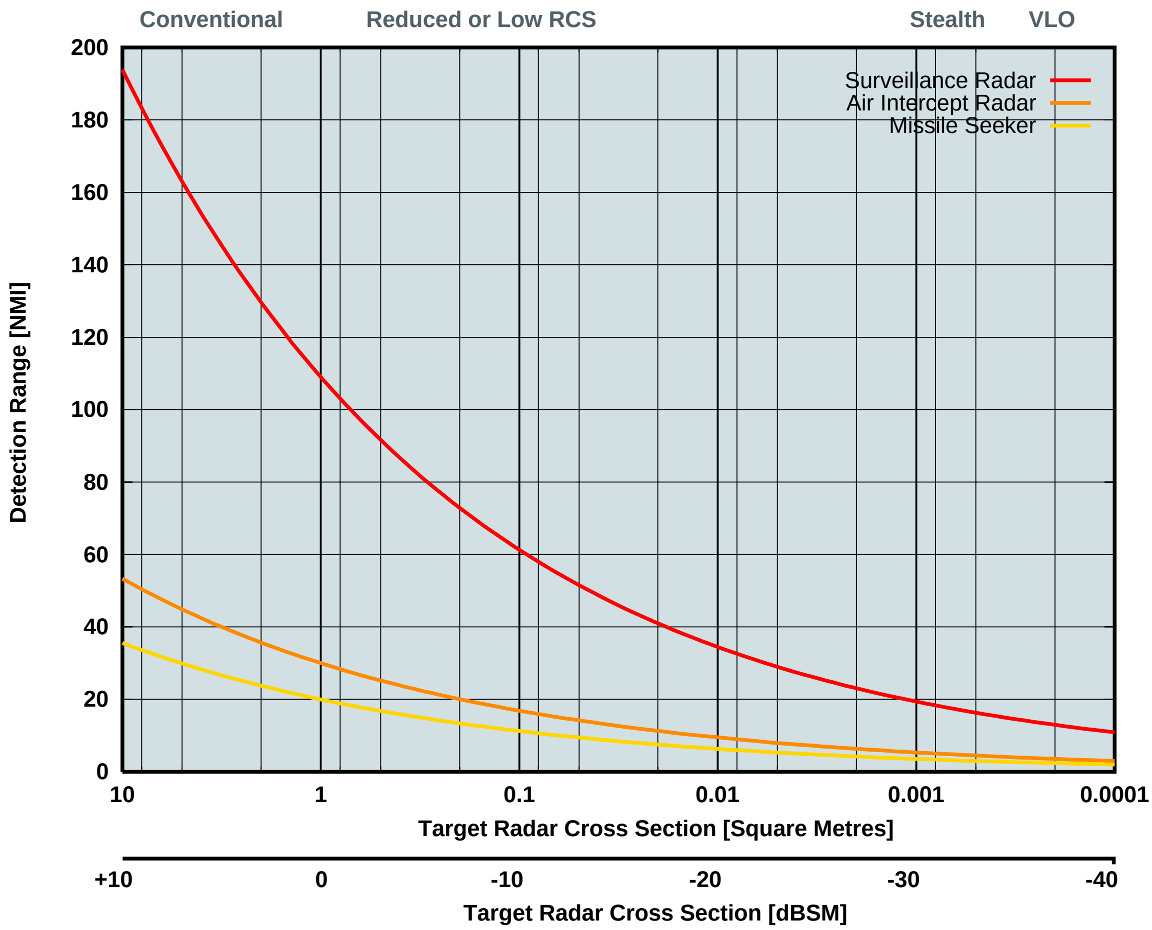
Supercruising engines provide persistence in supersonic combat, which confers many tactical advantages, especially when combined with stealth.



Detection/Engagement Ranges for Flanker/Adder Weapon System vs Target RCS

What is critically important is that this technology allows supersonic combat without the large infra-red signature penalty of afterburner use. Therefore, fighters equipped with such engines will have a great advantage over fighters with conventional engines. The latter will be forced to engage afterburners to compete in such high energy combat and become immediately susceptible to passive infra-red sensors and weapon seekers.

A no less important development is air-breathing solid rocket ramjet as used in the Russian R-77M variant, proposed for the UK FMRAAM and alleged to have been used in a US AMRAAM variant. Such powerplants provide a significant range improvement over established dual pulse rocket powered BVR AAMs, and no less importantly, they provide the AAM with significantly greater kinetic energy in the endgame manoeuvre.



Detection Range for Surveillance, Air Intercept and Missile Seeker Radars vs Target RCS

Combining such AAM propulsion technology with radar datalinking techniques results in a substantial expansion of the lethal envelope of "medium range" AAMs, making them competitive with older generation heavyweight long range BVR AAMs. Therefore, lightweight fighters, and fighters with modestly sized internal weapon bays, will be capable of assuming the roles performed by the classical "heavyweight" air defence fighter such as the F-14 or MiG-31.

These developments have been paralleled by the adoption of high impulse rocket engines in WVR AAMs, frequently combined with complex aerodynamic surfaces, and/or thrust vectoring to achieve performance in excess of 50G. Such missiles are typically equipped with agile, high off-boresight angle seekers.

Low Observables

Stealth technology, comprising large reductions in radar and infra-red signatures, is approaching its twentieth anniversary as a technological innovation to air combat. The important development in the last decade has been the refinement of materials technology, shaping techniques and measurement techniques, to allow high performance aircraft to acquire this capability.

The US F-22 and JSF programs promise insect class radar signatures, and if vendor statements are to be accepted, radar signatures tuned to order by the replacement of specific portions of aircraft leading edges, inlet components and nose sections.

This is important insofar as this generation of aircraft will have some potential for evolutionary growth in radar low observable performance, bounded by the shaping and detail signature performance of other portions of the airframe.

In terms of infra-red signature performance, the use of supercruising turbofan technology will confer a clear advantage over established aircraft.

The expectation that the currently achieved signature performance of this generation of aircraft cannot be further improved upon is unrealistic. As demonstrated by the never built YF-23 prototype, there is considerable scope for improvements in areas such as exhaust geometry and planform alignment.

Sensor Fusion

The availability of high performance sensor technology and very fast on-board computing assets creates conditions in which the fusing of sensor outputs becomes feasible and practical.

The pilot is thus no longer burdened with the need to interpret multiple sensor outputs, integrate the information so gathered, and then reach a conclusion about the identity and intent of the tracked vehicle. This demanding function can be shifted away from the pilot and embedded in the aircraft’s system software.

He, or she, can focus on flying and tactics, rather than the management and manipulation of a complex sensor suite.

Because the target identification criteria are buried in the software, it is feasible to achieve highly consistent and very fast threat identification performance across a fighter fleet. Moreover, it is possible to rapidly update these criteria across the fleet, should further intelligence be gathered.

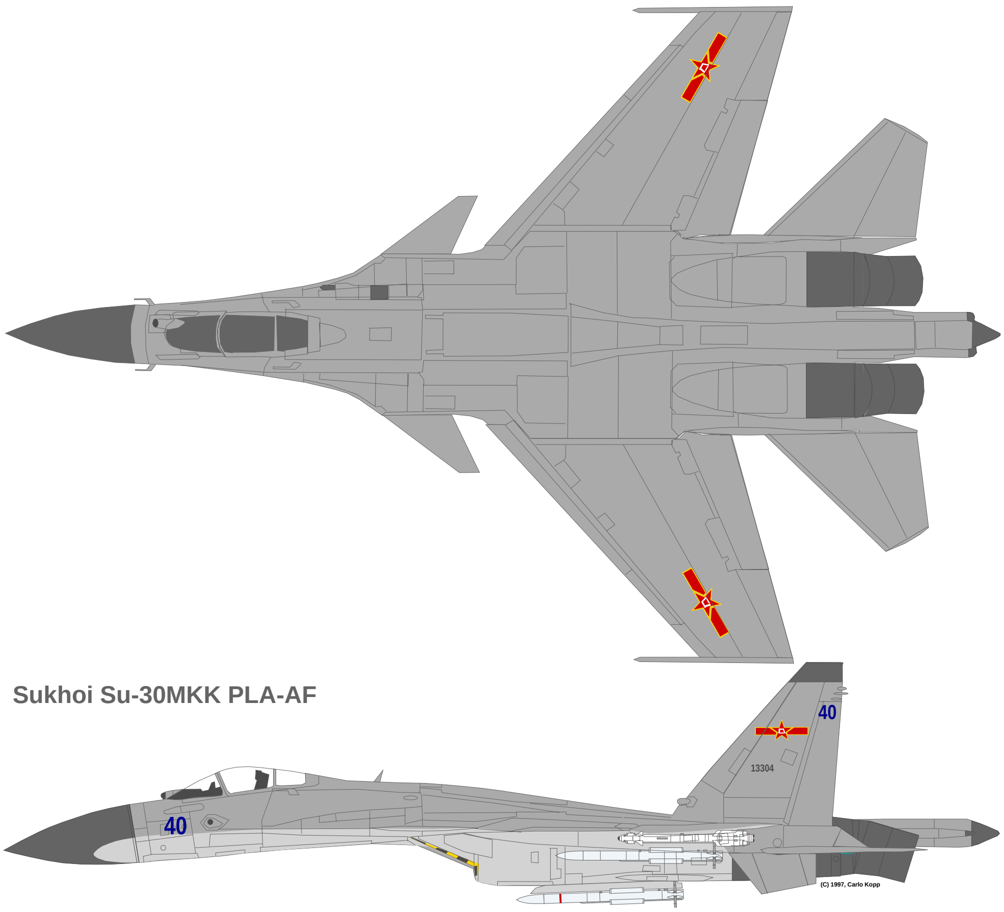
Sensor fusion techniques are still at an early phase in their evolutionary life cycle. Many further opportunities will exist to improve capabilities and performance, using modern information theory techniques and artificial intelligence techniques.

Like radar signal processing, sensor fusion is an area of technology which is set to see significant growth with the cumulative effects of Moore’s Law at play. It is another technology where the best is yet to come.

Conclusions

It is clearly evident that the coming decades will see significant growth in the capabilities of the primary sensors on combat aircraft and by the application of the same basic technology, commensurate improvements in the capabilities of missile seekers.

The operational deployment of directed energy weapons such as lasers and microwave beam weapons is now inevitable.



The kinematic performance of the latest generation of WVR and BVR AAMs now leaves few opportunities for escape by manoeuvre.

With the proliferation of high performance microprocessors being impossible to stop, potent ECCM features in radars and missiles will make effective jamming increasingly difficult. Sensor fusion will become increasingly common.

The result of these developments in weapons technology is simple - whoever gets the first firing opportunity is likely to win the engagement.

Therefore the primary game in the coming decades will be the contest between sensors and signatures. The players with the best combination of sensor performance and signatures will prevail over their opponents.

It would therefore be fair to restate Guderian's famous axiom about a tank's engine being as important as its gun, into a nineties form of:

"A fighter's (sensor) apertures and signatures are as important as its airframe and propulsion."

Inevitably, this situation is never static. Evolution is as much a part of warfare, as it is a part of biology. Therefore the ability of a combat aircraft to evolve along its lifecycle will be vital to its ability to remain competitive. In air warfare, doctrine is implicitly tied to the technology in use.

Therefore we can safely formulate another axiom for the coming century:

"The player who can evolve technology and doctrine faster, all other things being equal, will prevail."

The AIR 6000 program falls squarely into a period of technological paradigm shift, and therefore it is imperative that this be considered first and foremost when criteria are defined for the selection of types.

We propose that three basic tests be applied to all types to be considered:

1. How good is the aircraft's signature performance, and how much growth in this performance is feasible for the design over its life cycle ?

2. How good are the aircraft's sensors, and how much growth in sensor capability and performance is feasible for the design, over its life cycle ?

3. What capacity does the design have for further evolution in internal systems and basic performance, over its life cycle ?

How well candidate fighters measure up against these criteria will be a direct indicator of their operational longevity.

The next century will be the century of air power. For the RAAF to be relevant in this brave new world, it will have to embrace the paradigm shifts currently under way, without reservation.