Review of Defence Annual Report 2002-03: Analysis of Department of Defence Responses

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Preface

From the perspectives of strategy, technological strategy, force structure analysis planning, military science and engineering, the Air Force submission entitled 'Consideration of Defence Input to Defence Annual Report for FY02/03' is a deeply disturbing document.

The aim of the document was to articulate current Air Force leadership thinking on the current and planned RAAF force structure, the fundamental issues driving current planning, the history and reasoning behind the decision to retire the F-111 early, and the future capability in the Joint Strike Fighter.

What emerges from reading this document is a picture of an Air Force in a state of internal disarray, confronted and not coping with a regional arms race, ageing inventory, a period of rapid and ongoing technological evolution, competing demands for funding, inherited management and acquisition problems and a visible problem with personnel deskilling in a range of areas.

The Air Force submission is replete with errors in language, terminology, understanding, engineering, strategy, regional capability analysis and operational concept definition, as well as clearly misleading statements. It is permeated with ideas centred in internal ideology rather than critical scientific and doctrinal thought. Non-sequitur conclusions and arbitrary assumptions abound, despite the many months available to research and compile this document.

Australia is now confronting strategic changes in the region on a scale not seen for 65 years, and the Royal Australian Air Force will be pivotal to maintaining Australia's security in this new environment. Unless the Royal Australian Air Force gains a very large increase in key capabilities over the coming two decades, Australia will be in an increasingly weak position as the wider region expands and modernises its air power and supporting technological capabilities.

It is the sincerest hope of the authors that this critical analysis will become the catalyst for vital and deep changes in how Australia thinks about air power, how it invests in the Royal Australian Air Force, and in how Defence performs its role of developing future air power for the defence of this great nation.

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Analysis Summary

The Air Force submission entitled 'Consideration of Defence Input to Defence Annual Report for FY02/03' is divided into sections dealing with the 'Future Air Force', the 'Legacy Strike Capability' now in use, the 'Enhanced Strike Capability' during the period between F-111 retirement and JSF introduction, and the 'Mature Strike Capability' dealing with the Joint Strike Fighter.

The section dealing with the future of the Air Force is largely a philosophical discussion of the importance of networking. Networking of air forces is the direct equivalent of the 'digitisation' we observed in industry a decade ago, and offers many important gains. No differently from networking in industry, networking of air forces is not a substitute for the capacity to perform useful work.

Prior to the advent of networking, aircraft had to queue up as targets were found for them. There was not enough targeting information to keep all of the aircraft busy. As the Americans introduced better reconnaissance and surveillance systems to find targets during the 1990s, they discovered that the biggest obstacle to delivering the firepower they had was the time wasted by aircraft flying back and forth to be refuelled and reloaded with weapons. Large aircraft with plenty of fuel and bombs could orbit nearby targets and pounce on them as soon as they were detected, and proved to be more successful than small fighters.

Herein lies the value of networking - networks allow targeting information to be rapidly gathered and distributed, thus permitting the kind of devastating attacks observed in Afghanistan and Iraq.

Networking has also proven very useful in air combat, allowing fighters to receive surveillance information from airborne and ground based surveillance radars, and other surveillance systems. This allows them to often evade enemy fighters and missile systems, or set up ambush attacks.

Air Force have unfortunately misunderstood many of the most important ideas underlying networking. Air Force believe that the network and surveillance systems feeding it are more important than the size and capabilities of the platforms (aircraft) which are networked together.

As a result, Air Force see little value in large and highly capable aircraft, like the F/A-22A or F-111, and believe that smaller and less capable aircraft like the F/A-18A or JSF are good enough, in the belief that networking them together makes up for their inadequacies.

This is simply incorrect, as the limits on how much firepower a force can deliver against an enemy are determined by the the size and capabilities of the combat aircraft, and their numbers. In a 'high noon' shootout with an opposing fighter or missile battery, the capability of the combat aircraft is more important than the network feeding it. When hunting mobile ground targets, endurance and weapon payload are most important.

Air Force have made a number of very foolish assumptions, in putting networking above the capabilities of combat aircraft. One is that the RAAF will have networking and surveillance systems feeding it, but an opponent will not. Another is that an opponent will not jam the network or shoot down the surveillance aircraft feeding it. Regional buys of Russian equipment invalidate both assumptions.

The section dealing with the 'Legacy Strike Capability' explains the thinking behind the early retirement of the F-111.

This discussion first attempts to summarise the numbers in the current F-111 fleet, and fails to explain how and why Air Force failed to fully exploit the 15 F-111Gs bought in 1992, by not equipping them with precision weapons.

Air Force then claim that the current situation, where about half of the F-111 fleet is not counted as available, is a consequence of the age of the aircraft, rather than a consequence of well documented under-investment, inadequate funding for deep maintenance, under-management, under-staffing and often under-skilling of personnel.

This is followed by complaints about difficulties in maintaining older aircraft, despite the fact that in the dollar value of accrued investment into the F-111 fleet, 1990s avionics dominate. The 1990s avionics upgrade is cited as not arresting the effects of ageing, despite its success and the fact that it was not intended to fix issues with the airframe or engines.

Air Force then attribute problems with OH&S issues in fuel tank repair, known of since the 1970s, and historical shortcomings with maintenance management to the age of the aircraft.

The discussion of the cost of planned avionic and weapons upgrades required for a 2015-2020 F-111 withdrawal includes significant inflation of costs by, inter alia, 'double counting' of programs and munition warstock costs. It illustrates a failure by Defence to identify synergies between upgrades which could improve capabilities, and reduce costs. No costings are provided for the incorporation of networking capabilities, despite repeated claims of high expense in doing so.

Air Force subsequently complain about 'surprises' arising in the support of the F-111, and the cost of dealing with them. The first example cited was the grounding due to OH&S problems in fuel tank repair, despite the fact that it was known for some time a problem existed. The second example cited was the grounding due to the 'wing fatigue problem' despite the fact that this arose from poor prior planning. Finally the fuel tank explosion is cited, despite the fact that fuel tank explosions were by then a well known risk with commercial jets.

Air Force claim an expectation of declining availability, despite a steady trend in the opposite direction since Boeing took over F-111 deeper maintenance. A 'lack of confidence' in future improvements in F-111 is cited as the basic justification for F-111 early retirement, even though it contradicts engineering data.

Survivability of the F-111 is then criticised, despite the fact that planned cruise missile class weapons upgrades Air Force cancelled would solve most survivability issues, and alleviate others. The need to escort F-111s with fighters is claimed, despite the fact that in most situations where this is required, the F/A-18A also needs to be escorted. In describing delivery methods for bombs, Air Force opted to exclude the most survivable method, used since 1985.

The section dealing with the 'Enhanced Strike Capability' explains the thinking behind the use of tanker supported F/A-18As as substitutes for the F-111.

The virtues of planned F/A-18A upgrades are described, despite the fact that all of these capabilities are available on the more capable Russian Sukhoi fighters. The benefits of new weapons interfaces are described, omitting the fact that this investment has already been made in the F-111.

The virtues of equipping the AP-3C Orion maritime aircraft with cruise missile class weapons are described, despite the poor survivability, poor productivity and high cost of this option.

The description of the strike capability provided by tanker supported F/A-18As claims a larger strike capability than the F-111, but does not explain the fact that F/A-18A are still needed to perform escort tasks, and air defence tasks. Low altitude penetration of defences by F/A-18As is discussed, despite known difficulties in doing this with aircraft lacking the F-111's automated terrain following systems.

The section dealing with the 'Mature Air Combat Capability' explains the thinking behind the choice of the JSF as a single type replacement for the RAAF's fleet.

It provides a reasonable summary of the JSF's features, but does not explore the JSF's limitations in stealth capability and aerodynamic performance, or the availability of most of its avionics capabilities as retrofit options for older aircraft. No discussion of the limitations of the JSF against Russian Sukhoi fighters is included.

Air Force also avoid detailed comparisons of the JSF with the more capable F/A-22A. While the 2006 date for the JSF decision is raised, no mention is made of the fact that no opportunity will exist at that time for Air Force pilots to fly the JSF against other fighter aircraft to validate its capabilities.

The summary of JSF capabilities omits important details in many areas, and overstates the strike capability provided by tanker supported JSFs.

The subsequent discussion of future Air Force capability relative to the region lacks any supporting detail, and is centred on unrealistic and outdated assumptions about regional capabilities. The strike capability chart provided shows a 43% percent decline in capability as the F-111 is retired, but this is dismissed by comparing the post F-111 capability with the capability predating the introduction of tankers.

The discussion of prerequisite criteria for F-111 retirement fails to discuss the impact of the drawdown in spares and consumables, now under way, and how this will force F-111 withdrawal regardless of the prerequisites being met.

Present regional deployments and orders of Russian built Su-30 fighters are described in terms of 'may' be introduced, rather than 'are in service'. The superiority of the F/A-18 supported by tankers, networking and AEW&C is proclaimed, with the unstated assumption that regional nations will have no such supporting assets.

F/A-18A fatigue life extension is proposed as a hedge against late JSF delivery, despite the high cost, impact on availability and minimal return on investment.

Finally, conclusions are presented. These are largely unsupported and unsupportable by known facts. Measures intended to offset the loss of the F-111 are summarised, but most items are peripheral to the central issue of how many smart bombs can be carried to what distance by the Air Force fighter fleet.

The document displays an intellectually incoherent rationale for current force structure planning. Much of this rationale is centred in assumptions and premises about regional capabilities, technological capabilities and the viability of networking which have little or no basis in observable facts.

The reasoning presented for the decision to retire the F-111 is centred in beliefs and opinions, rather than intellectually rigorous analysis. Similar problems abound in the cases presented for networking and for the choice of the JSF over the F-111.

Analysis Conclusions

Conclusion 1: The belief held by Air Force that networking of platforms is a substitute for platform capabilities or numbers is incorrect. To accept the notion that networking is a substitute for platform capabilities and numbers ignores the experience of operations in Afghanistan and Iraq, where networking increased the workload and relative importance of the largest and most capable platforms, at the expense of the smallest and least capable platforms.

Conclusion 2: The belief held by Air Force that the 'combat effect of the system should exceed the sum of its parts' is not mathematically supportable, given the nature of large military systems. The emergence of this belief in Australian DoD leadership circles reflects a failure to properly understand the relationships which constrain the behaviour of such systems, and a failure to connect the behaviour of networks with the behaviour of large systems.

Conclusion 3: The implicit assumption by Air Force that the ADF will have a significant asymmetric advantage in situational awareness is not supportable, and strategically unsafe. The proliferation of modern AWACS systems and Russian networking equipment in this region during the next two decades will see defacto parity in situational awareness.

Conclusion 4: The implicit assumption by Air Force that the ADF will be able to operate AEW&C and networking systems unchallenged is not supportable, and strategically unsafe. A regional nation lacking an AWACS capability could 'equalise' the odds in a contest with the RAAF by deploying long range anti-AWACS missiles and jamming equipment targeted at the network. If this occurs the whole networked 'system of systems' collapses.

Conclusion 5: Defence have repeatedly rejected the alternative of using high power jamming aircraft to impair an opponent's surveillance radars, communications and networks, despite offers by the United States and several industry proposals.

Conclusion 6: The recent purchase of five A330-200 tankers cannot provide enough combat persistence to offset the loss of the F-111, let alone improve combat persistence over that currently provided by the RAAF's 27 'funded' F-111s. This lack of combat persistence will effectively nullify most of the potential gains in strike warfare from a networked force structure.

Conclusion 7: Inadequate persistent Intelligence Surveillance Reconnaissance capability will become a fundamental bottleneck to future RAAF strike capabilities, unless sufficient investment is made into numbers of HALE UAVs, adequate satellite bandwidth, and reconnaissance capabilities in the fighter fleet.

Conclusion 8: The policy decision by Air Force to favour small weapons over a broad mix of weapons, and to favour smaller aircraft limited to small weapons, significantly narrows the range of targets which the RAAF can effectively defeat in combat, and thus reduces rather than increases the RAAF's strike capability.

Conclusion 9: When Air Force identify only 16 F-111C aircraft out of 27 nominally operational airframes as operational strike assets, they are understating the usable combat potential of the strike fleet by 40%. Very little investment would be required to make the F-111G into a fully capable precision strike asset.

Conclusion 10: Air Force presented a case that the Rate of Effort available from the F-111 fleet has steadily declined since 1973, but failed to identify the underlying reasons for this situation, attributing the consequences of under-investment, inadequate funding for deep maintenance, under-management, under-staffing and often under-skilling to the age of the aircraft.

Conclusion 11: Air Force claims that 'no military combat aircraft operator has been able to predict with precision the way an ageing aircraft fleet will behave' amounts to claiming the consequences of not performing work on predicting fleet life cycle behaviour to be an attribute of ageing aircraft. This is non-sequitur.

Conclusion 12: Air Force claims that the F-111 is a '30 year old aircraft' are highly misleading from a reliability engineering perspective. If we take age to be determined by the manufacturing dates of the highest value subsystems in an aircraft, the F-111 would qualify as a 1990s aircraft, not a 1970s aircraft, by virtue of the accrued avionics investment.

Conclusion 13: The use by Air Force of the Avionics Update Program as a example of an upgrade which 'may arrest the [ageing] trend but will never do so completely' is misleading, as the project achieved its aims admirably. Most major difficulties observed with the F-111 were related to maintenance management and OH&S issues on the airframe, rather than age and avionics reliability.

Conclusion 14: Air Force citing of the cost of the largely completed AIR 5398 AGM-142 / Mil-Std-1760C upgrade in the 2015-2020 timeframe unnecessarily inflates capital investment costs and, therefore, is misleading.

Conclusion 15: Air Force claims that the AIR 5409 Bomb Improvement Program incurs AU$20-$30 million amounts to 'double counting' the cost of munition warstocks which will be purchased regardless of what aircraft carries them. This effectively inflates the F-111 specific costs of this program by a factor of up to 500%.

Conclusion 16: Air Force claims that the AIR 5418 Follow On Stand Off Weapon incurs AU$100-$150 million amounts to 'double counting' the cost of munition warstocks which will be purchased regardless of what aircraft carries them. This effectively inflates the F-111 specific costs of this program by a factor of up to 2900%.

Conclusion 17: The costs cited By Air Force for the AIR 5416 Electronic Warfare Self Protection / Radar Warning Receiver projects appear to encompass a complete retrofit of all 27 'funded' F-111C/G. Evidently no effort has been made to achieve any economies in such a program, which could save around AU$40 million.

Conclusion 18: A robust networking capability based on JTIDS/MIDS/Link-16 and IDM could be retrofitted into the F-111 fleet for an expense of the order of AU$20 million. Air Force claims that this is unaffordable are misleading.

Conclusion 19: The cost of investment for F-111 capability and weapons upgrades for a withdrawal in the 2015-2020 timescale cited by Air Force is unrealistically inflated, creating a misleading impression of the scale of investment required.

Conclusion 20: Had Air Force followed conventional engineering and airworthiness practices from the outset, and performed F-111 fatigue testing well ahead of accrued fatigue on the fleet, then no fleet grounding would have been required. The cited 'wing fatigue problem' arose principally due to poor planning.

Conclusion 21: It is unclear why the possibility of a fuel tank arcing problem was not anticipated by Air Force given the known precedents in commercial aircraft and the enormous media exposure this issue produced.

Conclusion 22: Air Force claims of 'declining availability and unscheduled repair arisings that are challenging to manage' are non-sequitur in relation to the F-111, as demonstrated by the increasing reliability and availability of the aircraft since Boeing and the Amberley SPO introduced the ageing aircraft engineering program in 2002.

Conclusion 23: There is no rational or intellectual basis for the claim by Air Force that 'there is not a high level of confidence' in F-111 availability improving. For all practical purposes this belief amounts to *guessing* rather than the conclusion from a rigorous intellectual analysis.

Conclusion 24: The stated conclusion by Defence planners that 'retaining the F-111 in-service beyond about 2010 is not a viable option' is simply wrong. It is predicated on assumptions which are not rationally supportable by fact. Therefore the conclusion itself must be irrational.

Conclusion 25: Claims by Air Force arguing poor survivability of the F-111 are not credible, given the most likely regional threat capabilities expected in the 2020 timescale, and given the option of equipping the F-111 with the AIR 5418 Follow On Stand Off Weapon and glide-bomb weapons such as the GBU-39 and JDAM-ER series. The requirement to escort the F-111 only arises in situations where airborne fighter patrols of Su-27/30 are expected, especially if supported by AWACS. Such threat environments will also require that the F/A-18 be escorted when tasked with strike.

Conclusion 26: The Mil-Std-1760C capability now being fitted to the F-111 permits low cost integration of new generation guided munitions, including the AIR 5409 BIP contenders, the AIR 5418 FOSOW contenders, and the GBU-39/B Small Diameter Bomb. By not stating this, Air Force are in effect concealing the significant growth potential in F-111 strike capability, and the low expenditures in doing so.

Conclusion 27: By excluding low level toss deliveries of guided and unguided bombs, Air Force have created a misleading impression that the F-111 is limited to the less survivable level overflight delivery technique.

Conclusion 28: While the upgrades planned by Air Force for the F/A-18A will result in enhancements to its air combat capability, these will not result in an aircraft which is competitive against a late model Su-30. As an investment strategy large expenditures on F/A-18 upgrades make little sense, given the increasing strategic irrelevance of this class of fighter in a region dominated by the Sukhois.

Conclusion 29: Investment by Air Force in full Mil-Std-1760 interface upgrades on the fleet of 71 F/A-18As effectively amounts to duplicating the investment already made into the Mil-Std-1760 capability in the F-111.

Conclusion 30: The cost of integrating the FOSOW on the AP-3C, its relatively high running cost, the poor productivity of the AP-3C and its poor survivability in many threat environments result in a very poor return on investment in providing the AP-3C with a littoral and land strike capability.

Conclusion 31: In opting for early retirement of the F-111 and the use of podded F/A-18As for reconnaissance, Air Force have effectively overtasked the small A330 tanker fleet which must support strike and reconnaissance roles, as well as escorts. Overtasking and survivability issues will also arise with the HALE UAV and AP-3C.

Conclusion 32: The capability planned for under the Defence 2000 White Paper, and represented in the 'blood chart' provided by Air Force, using tanker supported F-111s and F/A-18 escorts, is 43% greater than the capability provided by tanker supported F/A-18s alone. To claim there is no 'strike capability gap' is highly misleading, and as it directly conflicts with the very information provided by Air Force.

Conclusion 33: Air Force claims about low level penetration technique using strike tasked F/A-18A fighters do not accord well with US experience on the F-16C. There is a risk of combat losses through Controlled Flight Into Terrain (CFIT), as occurred with the loss of the F-111G in Malaysia.

Conclusion 34: It is unclear why Air Force are claiming a better defence penetration capability against sophisticated surface to air missile threats using the F/A-18A rather than the F-111. The F-111 is inherently better suited to this role with greater low level speed and automatic terrain following capability.

Conclusion 35: Air Force, by insisting on a single type combat fleet for the RAAF and insisting on a fleet size of 100 aircraft, have placed Australia in the position where it ends up either purchasing a JSF which is inadequate in the most difficult roles, or an F/A-22A which is superbly capable but too good and expensive for the less critical roles.

Conclusion 36: The preference shown by Air Force for the use of the JSF in air superiority / air dominance roles runs contrary to sixty years of cumulative historical combat experience. All historical precedents indicate the F/A-22A is the proper choice for defeating opposing air power, especially the Su-27 and Su-30.

Conclusion 37: The datalink and communications capabilities of the JSF are not unique, indeed most legacy US fighters expected to remain in service well past 2010 will receive block upgrades including most of these capabilities.

Conclusion 38: The intended 2006 Year of Decision for the JSF is too early to rigorously assess the air combat performance, reliability, and avionic/software capabilities of a representative production JSF variant.

Conclusion 39: Air Force's stated 'level of capability' resulting from the use of the JSF amounts to a reduction in the number of weapons which can be delivered to a given range, relative to the use of escorted and refuelled F-111s.

Conclusion 40: Claims by Air Force that the RAAF will retain a 'regional advantage' in strike capability do not account for planned and expected buys of Su-30 aircraft in the near region, let alone capabilities being developed on the Asian mainland.

Conclusion 41: The claim by Air Force that the F-111 will be retired only when specific prerequisite programs are completed conflicts directly with the effects arising from the current effort to drawdown F-111 support capabilities. As the drawdown effort is now under way the claim that retirement will not occur until specific prerequisite programs are completed is misleading. Retirement is effectively now in progress.

Conclusion 46: The claim by Air Force that the near region 'may see the introduction' of Sukhoi fighters is misleading, insofar as Indonesia has already taken delivery, and Malaysia has placed orders, while planning for a second buy.

Conclusion 47: Air Force claims that the F/A-18 equipped with networking equipment and supported by AEW&C provide 'the best way of defeating these [Su-30, SAM] systems' are predicated on unsupportable assumptions of asymmetric advantages in AEW&C and networking capability post 2010.

Conclusion 48:

The claim that no affordable programs exist to introduce a Link-16 capability on the F-111 is highly misleading given the wide availability of competitively priced Link-16 terminals, and ease of integration with the avionic system now in the aircraft.

Conclusion 49:

Rebarrelling a large fraction of the F/A-18A fleet to effect life extension past 2015 yields a very poor return on investment given the short remaining service life of the fleet beyond 2015, and the inadequacies of the F/A-18 against developing regional capabilities.

Analysis of

Air Force Submission to

Joint Standing Committee on Foreign Affairs,

Defence and Trade

entitled

Consideration of Defence Input to

Defence Annual Report for FY02/03

1 Analysis in Detail

1.1 FUTURE AIR FORCE - DRIVERS OF CAPABILITY (Para 5.)

RAAF Statement: *Australia will need to move away from a platform centric approach to air warfare toward the development of a networked system of systems which will achieve the required combat effect in both a joint and combined environment.*

RAAF Statement: *Put simply, we will need to focus on our ability to exploit information communication systems to build and maintain our capability edge by developing a network centric capability system.*

The terms ‘platform centric’ and ‘network centric’ have not been defined to date in Australia with any exactness, leaving these terms open to interpretation. The usage observed in this and other documents and statements indicates that networking is being accorded priority over platforms, as a matter of doctrine or belief. Indeed, the statement ‘we will need to focus on our ability to exploit information communication systems to build and maintain our capability edge by developing a network centric capability system’ asserts that the ‘capability edge’ is derived from networking first and foremost, rather than other capabilities.

This is a dangerous misconception as networking is not a substitute for platform capabilities, it is an enhancement to platform capabilities. Networking permits information derived from sensors and other sources to be used to enhance survivability, targeting effectiveness and coordination of platforms. In itself it cannot deliver weapons, or maintain a physical presence in an area of interest. The notion that networking is a substitute for platform capabilities, and indeed force structure capabilities, appears to be well established in current Australian DoD thinking, despite the absence of any intellectual or experiential basis for this belief.

> Networking of platforms is not a substitute for platform capabilities, or for platform numbers. To accept the notion that networking is a substitute for platform capabilities and numbers ignores the experience of operations in Afghanistan and Iraq, where networking increased the workload and relative importance of the largest and most capable platforms, at the expense of the smallest and least capable platforms. The US pattern of increased investment in upgrades to bombers and now planning for new bomber designs, at the expense of smaller fighters, demonstrates this convincingly.

1.2 FUTURE AIR FORCE - DRIVERS OF CAPABILITY (Para 6.)

RAAF Statement: *The combat effect of the ADF system should exceed the sum of its parts.*

RAAF Statement: *This improved and common situational awareness will markedly improve air combat lethality and survivability in both the air control and strike environments.*

The notion that the 'combat effect of the system should exceed the sum of its parts' is a statement of belief, not of fact. All systems are only as good as the components which make up the system. Large military systems display behaviours which reflect the behaviour of systems modelled using *Amdahl's Law*, which asserts that adding elements to the system can at best achieve the effect of the sum of the elements. The root of this problem derives from the need to coordinate, marshal and sequence assets, and make decisions, during combat operations. Whenever one asset in combat must wait for another to finish a task, behaviours which follow Amdahl's Law are mathematically inevitable. The experience of every air war observed in the modern era provides undeniable proof of this[1] [2].

There is little doubt that networking will enhance situational awareness for ADF platforms, and that situational awareness may improve survivability, and may improve lethality.

Situational awareness enhances survivability by facilitating evasion of threats. Where circumstances do not permit evasion, situational awareness is of little value. Knowing you are about to be killed does not necessarily prevent it from happening.

Situational awareness enhances lethality by permitting surprise attacks, where an opponent lacks the same situational awareness, or by permitting better coordination of assets. Unless a significant asymmetric advantage exists in situational awareness, no significant advantage in lethality can be derived from situational awareness.

The belief that the 'combat effect of the system should exceed the sum of its parts' is not mathematically supportable, given the nature of large military systems. The emergence of this belief in Australian DoD leadership circles reflects a failure to properly understand the relationships which constrain the behaviour of such systems, and a failure to connect the behaviour of networks with the behaviour of large systems. A naive appreciation of the theory underlying the behaviour of large networked systems has spawned a belief system which is producing a force structure model guaranteed to fail when used in combat, given developing regional capabilities.

There is no evidence to support the belief that the ADF will have a decisive asymmetric advantage over regional nations in AWACS/AEW&C and networking capabilities. India has ordered A-50I AWACS, China is now flying a prototype A-50I AWACS, Malaysia is tendering for AEW&C aircraft. Russian industry is actively marketing the encrypted TKS-2/R-098 (Tipovyi Kompleks Svyazi) Intra Flight Data Link (IFDL) which permits the networking of up to 16 Sukhoi Su-30MK fighters - the earlier APD-518 IFDL is used on the MiG-31 Foxhound and the Russian Air Force Su-35. Russian industry has already produced equipment for networking AWACS and fighters, such as the Raduga-Bort 5U15K-11 datalink on the A-50E/U AWACS. The unstated assumption that such hardware will not be sold in this region over the coming decade is strategically unsafe[3] [4] [5]

> The implicit assumption that the ADF will have a significant asymmetric advantage in situational awareness is not supportable, and strategically unsafe. The proliferation of modern AWACS systems in this region during this decade will see defacto parity in situational awareness. The availability of Russian fighter to fighter networking equipment, and AWACS to fighter networking equipment, indicates that networking capabilities will also proliferate across the region over the coming two decades.

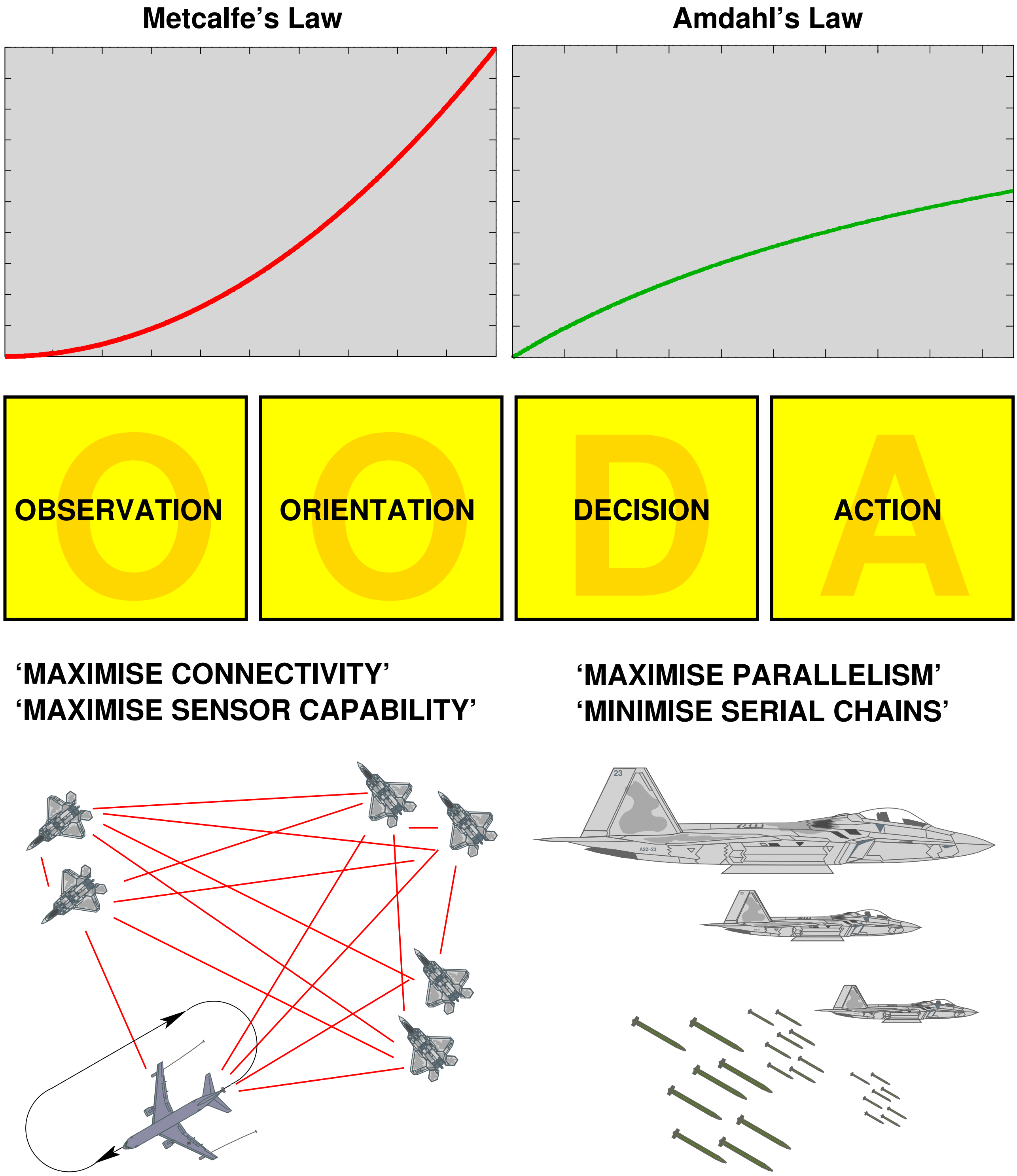


Figure 1: *At the root of the problem with the networked force structure model advocated by Air Force is a failure to connect the capability growth arising from networking with the capability bounds arising from limitations in platform capabilities and numbers. Air Force are effectively arguing that the mathematics of networked large systems do not apply, despite observable empirical evidence to the contrary. This is compounded by an ongoing failure by Air Force to appreciate developing regional capabilities (C. Kopp).*

Figure 2: *China is now flying a prototype AEW&C airframe, based on the Israeli prototype A-50I design. The scale of investment indicates a serious commitment to field a respectable AEW&C/AWACS fleet (Militaryphotos.net)*

1.3 FUTURE AIR FORCE - DRIVERS OF CAPABILITY (Para 7.)

RAAF Statement: *In the air control environment, air to air shooters within the system can remain passive thereby reducing their probability of detection.*

RAAF Statement: *In the air combat environment of the future, a capable and well designed networked system should always prevail over an adversary that is not supported by a similar system, even though that adversary might possess highly capable platforms.*

The idea that 'air to air shooters can remain passive' assumes implicitly that the AEW&C aircraft can operate safely and actively transmit information through the network to the fighters contesting the airspace in question. This assumption is not generally true for two reasons.

The first reason is the emergence of Russian 'counter-ISR' or 'anti-AWACS' weapons, long range missiles specifically designed to kill AWACS/AEW&C and surveillance platforms from stand-off distances. Good examples are the Kh-31A/R family of missiles, now being introduced in the PLA-AF, and the KS-172 family of missiles, currently the subject of negotiations between India and Russia for licence manufacture. Such missiles can be fired at an AWACS/AEW&C aircraft from very long ranges, to either destroy it, or to force it to shut down its radar and attempt to evade the missile. As a result combat aircraft reliant on information produced by the AWACS/AEW&C aircraft will be left to fend for themselves, exposing any limitations they may have in terms of radar and missile capabilities[6] [7].

The second reason is because all radio datalinks used for networking platforms can be either shut down or impaired by hostile radio frequency jamming. Most modern datalinks are designed with varying degrees of jam resistance, but none are immune to jamming, especially if a very powerful jammer is used. During the bombing of Iraq Russian built GPS jammers were smuggled in to Baghdad to compromise US satellite aided weapons. The assumption that regional nations could not and would not deploy jamming equipment to compromise ADF networking capabilities is naive[8].

> The implicit assumption that the ADF will be able to operate AEW&C and networking systems unchallenged is not supportable, and strategically unsafe. A regional nation lacking an AWACS capability could 'equalise' the odds in a contest with the RAAF by deploying long range anti-AWACS missiles and jamming equipment targeted at network operating frequencies. If the RAAF's AEW&C aircraft are destroyed or forced to retreat, or the network function impaired, the whole networked 'system of systems' collapses, leaving fighter aircraft to fight off Sukhois without external support.

The alternative of high power radio frequency jamming of an opponent's AWACS radar and networks is available to the RAAF, but it requires specialised jamming aircraft. Such jamming aircraft could be used to impair the function of an opponent's AWACS, ground based radars, communications and digital networks. This model was repeatedly proposed by industry, and has been proposed in at least one DSTO paper, but has to date been rejected by Defence on the basis of 'distorting the balanced approach to force structure priorities'[9] [10] [11].

Figure 3: *Counter-ISR or anti-AWACS weapons are now appearing in the market as options for the Sukhoi fighters. The Su-27SKU is armed with two Kh-31 missiles (KNAAPO), which would be used to attack an opposing AEW&C or AWACS (C. Kopp).*

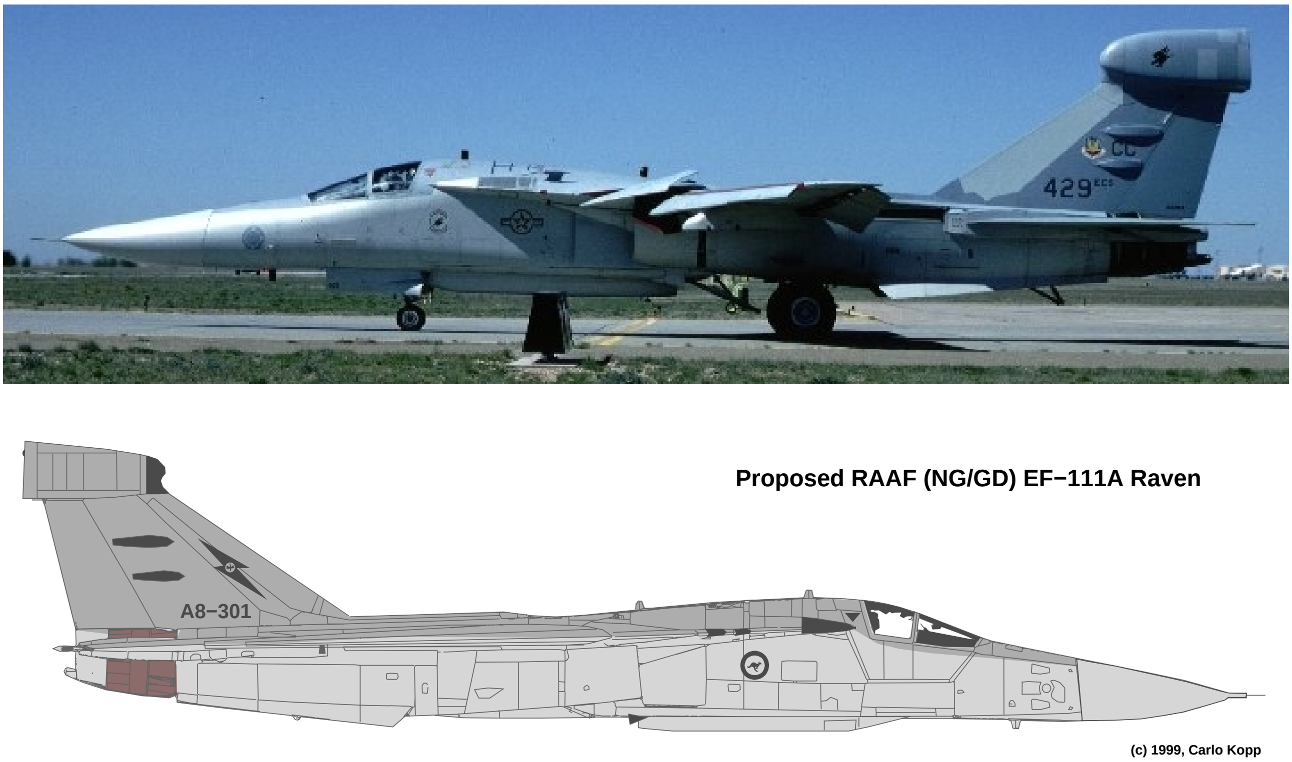


Figure 4: *Defence rejected the option of introducing the EF-111A Raven jamming aircraft. These were mothballed in 1999, and would require refurbishing and a jamming system upgrade based on the ICAP-III system (US Air Force).*

Defence have rejected the alternative of using high power jamming aircraft to impair an opponent's surveillance radars, communications and networks. This has occurred despite offers of EF-111A jamming aircraft by the Clinton Administration, and repeated industry proposals to introduce refurbished EF-111A aircraft, currently held in mothball storage in the US. Available evidence suggests that the belief system in Air Force which devalues the importance of high power jamming aircraft arises from an unrealistic expectation of an asymmetric advantage in AEW&C capability persisting indefinitely, and a belief that regional nations cannot operate such equipment.

1.4 FUTURE AIR FORCE - DRIVERS OF CAPABILITY (Para 8.) to (13.)

RAAF Statement: *The introduction of the Air to Air Refuelling aircraft around 2008 will improve operational flexibility and persistence.*

RAAF Statement: *In addition, the introduction of the High Altitude Long Endurance (HALE) Unmanned Aerial Vehicle (UAV) will provide a long range and persistent ISR capability that will be critical for undertaking precision targeting.*

RAAF Statement: *The future strike capability will have weapons and systems that are optimised to achieve the desired effects rather than applying excessive effects. ... The reduction in the mass of the weapon enables more of the smaller weapons to be carried resulting in a greater strike capability being delivered from smaller combat aircraft than is possible today.*

Persistence is vital to Network Centric Warfare. Without persistence, the whole paradigm of Network Centric Warfare collapses. This is for the simple reason that to take advantage of the speed of information transfer afforded by a networked system, a combat aircraft must be orbiting within proximity of a potential target. If the combat aircraft has had to depart for home due to exhaustion of weapons or fuel, it cannot engage a target found by the surveillance assets feeding the network. This is true for air combat engagements and the interception of cruise missiles, as it is true for interdicting mobile or fleeting ground targets[12].

Persistence is produced through the use of the largest possible combat aircraft for the role, and in part by aerial refuelling. Aerial refuelling can replenish burnt kerosene, but it cannot replenish expended weapons.

The US Air Force experience in Afghanistan and Iraq is illustrative, as larger strike aircraft such as the B-52H, B-1B and F-15E were favoured over the Cold War era lightweight fighters, such as the F-16. With large payloads of weapons and fuel, large strike aircraft can remain over the battlefield for hours. Smaller tanker refuelled fighters cannot achieve this.

The F-111 has the greatest persistence of any Western tactical fighter, and will only be matched by the proposed FB-22 post 2012, should the FB-22 enter development and production[13].

The claim by Air Force that the five A330-200 tankers will improve persistence only holds if the F-111 is retained or eventually replaced by an aircraft of similar size, like the FB-22[14].

A lack of combat persistence remains the single greatest strategic weakness in the RAAF force structure. The recent decision to purchase five A330-200 tankers cannot provide enough capability to offset the loss of the F-111, let alone improve combat persistence over that currently provided by the RAAF's 27 'funded' F-111s. Without a severalfold increase in the number of tankers to be operated by the RAAF, the lack of combat persistence will effectively nullify most of the potential gains from a comprehensively networked force structure.

Note[15]

To date Defence have not committed on a specific number of HALE UAVs, an example being the RQ-4 Global Hawk. Published material suggests that any HALE UAVs acquired will be tasked heavily with maritime patrol to reduce the tasking load on the AP-3C Orion maritime patrol fleet.

While HALE UAVs like the Global Hawk provide excellent persistence, and excellent sensor range, they are not without limitations. They are vulnerable to fighters with good high altitude performance, such as the Su-27/30, and they are critically dependent on available satellite bandwidth. While demands for satellite bandwidth to support maritime operations will be modest, the same is not true for strategic reconnaissance, surveillance and land warfare targeting.

> Inadequate persistent ISR capability will become a fundamental bottleneck to future RAAF strike capabilities, unless sufficient investment is made into adequate numbers of HALE UAVs, adequate satellite bandwidth, and reconnaissance capabilities in the fighter fleet. Defence chose to ignore an industry proposal to upgrade the F-111's Pave Tack system and retrofit a new radar, both providing an organic reconnaissance capability to all so equipped F-111 aircraft.

The 500 lb GBU-38 JDAM, 500 lb EGBU-12 and 385 lb GBU-39 Small Diameter Bomb are the weapons which Air Force are describing as 'optimised to achieve the desired effects' and 'resulting in a greater strike capability being delivered from smaller combat aircraft than is possible today'.

All three of these weapons evolved to meet the demands of battlefield strike, air defence suppression and urban strike operations, and are in many respects niche weapons, intended to kill soft or semi-hardened point targets. The are not substitutes for heavier weapons such as the 2,000 lb GBU-10, EGBU-10, EGBU-15, GBU/EGBU-24. Rather small weapons supplement heavier weapons. Of the roughly 16,000 guided munitions dropped on Iraq last year, only about 45 percent were small 500 lb weapons, in an air campaign dominated by battlefield rather than strategic strike operations[16].

Many targets require large weapons, and cannot be easily defeated by showering them with small albeit accurate weapons. The US Air Force is investing in the development of a range of new weapons even larger than the 2,000 lb class, to match weapons to diverse target types. In general, target types drive required weapon sizes, and aircraft which are limited to small payloads of small weapons will be ineffective against the full spectrum of targets, especially hardened targets and heavy infrastructure targets[17].

> Small precision munitions are exceptionally valuable for strikes on battlefield, air defence and urban targets. They are marginally effective against large infrastructure and hardened targets. A policy decision to favour small weapons over a broad mix of weapons, and to favour smaller aircraft limited to small weapons, is to significantly narrow the range of targets which the RAAF can effectively defeat in combat, and thus reduces rather than increases the RAAF's strike capability.

1.5 THE LEGACY STRIKE CAPABILITY (2004) (Para 14.) to (15.)

RAAF Statement: *Australia has an operational fleet of 16 F-111C strike aircraft, four RF-111C reconnaissance aircraft and seven F-111G training aircraft.*

RAAF Statement: *An additional five F-111G are in long term storage with a further two aircraft having been broken down for spares and one has been lost in an accident.*

RAAF Statement: *A seventeenth F-111C strike aircraft was severely damaged during an incident when fuel tank vapours detonated following a short circuit in the wiring loom of a fuel tank pump.*

The stated breakdown of F-111 fleet composition does not provide an accurate representation of the combat utility of the fleet, and reflects a history of under-investment and under-utilisation of a valuable taxpayer's asset.

Project AIR 5404 was intended to provide the F-111G aircraft with a precision weapons capability, which is absent in the AMP digital avionic system the aircraft were delivered with during the 1990s. At that time the F-111C aircraft were being retrofitted with the then state-of-the-art AUP digital avionic system, this presenting an opportunity to economically retrofit the F-111G with a largely identical digital weapon system and thus precision capability, while the AUP production line remained active. Instead, the AIR 5404 project created a largely unique configuration at much higher cost, and the project was effectively abandoned[18].

While the opportunity to cheaply retrofit an 'F-111C AUP-like' system on the F-111G has been lost, the current development effort under AIR 5398 to provide a Mil-Std-1760 weapons capability creates a similar opportunity for the F-111G to economically acquire a precision weapons capability. This could be effected by adapting the F-111C Block C-4 Station Interface Processor and modifying its recently developed software to interface with the F-111G AMP system. A Mil-Std-1760C capable F-111G would provide a precision capability via the weapons being acquired under the AIR 5398, AIR 5409 and AIR 5418 projects[19].

Since the US Air Force F-111F fleet was mothballed, weapon bay cradles for the Pave Tack targeting system have become available. This presents the opportunity to economically retrofit the F-111Gs with the Pave Tack system, rather than much more expensive new technology targeting pods.

Even without a precision targeting capability, the F-111G can be used in a number of roles paired with an F-111C, the latter providing laser illumination of targets for laser guided bombs carried by an F-111G. This technique was used for battlefield interdiction and strategic strike by the US Air Force during the 1970s, and the Royal Air Force during Desert Storm in 1991. Moreover, even very recent bombing campaigns have seen considerable use of unguided 'dumb bombs' for area and battlefield targets. During last year's bombing of Iraq, no less than 32% of delivered weapons were unguided 'dumb bombs' - virtually all instances involving targets ill suited to more expensive precision weapons[20].

When Air Force identify only 16 F-111C aircraft out of 27 nominally operational airframes as operational strike assets, they are understating the usable combat potential of the strike fleet by 40%. Very little investment would be required to make the F-111G into a fully capable precision strike asset, and even without a capability to target precision weapons, it remains a useful asset for a range of bombing tasks, especially in battlefield interdiction roles.

Of no less concern are the F-111G aircraft currently held in long term storage. At the cost of a deep overhaul, wing replacement and replacement of some cannibalised components, these aircraft could be used to further spread the fatigue load across the fleet, and provide a contingency reserve to rapidly bolster operational F-111 numbers in a crisis situation. The incremental investment in bringing all of the F-111G aircraft to a flyable and Mil-Std-1760 precision weapons capable configuration, with identical electronic warfare equipment to the F-111Cs, is relatively low, compared to the strategic and operational payoff in the effective doubling of the number of F-111 aircraft available for precision strike combat operations.

That we now have a situation where Air Force can claim that only 50% of the F-111 airframes in Australia are effectively available for combat operations at short notice is an indictment upon the much of the regime of past investment into this capability, and the attitude of the present Air Force leadership toward this capability. Air Force presented a case that the Rate of Effort available from the F-111 fleet has steadily declined since 1973, but failed to identify the underlying reasons for this situation, attributing the consequences of under-investment, inadequate funding for deep maintenance, under-management, under-staffing and often under-skilling to the age of the aircraft. The current state of Australia's F-111 fleet reflects a long chain of decisions made or not made, by Defence, over the last 20 years. It does not reflect any inherent inadequacy of the aircraft or the technologies from which it is built. The F-111 was designed and built in the halcyon days of the American aerospace industry. Its robust capabilities make it superior to other airframes of its generation, and most more recently built aircraft.

1.6 THE LEGACY STRIKE CAPABILITY (2004) (Para 16.)

RAAF Statement: *No military combat aircraft operator has been able to predict with precision the way an ageing aircraft fleet will behave.*

RAAF Statement: *Signs of obsolescence and increasing maintenance effort usually become evident after 10-15 years of operation, driven by the cumulative reliability of the thousands of components that make up an aircraft, wear and tear, and the effects of time.*

RAAF Statement: *Modifications to the aircraft, as was the case with the Avionics Update Program (Project AIR 5225) during the late 1990s, may arrest the trend but will never do so completely. Unforeseen maintenance costs inevitably will arise and new issues will emerge.*

RAAF Statement: *The Sole Operator Program was designed to manage the issues as cost effectively as possible.*

The claim that ‘no military combat aircraft operator has been able to predict with precision the way an ageing aircraft fleet will behave’ misrepresents recent history in combat aircraft life cycles. Until 1991, when the Soviet Union collapsed, virtually all combat aircraft were retired and replaced for reasons of capability rather than ageing. The highly competitive technological arms race saw new aircraft types being developed and mass produced specifically to defeat opposing types, and this was reflected in aircraft life cycles much shorter than observed today. The need to retain large latent production capacities in the US, EU and Warpac industrial bases to permit a rapid ramp up to overcome combat attrition produced a strong incentive to replace uncompetitive aircraft as early as possible.

Since 1991 the absence of a credible technological peer competitor to the US/EU military-industrial complex led to a large scale draw-down in US and EU production capacity for combat aircraft, as the pressure to compete with new designs abated. That the Eurofighter Typhoon and F/A-22A were conceived during the 1980s and are only now entering service reflects more than a decade of time during which Western air forces have confronted mostly Third World air forces, flying obsolescent Soviet designs.

It was only during the 1990s that ageing combat fleets became a maintenance issue in the West. Until then aircraft were maintained with the expectation of rapid block replacements for capability reasons alone - aircraft were ‘burned out of life’ with no regard for longevity. Therefore no reason existed to perform ageing aircraft engineering programs, let alone gather the detailed life cycle duration failure rate statistics required for this purpose. This is a problem which has only arisen over the last decade, and most operators are still in the phase of gathering statistics to identify reliability hot-spots in operational types, let alone attempt analytical predictions.

Claiming ‘no military combat aircraft operator has been able to predict with precision the way an ageing aircraft fleet will behave’ amounts to claiming the consequences of not performing work on predicting fleet life cycle behaviour to be an attribute of ageing aircraft. This is non-sequitur.

The claim that 'signs of obsolescence and increasing maintenance effort usually become evident after 10-15 years of operation, driven by the cumulative reliability of the thousands of components that make up an aircraft, wear and tear, and the effects of time' misrepresents the diversity of components which make up a combat aircraft, and their widely varying life cycles, as well as misrepresenting the impact of maintenance engineering policies.

In assessing ageing effects in any combat aircraft, it is vitally important to distinguish between structural components, engine components, avionics, electrical and hydraulic components. Claiming 'obsolescence' can be highly misleading, as many components are specific to a type of aircraft and the term thus has no meaning.

Recent studies indicate that support costs of new and ageing aircraft are dominated by engine overhaul costs, as engines are a highly stressed subsystem. Airframe overhaul and maintenance costs can vary widely, reflecting prior maintenance and fatigue management strategies, and are virtually impossible to compare across types, unlike the behaviour of other subsystems.

Avionics are frequently replaced at intervals much shorter than their wearout and obsolescence life cycles, reflecting pressures for capability enhancements. Conversely, computers may become obsolete in mere years, despite having a physical operating life possibly of decades.

To claim the F-111 to be a '30 year old aircraft' is highly misleading from an engineering perspective. The physical airframe is largely a mix of structural components manufactured during the late 1960s and early 1970s. The engines are a mix of components manufactured between the late 1960s and 1990s. Most of the avionics, including the digital flight controls, were manufactured during the early 1990s, but some components post 2000. In terms of raw dollar value as a collection of parts, avionics dominate the accrued capital investment into the F-111 fleet. If we take age to be determined by the manufacturing dates of the most expensive components in an aircraft, the F-111 would qualify as a 1990s aircraft, not a 1970s aircraft, by virtue of the avionics investment.

The claim that 'modifications to the aircraft, as was the case with the Avionics Update Program (Project AIR 5225) during the late 1990s, may arrest the trend but will never do so completely .... unforeseen maintenance costs inevitably will arise and new issues will emerge' is misleading. The aims of Project AIR 5225 were focussed on improving avionics reliability and capability, not on replacing fatigued and corroded structural components, nor in replacing engines, hydraulics or electrical wiring. The problems which grounded the F-111 fleet four years ago occurred as a result of delays in airframe fatigue testing, and legacy OH&S issues from repairing fuel tank leaks characteristic of the aircraft since the 1970s, and neither could be remedied by avionics replacement.

The use of the Avionics Update Program as a example of an upgrade which 'may arrest the [ageing] trend but will never do so completely' is misleading, as the project achieved its aims admirably. Most major difficulties observed with the F-111 were related to maintenance management and OH&S issues on the airframe, rather than age and avionics reliability.

The F-111 Sole Operator Program represents a world class effort by DSTO, RAAF, DoD and contractor participants. Indeed, it is almost unique in its scope and depth, providing an engineering basis for longer term structural and corrosion life extension of the F-111. While its aims were focussed on achieving a 2020 target, the volume and quality of data gathered would facilitate aircraft life extension well beyond that date. Much credit must go to the farsighted RAAF officers and DSTO personnel involved in defining and launching the program during the 1990s.

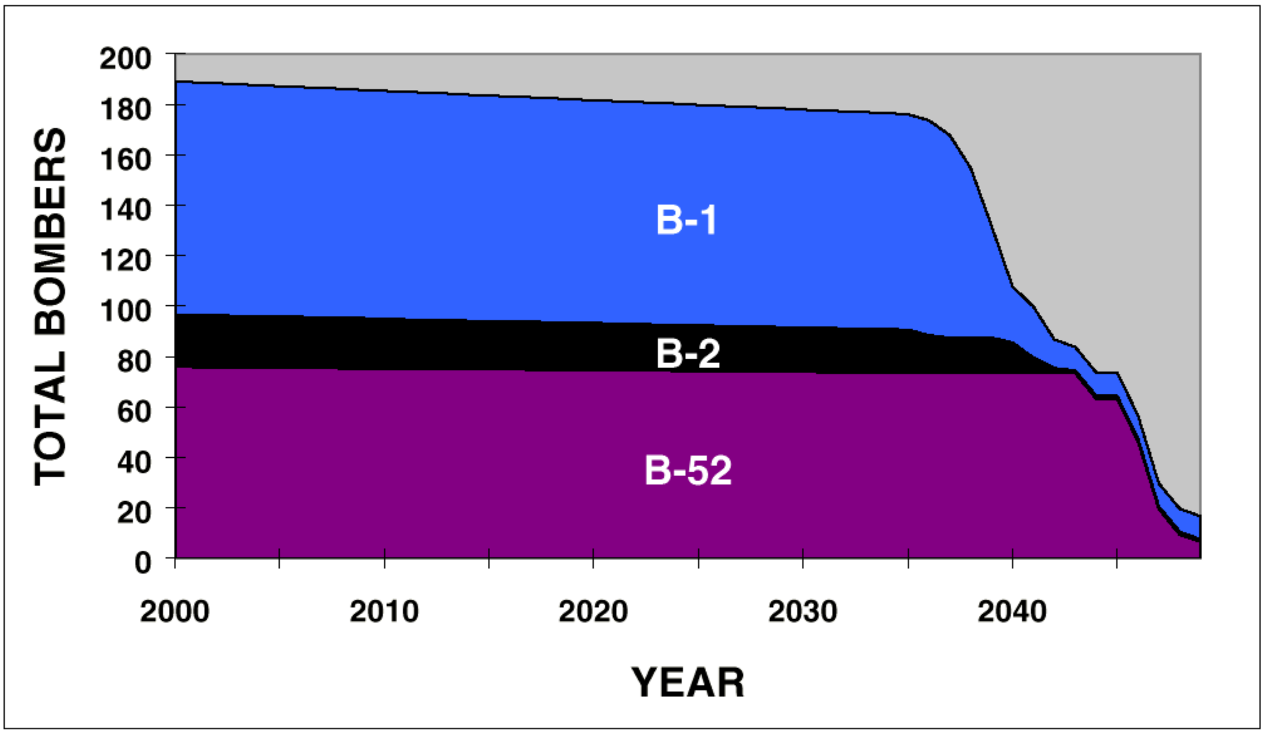


Figure 5: *Current USAF long term planning envisages the retention of the existing fleet of B-52, B-1B and B-2A aircraft until the 2035-2045 period. Survivability and supportability will be ensured by a combination of upgrades and supporting assets (U.S. Air Force White Paper on Long Range Bombers).*

> The F-111 Sole Operator Program provides an engineering and scientific knowledge base which would facilitate life extension of the F-111 well beyond the originally proposed 2020 withdrawal date, in a manner similar to the US B-52H and B-1B bombers, currently planned to operate until 2040. Should significant life extension be sought, the results of the F-111 Sole Operator Program would permit identification and selective replacement or modification of structural components with known corrosion or fatigue life limitations, minimising the cost of life extension.

1.7 THE LEGACY STRIKE CAPABILITY (2004) (Para 17.)

RAAF Statement: *Planned Withdrawal Date 2015-2020 Project AIR 5398 Stand-Off Weapon cited at AU$42 million.*

RAAF Statement: *Planned Withdrawal Date 2015-2020 Project AIR 5409 Bomb Improvement Program cited at AU$20-$30 million.*

RAAF Statement: *Planned Withdrawal Date 2015-2020 Project AIR 5418 Follow On Stand-Off Weapon cited at AU$100-$150 million.*

RAAF Statement: *Planned Withdrawal Date 2015-2020 Project AIR 5421 Reconnaissance Life of Type Equipment cited at AU$50-$75 million.*

RAAF Statement: *Planned Withdrawal Date 2015-2020 Project AIR 5416 Electronic Warfare Self Protection / Radar Warning Receiver cited at AU$150-$200 million.*

RAAF Statement: *Planned Withdrawal Date 2015-2020 Project AIR 5426 Strike Capability Enhancement cited at AU$200-$250 million.*

RAAF Statement: *Planned Withdrawal Date 2015-2020 Project JP 2089 Phase 2 TIED (Datalinks) cited at 'additional cost'.*

RAAF Statement: *Planned Withdrawal Date 2015-2020 Project JP 5408 ADF GPS Enhancement cited at 'additional cost'.*

RAAF Statement: *Planned Withdrawal Date 2015-2020 Project JP 90 Phase 1 ADF Identification Friend Foe cited at 'additional cost'.*

RAAF Statement: *Planned Withdrawal Date 2015-2020 Project JP 2030 Mission Planning Systems cited at 'additional cost'.*

Air Force have added the cited AU$42m cost of the AIR 5398 AGM-142 / Mil-Std-1760C upgrade in the category of costs incurred with a 2015-2020 withdrawal date, despite this project having been already largely paid for[21].

> Citing the cost of the largely completed AIR 5398 AGM-142 / Mil-Std-1760C upgrade in the 2015-2020 timeframe unnecessarily inflates capital investment costs and, therefore, is misleading.

Project AIR 5409 Bomb Improvement Program will see RAAF aircraft equipped with GPS aided inertially guided bombs, the two principal candidates being the Boeing GBU-31/38 JDAM family or weapons, or the Raytheon EGBU-10/12/24 family of weapons. Whether the F-111 is retained or retired early, the cost of warstocks will be borne by the Commonwealth. The cost of integration for these weapons will involve software modifications to the already paid for F-111 Block C-4 system and clearance drops of the chosen weapons, placing integration costs unique to the F-111 into the bracket of AU$5 million or less. Indeed clearance costs for the EGBU-10/12/24 series would be minimal, as the GBU-10/12/24 are already carried by the F-111. The cited AU$20-$30 million can only refer to integration costs and warstocks - if we assume AU$50,000 per round, the cited figure would pay for integration and a warstock of up to 500 weapons.

> The claim that the AIR 5409 Bomb Improvement Program incurs AU$20-$30 million amounts to 'double counting' the cost of munition warstocks which will be purchased regardless of what aircraft carries them. This effectively inflates the F-111 specific costs of this program by a factor of up to 500%.

Project AIR 5418 Follow On Stand Off Weapon will see RAAF aircraft equipped with a shorter ranging 'cruise missile' weapon with a range in excess of 100 nautical miles. An example is the US LM AGM-158 JASSM missile. Whether the F-111 is retained or retired early, the cost of warstocks will be borne by the Commonwealth. The cost of integration for these weapons will involve software modifications to the already paid for F-111 Block C-4 system and clearance drops of the chosen weapons, placing integration costs unique to the F-111 into the bracket of AU$5 million or less. Such weapons are delivered in a similar fashion to the existing Harpoon missile and do not present unusual integration challenges. The cited AU$100-$150 million can only refer to integration costs and warstocks - if we assume AU$550,000 per round, the cited figure would pay for integration and a warstock of up to 250 weapons.

> The claim that the AIR 5418 Follow On Stand Off Weapon incurs AU$100-$150 million amounts to 'double counting' the cost of munition warstocks which will be purchased regardless of what aircraft carries them. This effectively inflates the F-111 specific costs of this program by a factor of up to 2900%.

Project AIR 5416 Electronic Warfare Self Protection / Radar Warning Receiver cited at AU$150-$200 million refers to the replacement equipment planned for under the Defence 2000 White Paper. This equipment is vital to the combat survivability of any aircraft.

The Commonwealth invested during the 1990s in the development and integration of the ALR-2002 Radar Warning Receiver for the F-111, designed from the outset as a 'drop-in replacement' for the existing ALR-62 equipment. This equipment was prototyped and flight tested on the F-111 under the Block C-2A upgrade, therefore the integration and testing costs have been largely paid for already. Even assuming a very pessimistic AU$1 million per system, the cost of fitting 27 'funded' F-111C/G comes to about AU$30 million for the fleet.

Of the remaining key components of an Electronic Warfare Self Protection suite, the F-111 has already been fitted with the ALE-47 dispenser and ALQ-213 management system under the Block C-3 upgrade, and the Elta 8222 jamming pod is now being installed under the Block C-3A upgrade. The Elta 8222 jamming pod is one of the newest and most capable in the market, and should remain viable until 2020[22].

From a capability perspective, an internal jamming system as proposed under the Defence 2000

White Paper, is highly desirable, as it provides better angular coverage than a podded jammer and frees external stations for other stores. A representative internal jamming system is the US BAE SYSTEMS AN/ALQ-214 IDECM. Early production systems each cost around AU$6 million, with later production units cheaper. Therefore the largest cost component for an internal jammer retrofit is the equipment, which for 27 'funded' F-111C/G comes to about AU$160 million. Including integration, an internal jamming system retrofit would be unlikely to exceed a total cost of AU$170 million[23]

The cited costs for the AIR 5416 Electronic Warfare Self Protection / Radar Warning Receiver projects appear to encompass a complete retrofit of all 27 'funded' F-111C/G with new warning receivers and new internal jamming equipment. Evidently no effort has been made to achieve any economies in such a program, such as limiting the retrofit of new internal jamming equipment to the F/RF-111C and reusing the current Elta 8222 external jamming pods on the F-111G, or incorporating more recent technology. Careful choices in implementing AIR 5416 could save around AU$40 million.

The scope of AIR 5426 Strike Capability Enhancement, costed at AU$200m to $250m is not defined. The cited costs are of the order of 50% of the published cost structure of the AIR 5225 AUP program and would correspond to the likely cost of retrofitting the F-111G with an AUP-like core avionic system. Given the opportunity to now retrofit the F-111G with the AIR 5398 Mil-Std-1760C Station Interface Processor and a derivative Operation Flight Program, a similar effect in capability could be achieved at a much lower cost. Even budgeting AU$5 million per aircraft for a Mil-Std-1760C capability retrofit yields AU$35 million to AU$70 million for 7 to 14 F-111G upgrade packages.

Should AU$200m to $250m be made available for Strike Capability Enhancement of the F-111C/G, then even retrofitting 14 F-111Gs with a Mil-Std-1760C capability leaves AU$130 to $ 180 million for other upgrades.

Retrofitting 27 to 32 aircraft with a modern AESA attack radar such as the APG-79 or APG-80 yields an equipment cost of around AU$100 to $115 million, plus an integration and clearance cost estimated around AU$20 to AU$30 million, still well within the cost envelope of the cited AIR 5426 budget[24].

The retrofit of a Head Up Display to support air-air modes in the radar could be effected very economically by rebuilding stocks of the SU-46 Head Up Display, available from mothballed F-111D aircraft in the US[25].

New targeting pods to replace the AVQ-26 Pave Tack system have been discussed at various times, but at a unit cost of about US$3.5 million, they are expensive hardware. Conversely, a block upgrade of the existing AVQ-26 Pave Tack thermal imager and computer even budgeted at AU$2.5 million apiece for 16 pods comes in at AU$40 million, still within the budgetary envelope of AIR 5426[26] [27] [28].

The budget allocated to AIR 5426 Strike Capability Enhancement would provide, if carefully spent, sufficient funding to retrofit the F-111G with a Mil-Std-1760C precision weapons capability, retrofit a modern AESA attack radar, retrofit a rebuilt F-111D Head Up Display, and fund a block upgrade to the Pave Tack targeting system. Such an upgrade package would remain competitive and supportable into the 2025 timeframe, providing radar and electro-optical targeting capabilities similar to those in the new JSF.

Project AIR 5421 Reconnaissance Life of Type Equipment is cited at AU$50-$75 million and would involve the acquisition of a number of podded reconnaissance systems. Using podded systems is expensive in integration and clearance costs. A more cost effective strategy is to merge the functions of AIR 5421 and AIR 5426, as the cost of adding an organic reconnaissance capability to an AESA radar and the AVQ-26 Pave Tack is much lower in hardware and integration costs than the purchase and integration of external podded reconnaissance equipment[29] [30].

Merging the functions provided for in the AIR 5426 Strike Capability Enhancement and AIR 5421 Reconnaissance Life of Type Equipment upgrades would provide a cheaper and in many respects more flexible reconnaissance capability, one which could be installed on all F-111s equipped with a new radar and upgraded Pave Tack pod. Rather than carry a small number of pods on some F-111s, all F-111s could be flexibly tasked for reconnaissance.

No funding is cited for Project JP 2089 Phase 2 TIED (Datalinks) required to provide a networking capability on the F-111C/G.

Current MIDS-LVT Link-16/TACAN terminals are designed to replace legacy TACAN installations with a single box, to minimise integration costs. Improved Data Modem terminals are now available on a single VME card, hardware compatible with the spare slots in the new Block C-4 Station Interface Processor. The power and cooling demands of form fit replacement Link-16 terminals like the MIDS-LVT are designed to match the legacy TACAN box they replace. The power and cooling demands of VME based IDM hardware are already covered in the Block C-4 SIP design. How complex any software might be is a function of how elaborate the sought functionality is, basic functions could be done for AU$3 million or less, for a total project cost of around AU$17 million for 27 F-111s, given a US$300k unit cost per Link-16/TACAN terminal.

A robust networking capability based on JTIDS/MIDS/Link-16 and IDM could be retrofitted into the F-111 fleet for an expense of the order of AU$20 million, although additional investment in software could further expand this capability. A networking package designed around a high production volume Link-16/TACAN terminal like the MIDS-LVT could also be retrofitted to other ADF platforms, enabling much of the software cost to be amortised across a much larger number of platforms.

Project JP 5408 ADF GPS Enhancement and Project JP 90 Phase 1 ADF Identification Friend Foe equipment are cited at 'additional cost'. These upgrades are replacements for existing hardware in the F-111 and are neither unusually complex or difficult upgrades in comparison with other upgrades discussed. Project JP 2030 Mission Planning Systems is also cited at ‘additional cost’, but since this involves primarily software for desktop or laptop computers, it does not incur integration or hardware costs.

The cited cost of investment for F-111 capability and weapons upgrades for a withdrawal in the 2015-2020 timescale is unrealistically inflated, creating a misleading impression of the scale of investment required. Moreover, no effort has been made by Defence to find cost saving or capability enhancing synergies between these proposed upgrades. A more realistic estimate is AU$300 to $550 million, which provides an avionic upgrade package viable into the 2025 timescale, and more reliable and capable than the model cited by Air Force. In terms of annual outlays over a 7 year period, this falls into the range of AU$43 to $79 million per annum.

1.8 THE LEGACY STRIKE CAPABILITY (2004) (Para 18.)

RAAF Statement: *The Sole Operator Program was successful in identifying the wing fatigue problem that arose in 2002 but nothing anticipated the fuel tank explosion incident later that year.*

RAAF Statement: *The lesson from these and other general experiences is that ageing aircraft have increasing uncertainty attached to their technical integrity. This normally manifests itself as declining availability and unscheduled repair arisings that are challenging to manage.*

The cited 'wing fatigue problem' and subsequent grounding which arose in 2002 was a result of delayed fatigue testing performed on the 'long wing' configuration, never fully fatigue tested by the US Air Force. Conventional engineering and airworthiness practice is to fatigue test aircraft structural components to validate their integrity to some given number of flight hours before an operational fleet accrues such hours. The fatigue testing activity must therefore 'lead' the accrued fatigue in the operational fleet. For reasons unstated by Air Force, fatigue testing of the F-111C/G 'long wing' configuration was allowed to 'lag' the accrued fatigue in the operational fleet, forcing a grounding of those F-111s which had exceeded the safe number of hours predicted by the DSTO test. [31].

Had Air Force followed conventional engineering and airworthiness practices from the outset, and performed fatigue testing well ahead of accrued fatigue on the fleet, then no fleet grounding would have been required. The replacement wings could have been retrofitted during scheduled R4/R5 deep maintenance and block upgrade downtime, thus not incurring any additional downtime. The cited 'wing fatigue problem' and subsequent grounding arose principally due to poor planning.

Arguing that 'nothing anticipated the fuel tank explosion incident' is non-sequitur. Problems with 1960s electrical wiring, especially in fuel systems, have been implicated in a number of widely publicised commercial airline accidents, especially the loss of a 747 near New York due to a fuel tank explosion, with a large number of fatalities. The latter was the subject of considerable debate in the engineering literature, mass media, and the Internet, in the period immediately preceding the 'fuel tank explosion incident'. The Amberley WSBU has facilities on site for manufacturing cable harnesses for use in the F-111. Fuel tank deseal-reseal operations involve personnel working inside the F1/F2 fuel tank area, so inspection would not present difficulties.

The question must be asked why the possibility of a fuel tank arcing problem was not anticipated *apriori* given the known precedents in commercial aircraft and the enormous media exposure this issue produced. The materials and age of the fuel tank cabling and hardware used in the F-111 were similar if not identical to commercial aircraft constructed during the same period. The derivation of 'lessons learned' should not be constrained to the experiences on a sole aircraft type.

Air Force argue that 'that ageing aircraft have increasing uncertainty attached to their technical integrity' and that this 'normally manifests itself as declining availability and unscheduled repair arisings that are challenging to manage'

This is a non-sequitur. In engineering terms, uncertainty only occurs as a result of not possessing knowledge about the condition of a system. In an ageing aircraft, or any aircraft for that matter, knowledge about the condition of the aircraft is accrued over time and can be analysed statistically to identify component failure rates and effect pre-emptive replacements.

At the hearing on 04 June 2004, the RAAF argued:

'The other fact I want to highlight about the F111 is that we have been surprised in recent years. Back in 2000 we had the fuel leaks followed very quickly by the wing breakage and then the fuel tank explosion. We were not expecting any of those things to occur, and the F-111 has surprised us. With aircraft that are 30 years old, surprises are the norm. Indeed, just last week we had a surprise with our Boeing 707s when we found cracks in an area where we had not anticipated them. It is a fairly simple problem with the Boeing 707 and we will be able to repair it in the short term. But the point is that you find things that you were not expecting.'

The use of the Boeing 707 as an example is misleading, as the aircraft is of entirely difference construction, has been maintained differently and has had a very different operational history.

The F-111 has been subjected to a world class study in the DSTO Sole Operator Program, which has seen the teardown of an F-111A airframe to analyse the corrosion and fatigue condition of flight critical structural components. Moreover, Boeing and the Amberley SPO are performing a world class ageing aircraft engineering program at Amberley, to further refine the understanding of age and maintenance related failures in components.

The claim of 'declining availability and unscheduled repair arisings that are challenging to manage' is non-sequitur in relation to the F-111, as demonstrated by the increasing reliability and availability of the aircraft since Boeing and the Amberley SPO introduced the ageing aircraft engineering program. It would apply to any aircraft maintained in an environment of declining engineering capability and capacity, extraneously overtasked resources and consequential deskilling as was the case on the F-111 prior to the implementation of the RAAF plan for a stable, appropriately skilled, contract resourced and contract governanced Industry Team assuming responsibility for the deeper maintenance.

1.9 THE LEGACY STRIKE CAPABILITY (2004) (Para 19.)

RAAF Statement: *Air Force planning anticipates the rate of effort recovering to near historical levels, but there is not a high level of confidence this will be achieved. In all likelihood the F-111 fleet will be characterised by an increasing budget and under-achievements in rate of effort.*

RAAF Statement: *The magnitude of the likely F-111 costs over the period of FY 11/12 to FY 14/15, and the opportunity cost this would have to the rest of the Defence budget, has convinced Defence planners that retaining the F-111 in-service beyond about 2010 is not a viable option.*

Air Force have stated that 'there is not a high level of confidence' in F-111 rate of effort recovering to near historical levels. There is no rational basis for such a claim. The trend in aircraft availability has displayed continuous improvement since July 2002. The period of a sustained trend of decline in availability lasted approximately 12 months between September 2001 and July 2002, while the period of a sustained trend of improving availability has lasted for 24 months, since July 2002. In terms of mathematically validating the hypothesis of future F-111 availability, the duration of the respective trends clearly does not support claims by Air Force. In engineering terms, the observed improvements in availability and reliability are the expected consequence of a successful ageing aircraft engineering program effort.

The use of 'rate of effort' as a measure of availability is however misleading, insofar as 'rate of effort' is bounded by available funding for aircrew hours, ground personnel hours, fuel, expended munitions and consumed spare parts. An aircraft with 100% availability could still achieve very low 'rate of effort' if funding is not provided for personnel time and consumables.

Claiming 'in all likelihood the F-111 fleet will be characterised by an increasing budget and under-achievements in rate of effort' is a non-sequitur which is not supportable by the evidence. Increasing maintenance budgets can only arise if there is a sustained trend of declining reliability. Such a trend is contrary to the observed availability trend since July 2002. Air Force appear to be assuming that the ageing aircraft engineering program and SOP are not producing effect, or will no longer produce effect. It is worth observing that the US Air Force B-52H is cheaper to operate and more reliable than the newer B-1B and B-2A bombers, due to the maturity of its ageing aircraft engineering program.

There is no rational or intellectual basis for the claim by Air Force that 'there is not a high level of confidence' in F-111 availability improving. For all practical purposes this belief amounts to *guessing* rather than the conclusion from a rigorous intellectual analysis.

Air Force claim that 'The magnitude of the likely F-111 costs over the period of FY 11/12 to FY 14/15, and the opportunity cost this would have to the rest of the Defence budget, has convinced Defence planners that retaining the F-111 in-service beyond about 2010 is not a viable option'.

Air Force have been unable to produce a rigorous analysis to date of projected future F-111 costs.

The tabulated data in (17) indicates inflated estimates for future upgrade costs. The engineering data indicates a trend of reducing support costs as the ageing aircraft engineering program takes effect and matures. *The assumptions underpinning the belief that future cost increases are inevitable are not rational.*

In terms of 'opportunity cost' the F-111 provides a range of valuable opportunities in delaying the acquisition of replacement aircraft, reducing fatigue life consumption on the F/A-18A, providing a platform for a dual role strike/reconnaissance capability, providing a platform for a much needed electronic attack capability, providing a platform for a cruise missile defence capability and providing a platform for developing network centric warfare systems usable on other ADF platforms. The incremental cost of using the F-111 for expanding ADF capabilities is much lower than the cost of acquiring new platforms.

> The stated conclusion by Defence planners that 'retaining the F-111 in-service beyond about 2010 is not a viable option' is simply wrong. It is predicated on assumptions which are not rationally supportable by fact. Therefore the conclusion itself must be irrational.

1.10 THE LEGACY STRIKE CAPABILITY (2004) (Para 21.)

RAAF Statement: *The F-111 aircraft's ability to operate in our region, in concert with F/A-18 escort aircraft, is currently assessed as excellent. However, the F-111 electronic warfare self protection (EWSP) capability will degrade beyond 2010, when obsolete systems will need replacement and when taken in concert with the increasing regional threat the survivability of the F-111 is threatened.*

RAAF Statement: *During this period the F/A-18 will be undergoing major upgrades and while the overall level of capability should be extremely good, there is a risk the upgrade process may cause restrictions in F/A-18 availability.*

The survivability of the F-111 has been criticised by Air Force in a number of statements to date, but never substantiated with hard data or detailed argument[32].

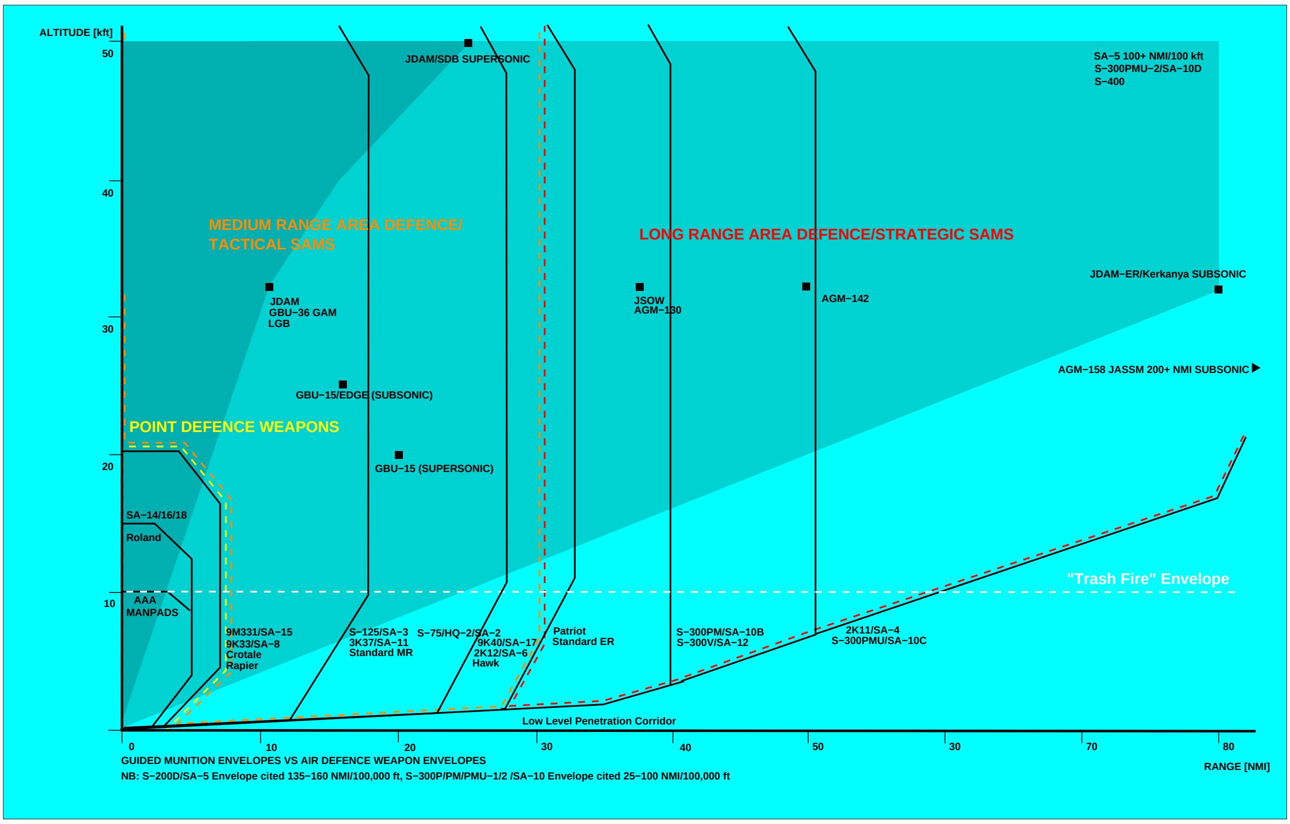


Figure 6: *Surface based air defences statistically account for most Western combat aircraft losses since the 1960s. This chart shows representative order of magnitude envelopes for various SAM types, and compares them with delivery ranges for various guided weapons. Air defence weapons can be broadly divided into three categories - Point Defence Weapons, Medium Range Area Defence SAMs and Long Range Area Defence SAMs. Glide bombs and stand-off missiles defeat most if not all of these threats (C. Kopp).*

The F-111 was designed to penetrate hostile defences by dashing to and from its target at very high speed and low altitude, using a Terrain Following Radar (TFR) to remain below the radar horizon of hostile Surface to Air Missiles (SAM) and Anti-Aircraft Artillery (AAA) systems, and jamming equipment (EWSP) to disrupt opposing threat radars. Its design is optimised to sustain very high subsonic speeds at extremely low altitudes, without the use of afterburner. Penetrating in this fashion the F-111 can defeat a large fraction of Surface to Air Missile, Anti-Aircraft Artillery systems and fighter aircraft. In addition, clever use of tactics and good choices in weapons can further enhance survivability against surface bound threats.

In terms of defeating threat fighter aircraft, the F-111 uses a combination of high speed, high speed endurance, jamming equipment and air-to-air missiles.

At this time we are observing important changes in available strike weapons technology, which further enhance survivability. These are glide bombs which can provide often significant stand-off range during an attack, and stand-off and cruise missiles, which provide tens to hundreds of nautical miles of stand-off range[33]

It is important to observe that the capability of an opposing air defence characteristically declines during a conflict, as defending radars, fighters, surface to air missiles and artillery pieces are progressively destroyed. Beyond some point the air defences will effectively collapse and cease to present a significant threat to attacking strike aircraft. Therefore opposing air defences are always most potent in the opening hours or days of a conflict.

The survivability of the F-111, or the F/A-18, can only be assessed in relation to a specific type of threat or combination of threats, and the weapon type the striking aircraft is employing for the attack. Typical regional threat scenarios are thus:

Short Range SAM/AAA: The most widely deployed regional air defence weapons. The F-111 is highly survivable against these threats and will continue to be indefinitely given the aircraft's low altitude high speed capability. Glide bombs would further enhance survivability.

Long/Medium Range SAM: Now deploying in regional air defence systems, examples are the S-300PMU operated by China and sought by Indonesia. The F-111 is highly survivable against these threats if penetrating at low level and using a stand-off weapon or glide-bomb. If a cruise missile class weapon is used, there is almost no risk to the F-111 from any SAM system.

Ground Alert Fighters: Fighter aircraft on ground alert, supported by long range early warning radars, are by far the most likely fighter defences the F-111 will encounter in the region. Generally, the F-111 will remain highly survivable against this type of air defence. Assuming the fighter is scrambled when the F-111 attacks its target, the typical 10 minutes it will take for a defending fighter to get airborne allows the escaping F-111 to get a head start of up to 90 nautical miles, defeating the interceptor. If a cruise missile class weapon is used, there is no risk to the F-111 from a ground alert fighter.

Fighter Combat Air Patrols: Fighter aircraft patrols orbiting the target area can present a much greater risk to penetrating aircraft, including the F-111, than ground alert fighters. However, compared to other aircraft, the high speed of the F-111 makes it very difficult to intercept, and its low altitude in the target area makes it extremely difficult to track using a ground based early warning radar. Fighter escorts can be used to enhance survivability in this scenario but would only be required if very capable opposing fighters exist. Arming the F-111 with a high performance air-to-air missile like the ASRAAM now carried on the F/A-18A will defeat or deter fighters not equipped with long range missiles. If a cruise missile class weapon is used, there is little risk to the F-111 from a fighter patrol supported by an early warning radar near the target being attacked.

AWACS + Fighter Combat Air Patrols: Fighter aircraft patrols orbiting the target area and supported by AWACS / AEW&C present the greatest risk to attacking aircraft, including the F-111. While a cruise missile class weapon with range well in excess of 250 nautical miles can defeat such defences, affording high survivability to the F-111, this scenario typically requires fighter escorts. In penetrating such defences the F-111's high speed makes interception by fighter patrols more difficult, compared to a strike tasked F/A-18A. Arming the F-111 with a high performance air-to-air missile like the ASRAAM now carried on the F/A-18A will defeat or deter fighters not equipped with long range missiles.

The AIR 5418 Follow On Stand Off Weapon was intended to be carried by the F-111 and would defeat all of the regional threats to the F-111, other than AWACS / AEW&C supported Su-27/30 fighters. As observed by Group Capt. Brown in evidence, an AWACS supported Su-27/30 fighter threat would require that strike tasked F/A-18A aircraft be escorted not unlike the F-111.

In the event of a regional conflict, the opening hours of the campaign would see a concerted effort by the RAAF to destroy opposing early warning radars, surface to air missile batteries and a large fraction of sorties to shut down enemy airfields, and destroy aircraft on the ground. Using cruise missile class weapons like the AGM-158 JASSM or glide and free fall weapons, the effectiveness of the opening phase of the battle would depend critically on the weight of fire delivered. If the opponent is using AWACS supported Su-27/30 fighters, then a large fraction of the tanker constrained F/A-18 aircraft used would have to tasked for air combat rather than strike, severely diminishing the weight of fire if the RAAF had only F/A-18 aircraft to use. Conversely, retention of the F-111 permits a large fraction of the F/A-18 aircraft to be tasked for air combat without diminishing the weight of fire available - an F-111 easily carries up to four large weapons.

In terms of the F-111's Electronic Warfare Self Protection suite, the only component which must be replaced in the 2010 timeframe is the ALR-62 warning receiver. The Elta 8222 jamming pod, ALQ-213 management system and ALE-47 are all new hardware and will not be obsolete in 2010. Replacing the ALR-62 is not an expensive upgrade.

> Claims by Air Force arguing poor survivability of the F-111 are not credible, given the most likely regional threat capabilities expected in the 2020 timescale, and given the option of equipping the F-111 with the AIR 5418 Follow On Stand Off Weapon and glide-bomb weapons such as the GBU-39 and JDAM-ER series. The requirement to escort the F-111 only arises in situations where airborne fighter patrols of Su-27/30 are expected, especially if supported by AWACS. Such threat environments will also require that the F/A-18 be escorted when tasked with strike.

1.11 THE LEGACY STRIKE CAPABILITY (2004) (Para 22.)

RAAF Statement: *Typical maximum weapons and typical weapons loads are shown in Table 2 with each row indicating a possible weapons load.*

The cited 'typical' weapon loads do not agree with published reports of F-111 usage during the 1991 Desert Storm campaign, the 1986 El Dorado Canyon raid or the 1972 Linebacker II campaign. During these operations F-111s frequently carried four large 2,000 lb low drag weapons, or twenty four 500 lb low drag weapons, both cited by Air Force as 'maximum' payloads.

In citing 'half weight' payloads as 'typical' Air Force are presenting half of the capability the aircraft can deliver to a useful combat radius, or from a station with useful loiter endurance, particularly for the vital 'persistent strike' (Killbox Interdiction) regime. In performance terms weapon aerodynamic drag dominates over weight induced fuel burn, for low drag weapons such as the GBU/EGBU-10/24 or GBU-31 JDAM. With the advent of boom capable A330 tankers, there are no issues with the F-111 carrying large payloads of relatively high drag weapons beyond a 1,000 nautical mile strike radius.

> Air Force have cited unusually light weapon payloads as 'typical' in Table 2. The payloads assume the use of the inboard pivot pylons for air to air missiles, rather than the outboard ESMA launchers (stations 3A and 6A), reducing air to ground weapons loads by 50% typically. The use of such payloads as examples of 'typical' payloads is misleading, as it reduces the perceived capability of the F-111. Published General Dynamics performance data, and US Air Force performance data do not agree with the cited weapon payloads for 2,000 lb weapons, nor does photographic evidence from the Linebacker II and Desert Storm campaigns.

Air Force have not explained the capabilities the F-111 gains with the weapons planned for under AIR 5409 and AIR 5418. Representative payloads of these weapons are depicted in Figures 7 and 8. Of particular interest are the GBU-38 500 lb JDAM, and the Hawker De Havilland / DSTO glide variant, the JDAM-ER, currently being developed using RAAF funding. The F-111 could carry between 20 and 24 of these precision weapons providing a formidable battlefield precision strike capability. Current US planning sees the GBU-38 integrated on the B-2A, and likely also the B-52H and B-1B.

Air Force have also not disclosed that the F-111G was being used in Australia as a trials platform for test drops of the new US GBU-39/B Small Diameter Bomb, intended to arm the JSF and F/A-22A, despite this being publicly disclosed by the US Air Force overseas. This new weapon, which has glide wings to provide significant standoff range, could be carried internally or externally by the F-111. As significant clearance testing has been already done on the F-111G, and the F-111C will have a Mil-Std-1760C capability, integration of this weapon on both the F-111C and F-111G is not an expensive proposition. Refer Figure 9.

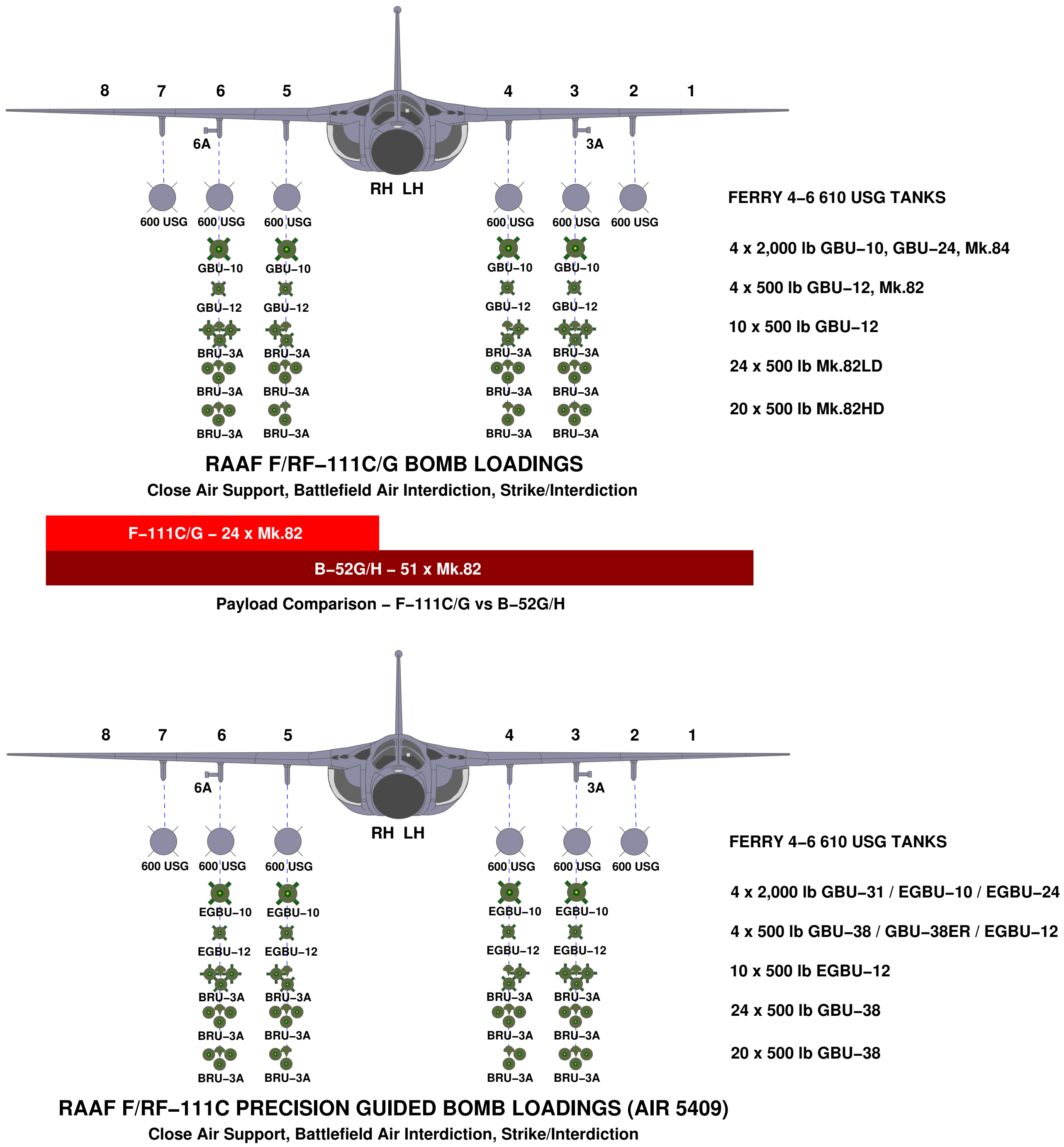


Figure 7: *F-111 weapons payloads for existing 'smart' and 'dumb' bombs, and the previously planned AIR 5409 BIP (C. Kopp).*

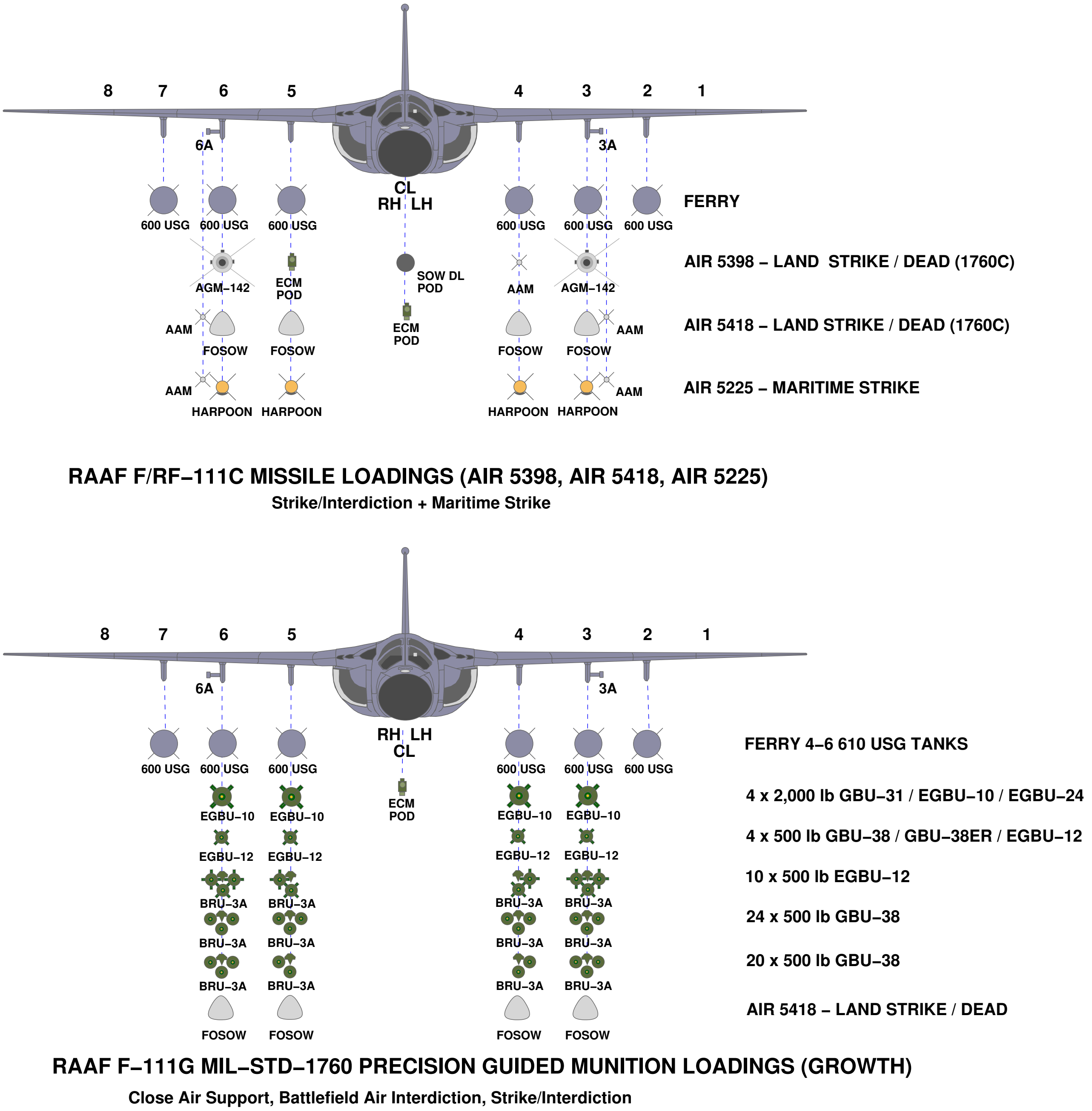


Figure 8: *F-111C weapons payloads for the AGM-84 Harpoon, AGM-142 and new weapons previously planned under AIR 5418 FOSOW (Top), F-111G weapons options using AIR 5398 Stores Interface Processor and Mil-Std-1760C interfaces (Bottom) (C. Kopp).*

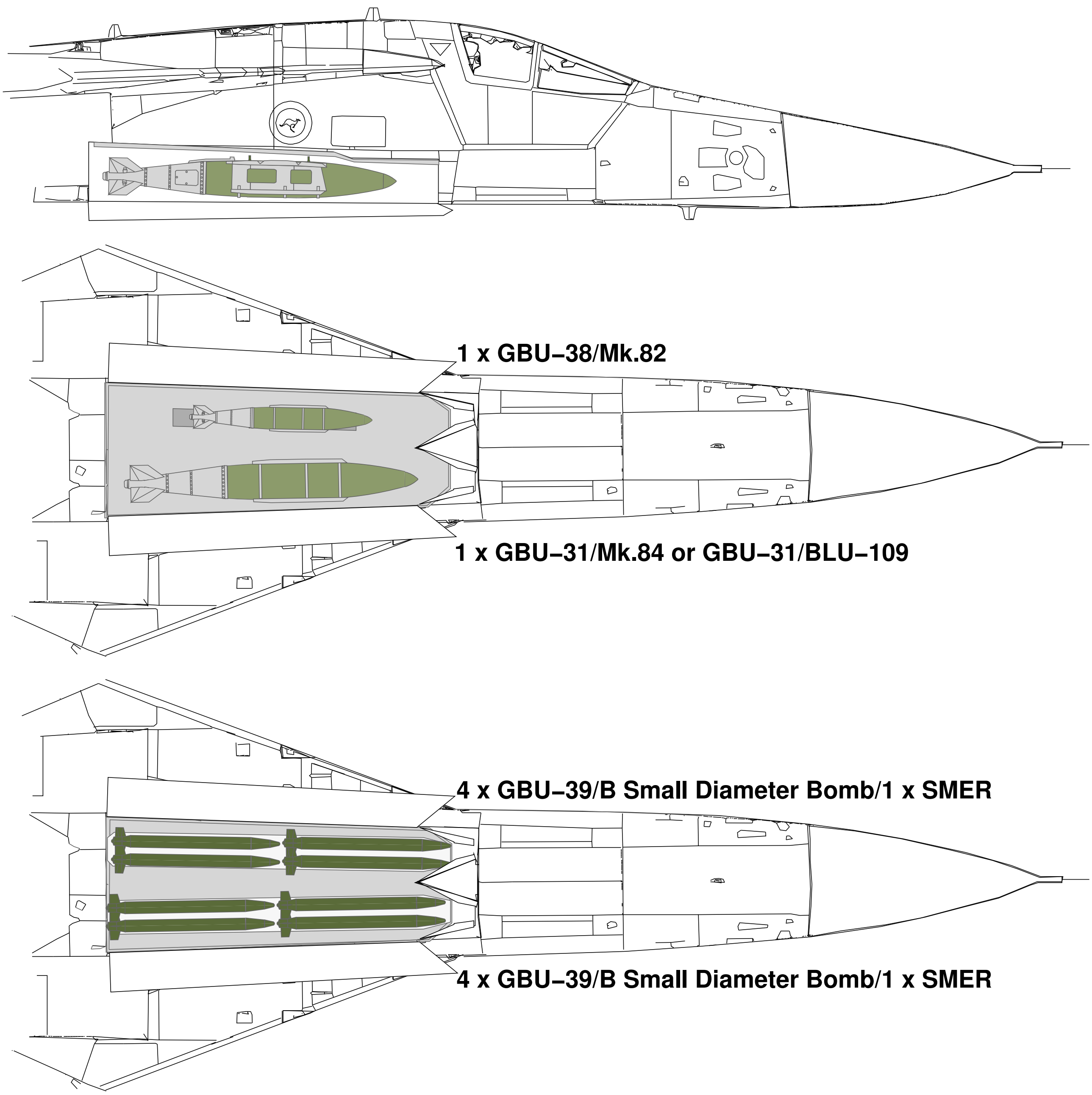


Figure 9: *All F-111s have a large internal weapons bay, similar in capacity to the internal weapons bays in the JSF, and used by the US Air Force to carry SRAM standoff missiles on the FB-111A (now F-111G). The F-111G was used as a trials platform under US Air Force contract for test drops of the GBU-39/B Small Diameter Bomb demonstrators. Therefore integration of internally carried GBU-39/B is a low risk proposition on the F-111 (C. Kopp).*

Figure 10: *The USAF FB-111A employed the internal weapon bay for the B43, B57 and B61 nuclear weapons, while around 50% of the FB-111A fleet was configured to launch the 2,230 lb AGM-69A SRAM missile from the bay (US Air Force).*

> The Mil-Std-1760C capability now being fitted to the F-111 permits low cost integration of new generation guided munitions, including the AIR 5409 BIP contenders, the AIR 5418 FOSOW contenders, and the GBU-39/B Small Diameter Bomb. Given that significant trials work on the GBU-39/B Small Diameter Bomb has already been done in Australia using the F-111G, funded by US taxpayers, this weapon would be economical to integrate. By not stating this, Air Force are in effect concealing the significant growth potential in F-111 strike capability, and the low expenditures in doing so.

Additionally, the Mil-Std-1760C capability of the F-111 along with its internal weapons bay, performance and handling envelopes, internal volume and variable geometry coupled makes the F-111 an ideal platform for mitigating risks on such programs as the JSF. The extensive knowledge base Australia has on the aircraft and the world class talents of our engineering, scientific and test/evaluation professionals enhance this opportunity.

Taking a pro-active and pre-emptive approach to the risks in the NACC Project was one of the corner stones of the Evolved F-111 Proposals. This could be achieved by actively seeking the engagement of the capabilities within Australian Industry and Defence in the JSF and F/A-22A programs to help the USAF and LM to mitigate and meaningfully reduce risks as early as possible.

Rather than remain 'just a third tier member of the JSF program' and thereby limit itself to a self induced observer's position, Australia could be pro-active in its approach and offer the USAF/LM Team a flying test bed in the form of the F-111. Such a capability need not be limited to just helping to meaningfully reduce the risks in the weapons clearance programs which, in themselves, are not insignificant.

Even a cursory look at 'the Evolved F-111' proposals will reveal very effective opportunities for reduction of JSF program risks in the critical and essential activities of airborne Test and Evaluation, Verification and Validation. Key areas where this unique Australian capability could be used to meaningfully and cost effectively reduce program risks include radar, avionics, armament, environmental and instrumentation systems. Much if not all this work could be undertaken before the first flight of the SDD JSF, thus making a meaningful contribution to the JSF program's ability to manage, mitigate and retire risks.

By not recognising the unique capabilities, risk management opportunities and IV&V model for the NACC that reside in the F-111 and Australian Industry, Defence are in effect missing a never to be repeated opportunity to make a positive difference.

1.12 THE LEGACY STRIKE CAPABILITY (2004) (Para 23.)

RAAF Statement: *Attack a limited number of targets in high threat areas restricted by F/A-18 ranges when supplemented by limited B707 Air to Air refuellers.*

RAAF Statement: *Strike using weapon delivery by overflight or at AGM-142 standoff ranges.*

The claim that only a 'limited number of targets in high threat areas' could be attacked given restrictions in the operating radius of the F/A-18 supported by B707 tankers is only partly true. The number of F/A-18s tasked with providing Combat Air Patrol sweeps to provide escort for F-111s, assuming threat conditions justify this, is not proportional to the number of F-111s flown. A fighter sweep to escort six F-111s could equally so protect a dozen F-111s, if good tactics are employed. The capability in the A330-200 would remove this limitation in the numbers of F/A-18 escorts available to support the F-111.

The claim that the Block C-4 F-111 capabilities permit 'strike using weapon delivery by overflight or at AGM-142 standoff ranges' fails to mention the use of low altitude toss delivery of laser guided or dumb bombs. Given the choice of flying over a defended target to drop bombs, or tossing these bombs from 3 miles away, an F-111 crew will always opt for the toss manoeuvre. Overflight bomb delivery techniques are only employed when there is no credible opposing missile or directed anti-aircraft artillery defence. By excluding low altitude toss bombing deliveries, Air Force have created an appearance that the F-111 is constrained to less survivable delivery techniques, which is misleading[34].

> By excluding low level toss deliveries of guided and unguided bombs, Air Force have created a misleading impression that the F-111 is limited to the less survivable level overflight delivery technique.

1.13 ENHANCED STRIKE CAPABILITY (CIRCA 2010) (Para 24.)

RAAF Statement: *F/A-18 air control capability against regional threats is improving with the introduction of the AMRAAM Beyond Visual Range weapon.*

RAAF Statement: *The Hornet capability will be further enhanced on completion of the various system development phases of Air 5376 Hornet Upgrade Program, in particular following integration of of the Helmet Mounted Cueing System.*

RAAF Statement: *The F/A-18 electronic warfare self protection capability is being upgraded while a Link 16 datalink will be fitted ...*

While the AIM-120 AMRAAM BVR missile is a significant improvement to the F/A-18A's capability, the aircraft will remain uncompetitive in BVR combat against the Su-30 series, as the Su-30's N-001, N-011 and N-011M radars have a significant range advantage over the F/A-18A's APG-73 radar. This cannot be changed by upgrades as the limitations in the APG-73 arise from its antenna size, half that of the Sukhoi Su-30 radar, and its lower power rating, limited by radar transmitter cooling capacity. Therefore in any 'symmetric' BVR engagement scenario, with both aircraft either without AWACS support, or with AWACS support, the F/A-18A is at a disadvantage[35].

All Su-27 and Su-30 fighters are equipped with an Infra-Red Search and Track (IRST) set to supplement the radar with passive tracking information on targets. The IRST is coupled with a laser and usable for BVR and close-in engagements. The F/A-18A has no such capability.

The Soviets introduced Helmet Mounted Cueing Systems on their Su-27P and Su-27S fighters during the 1980s, to support the agile Vympel R-73 (AA-11 Archer) missile. More recent Helmet Mounted Cueing Systems have been fitted as upgrades and production items to later Sukhoi variants.

A number of digital datalinks are available for Sukhoi Su-27 and Su-30 fighters, including the TKS-2 IFDL and the earlier APD-518 IFDL for fighter to fighter networking.

While the upgrades planned for the F/A-18A will result in enhancements to its air combat capability, these will not result in an aircraft which is competitive against a late model Su-30. Addition of Helmet Mounted Cueing Systems and datalinks merely brings the F/A-18A to parity with the Su-30 in these avionic capabilities, but does not and cannot overcome the aerodynamic and radar performance deficiencies of the F/A-18 family against the Su-30. As an investment strategy large expenditures on F/A-18 upgrades make little sense, given the increasing strategic irrelevance of this class of fighter in a region dominated by the Sukhois.

1.14 ENHANCED STRIKE CAPABILITY (CIRCA 2010) (Para 25.)

RAAF Statement: *Land strike will be predominantly transferred to the F/A-18 through the integration of the all weather day and night bombing capability and the long range standoff missile.*

RAAF Statement: *The AP-3C will also have the long range standoff missile integrated, predominantly for the lower threat littoral strike requirement, but it will have a credible land strike capability, albeit not for a high threat environment.*

While there are no technical obstacles to integrating the AIR 5409 and AIR 5418 weapons on the F/A-18A, the expense in doing so will inevitably be greater than the expense in integrating these weapons on the F-111. This is because 71 aircraft would need to be modified with a full Mil-Std-1760 capability, unlike the F-111 which is already being fitted with this capability at this time. This results in 71 shipsets of hardware being acquired, against the F-111 installation which has already been paid for. In effect, retirement of the F-111 results in a more than doubling of the total investment in Mil-Std-1760 platform installations - the taxpayer is effectively paying twice for the same level of capability.

> Investment in full Mil-Std-1760 interface upgrades on the fleet of 71 F/A-18As effectively amounts to duplicating the investment already made into the Mil-Std-1760 capability in the F-111.

Availability of the F/A-18 will present a genuine problem if the intended plan to rebarrel most of the fleet is implemented. Unlike F-111 wing replacement which incurs little downtime, rebarrelling puts an F/A-18 into the depot for up to 12 months. Given the limited return on investment in rebarrelling F/A-18s which may only be flown for several years after such an expensive structural rework is performed, the alternative of shifting flying hours to the F-111 in lieu of early retirement is is far more sensible and better value for money.

The stark reality is that the F/A-18 is a poor performer in the strike role, requiring tanker support and typically carrying half the payload of an F-111. From an economic perspective it is cheaper to fly 9 F-111s versus 18 F/A-18s plus the four tankers required to support these F/A-18s. If 77 SQN were converted from the F/A-18A to fly the F-111 instead, the total annual flying hours of the F/A-18 fleet would be reduced by 25%, thus reducing the aggregate F/A-18A fleet fatigue life consumption rate by 25%.

If we assume an active squadron deployment size of 9 F-111s, then equipping 1 SQN, 6 SQN and 77 SQN requires 27 F-111s plus spares to cover depot overhauls and block upgrades. The existing inventory of F-111C and F-111G would be adequate, although additional spares could be acquired from the US to spread the flying load. The cost of putting Mil-Std-1760C capability and EWSP upgrades on nine F-111Gs will be roughly half the cost of doing the same upgrades on eighteen F/A-18s[36].

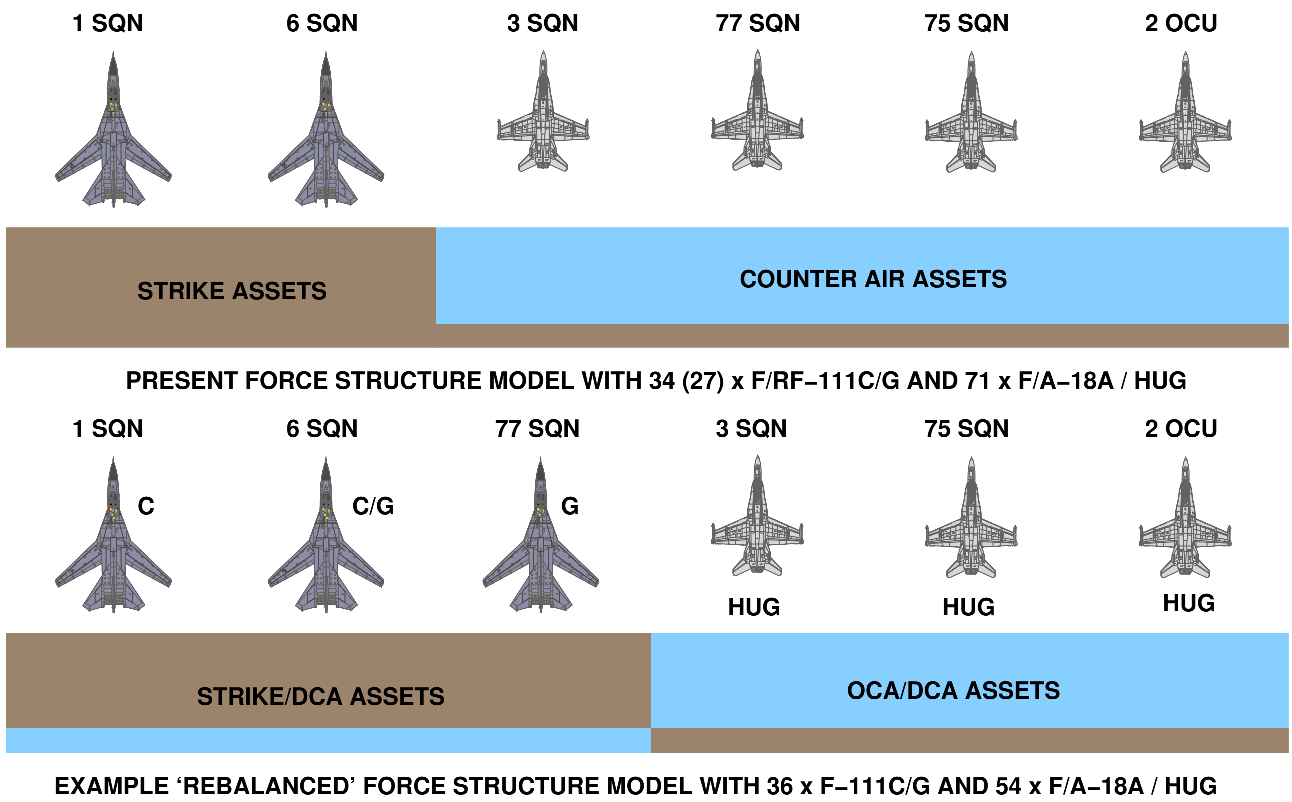


Figure 11: *Exploiting the F-111 to minimise F/A-18A fatigue life extension costs (C. Kopp).*

> The prospect of F/A-18 fuselage rebarrelling grounding a large fraction of the F/A-18 fleet during the 2010-2020 timeframe will present genuine problems if the RAAF is to maintain credible numbers of F/A-18s to provide concurrent strike and air combat capabilities. The alternative of retaining the F-111, converting 77 SQN to the F-111G and upgrading these aircraft would reduce the rate of fatigue accrual in the F/A-18 fleet by 25% reducing the number of F/A-18 aircraft requiring structural reworks. The strike capability provided by 3 squadrons of F-111s significantly exceeds the strike capability provided by 3 squadrons of F/A-18s and 5 A330 tankers.

The AP-3C does not provide a credible strike capability by any contemporary measure. While Air Force have acknowledged that the AP-3C is unusable in environments with anything above a trivial threat level, Air Force have failed to explain the limitations arising from AP-3C cruise speed and tasking.

A key measure of utility in any strike aircraft is its productivity, in terms of how many weapons it can deliver to a given range, at what cost in personnel and supporting assets. Leaving aside the issue of fighter escorts, which are required for the F/A-18A tasked with strike, the F-111 and the AP-3C in any environment where a risk of engagement by Su-30 exists, the issue of total effort expended per warhead on target is critical.

The F/A-18A performs poorly against the F-111 in this respect as it requires supporting tankers,

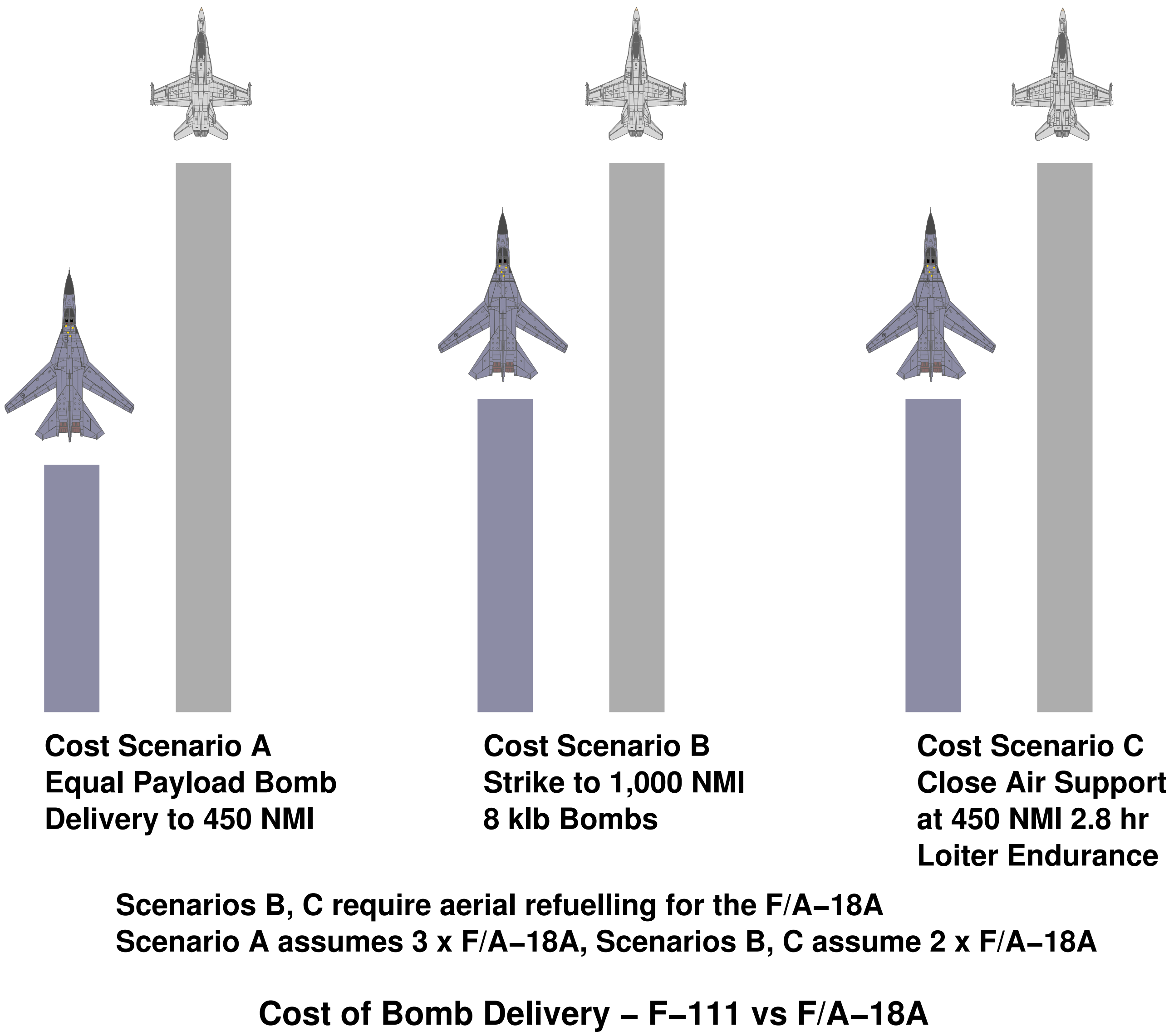


Figure 12: *Air Force have presented a misleading argument in claiming the F-111 is 'more expensive' than the F/A-18A in the strike role. This is because the cost of aerial refuelling must be counted against the F/A-18A when it is being used as a substitute for the F-111. In terms of taxpayer's dollars expended per bomb delivered on target, the F-111 is much cheaper. The depicted model is based on Defence Annual Report annual expenditures (C. Kopp).*

which adds to personnel, fuel and consumables costs to deliver a given number of weapons. Indeed, an F-111 could cost twice as much to operate against an F/A-18A and still be cheaper as it can deliver those weapons without tanker support.

The AP-3C performs poorly against the F-111 as its transit speed to and from the target is much slower, and it remains the most expensive RAAF asset to run in personnel and hardware support costs. Transit speed means that one AP-3C can fly a much smaller number of sorties per 24 hour cycle, or per week, compared to an F-111, at a given distance. Given the finite fatigue life in the AP-3C fleet, and the intention to task the HALE UAV to alleviate this problem, tasking AP-3Cs with strike operations will add an additional source of fatigue life consumption.

The cost of integrating the FOSOW on the AP-3C, its relatively high running cost, the poor productivity of the AP-3C and its poor survivability in many threat environments result in a very poor return on investment in providing the AP-3C with a littoral and land strike capability.

1.15 ENHANCED STRIKE CAPABILITY (CIRCA 2010) (Para 27.)

RAAF Statement: *The tactical reconnaissance capability will be transitioned to the HALE UAV, the AP-3C for lower levels of threat and F/A-18 via its targeting pod.*

Tactical and strategic reconnaissance capabilities remain a key weakness in the RAAF force structure, challenging inadequate aerial refuelling capability as the most critical capability bottleneck.

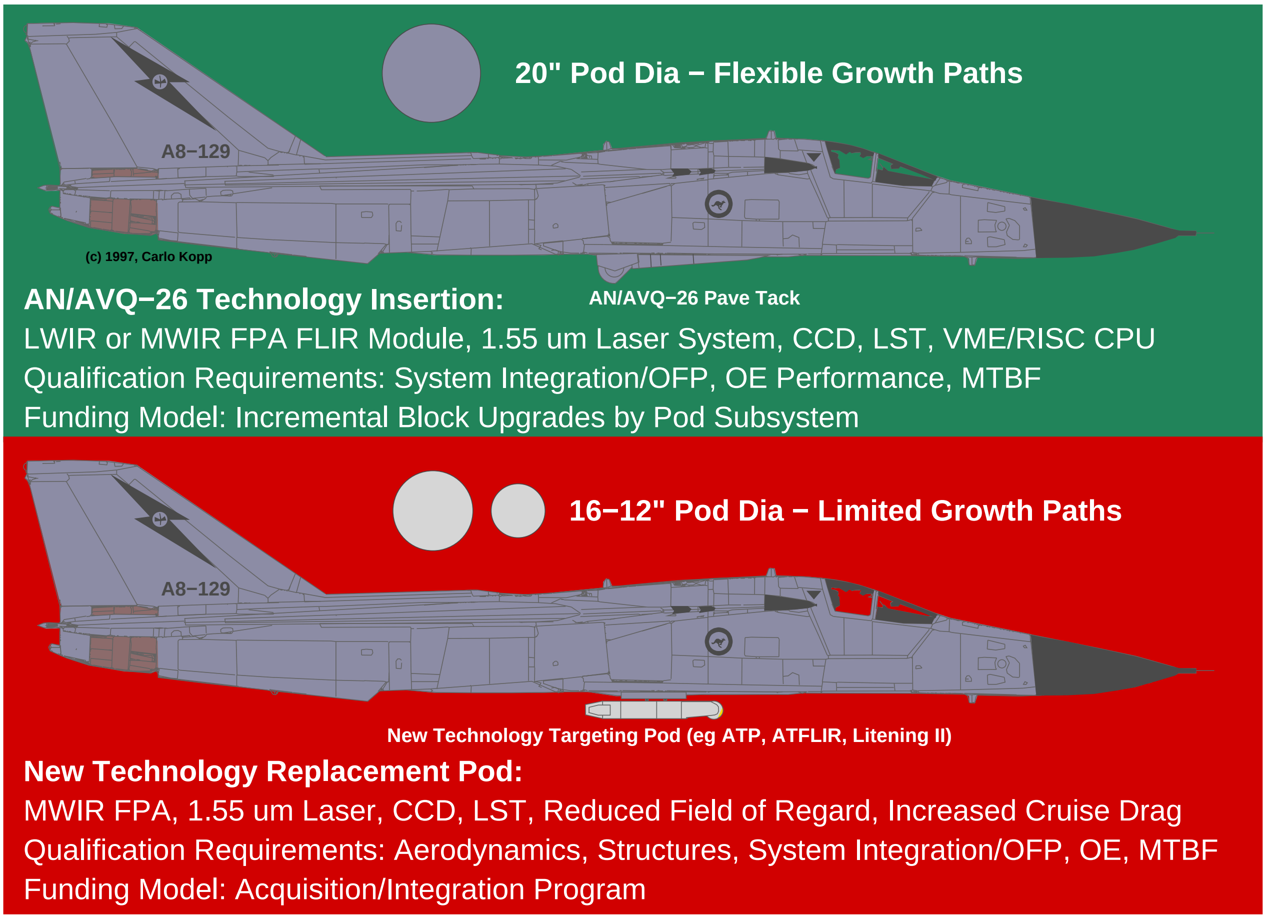


Figure 13: *Exploiting the F-111 to provide increased reconnaissance capability, using Pave Tack block upgrades (C. Kopp).*

The HALE UAV will provide vital capabilities for both strategic and tactical reconnaissance roles. Unresolved issues remain with both numbers and with the types of payloads to be carried by the UAV. However, its survivability when challenged by the Su-27/30 fighter is not high. The Sukhoi Su-27 has won and held a great many time-to-height absolute records and HALE UAVs do not present an unusual challenge for a Sukhoi to intercept[37].

Like the HALE UAV, the AP-3C will provide excellent persistence and a diverse payload of sensors, with a particularly good electronic reconnaissance package. However, its survivability is much lower than the HALE UAV as it is slower and operates at much lower altitudes.

The F/A-18A is not a particularly good platform for reconnaissance tasking. As with strike roles, it requires considerable tanker support to achieve useful persistence or range in performing reconnaissance. If a high threat environment is present, such as the Su-27/30 with or without AWACS support, it will need to be escorted by other F/A-18s, thus driving up demands on tankers.

The cited option of using a targeting pod for reconnaissance limits both the quality of reconnaissance imagery and achievable imaging standoff range. Targeting pods are primarily designed for targeting and unless a higher resolution imaging chip, high performance optical platform stabilisation and larger optical aperture are installed, the pod will not produce the kind of reconnaissance product specialised equipment will, or, moreover, the modern day commander needs and has every right to demand.

The existing capability in the four RF-111Cs is not viable given its use of film technology. However, the F-111 is a much better airframe for reconnaissance roles as it is more stable at low altitude than the F/A-18A, more survivable against missile threats and it can achieve significant operating radius or persistence without tanker support.

Industry proposed a dual-role strike/capability upgrade for all 21 F/RF-111C airframes based on a block upgrade for the AVQ-26 Pave Tack targeting pod and the retrofit of an active array radar. This would result in a 'multispectral' reconnaissance capability embedded in every F-111C aircraft, making reconnaissance a matter of tasking rather than available hardware. Extending the radar retrofit to the F-111G would increase the number of F-111s capable of performing imaging radar reconnaissance[38] [39] [40].

> In opting for early retirement of the F-111 and the use of podded F/A-18As for reconnaissance, Air Force have effectively overtasked the small A330 tanker fleet which must support strike and reconnaissance roles, as well as escorts. Overtasking and survivability issues will also arise with the HALE UAV and AP-3C. Retention of the F-111 and merging the AIR 5421 and 5426 upgrades would produce a significantly better reconnaissance capability than afforded by current Air Force planning.

1.16 ENHANCED STRIKE CAPABILITY (CIRCA 2010) (Para 28.)

RAAF Statement: *Attack a significantly larger number of targets than possible today using F/A-18 aircraft supported by new AAR tanker aircraft at F-111 radius of action ranges.*

RAAF Statement: *Strike using precision standoff weapons.*

RAAF Statement: *Ingress and egress at low level and off axis should that be necessary.*

RAAF Statement: *Retain a medium level of situational awareness provided through the networked system of systems supported by AEW&C and other national/coalition assets.*

RAAF Statement: *... will have a limited capacity to penetrate sophisticated surface to air missile threats even though that capability will be better than today.*

The claim that the 'enhanced strike capability' comprising tanker supported F/A-18As armed with the AIR 5409 bombs and AIR 5418 FOSOW will be able to 'attack a significantly larger number of targets than possible today' is misleading and does not even support the strike capability chart depicted in Figure 3 of the Air Force submission, on page 10 of that document.

The 'blood chart' in Figure 3 is the result of analysis and modelling by Air Force, and claims that the capability Air Force believe will be available from tanker supported F/A-18A is only 14% greater than what Air Force believe to be the current capability (circa 2004) as provided by the unrefuelled F-111. To claim that an 14% increase in capability is 'significantly larger' is clearly misleading.

What is more significant is that the capability planned for under the Defence 2000 White Paper, and represented in the chart provided by Air Force, using tanker supported F-111s and F/A-18 escorts, is 43% greater than the capability provided by tanker supported F/A-18s. Air Force have provided a compelling illustration of how they have produced a 43% reduction in RAAF strike capability to a radius of 1,000 nautical miles, by early retirement of the F-111. To claim there is no 'strike capability gap' as Air Force have repeatedly claimed in public is highly misleading, moreso as it directly conflicts with the very information provided by Air Force.

Independent analysis performed by the authors does not agree with claims made by Air Force. This is depicted in Figures 14, 15,16, and 17. Whether 'available' aircraft are considered, or a 'complete force structure' considered, using the stated set of initial assumptions, the strike capability gap arising from F-111 retirement is even greater than that presented by Air Force. While the use of strike capability at 1,000 nautical miles against the strike capability at any range reduces the size of the capability gap by a few percent, it cannot eliminate it.

Of all of the claims made by Air Force in relation to the early retirement of the F-111, the claims concerning levels of strike capability are most disturbing. This is because Air Force have carefully chosen measures of strike capability which minimise the loss incurred by removing the F-111, and appear to have made a range of unusually optimistic assumptions about F/A-18A tasking when performing strike operations.

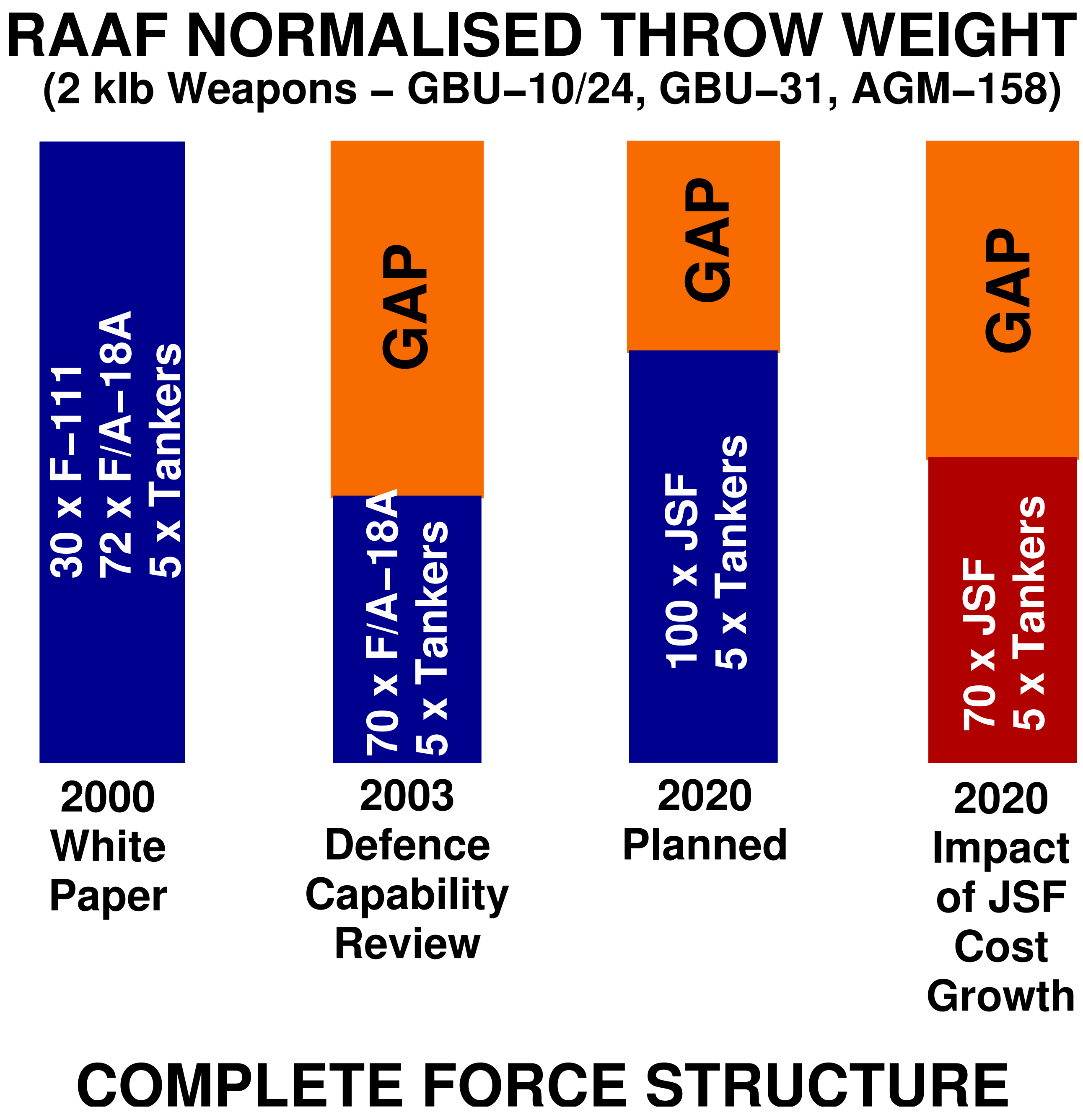

RAAF NORMALISED THROW WEIGHT
(2 klb Weapons – GBU–10/24, GBU–31, AGM–158)
30 x F–111
72 x F/A–18A
5 x Tankers
GAP
70 x F/A–18A
5 x Tankers
GAP
100 x JSF
5 x Tankers
GAP
70 x JSF
5 x Tankers
2000 White Paper
2003 Defence Capability Review
2020 Planned
2020 Impact of JSF Cost Growth
COMPLETE FORCE STRUCTURE

Figure 14:

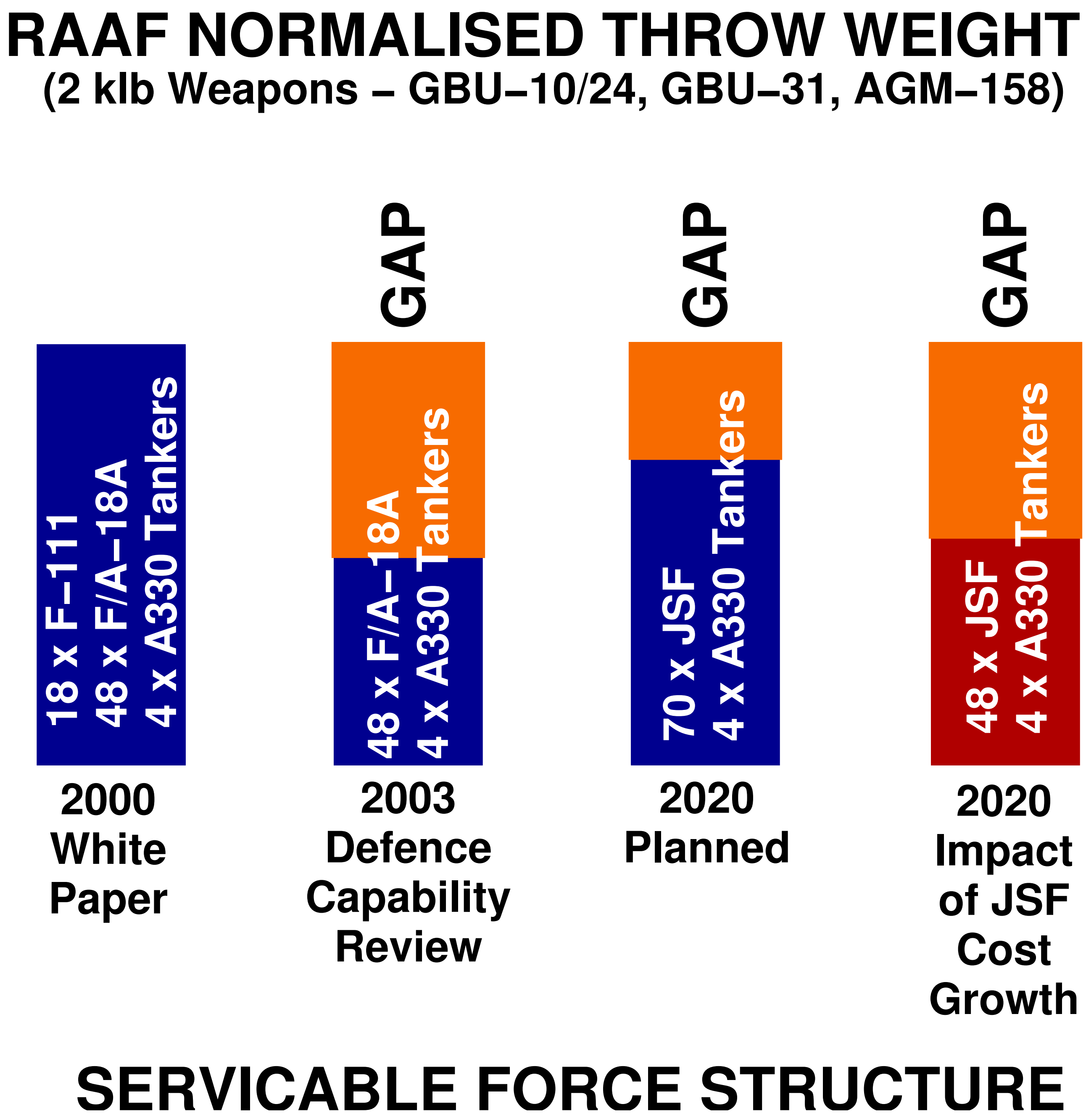

RAAF NORMALISED THROW WEIGHT
(2 klb Weapons – GBU–10/24, GBU–31, AGM–158)
18 x F–111
48 x F/A–18A
4 x A330 Tankers
2000 White Paper
GAP
48 x F/A–18A
4 x A330 Tankers
2003 Defence Capability Review
GAP
70 x JSF
4 x A330 Tankers
2020 Planned
GAP
48 x JSF
4 x A330 Tankers
2020 Impact of JSF Cost Growth
SERVICABLE FORCE STRUCTURE

Figure 15:

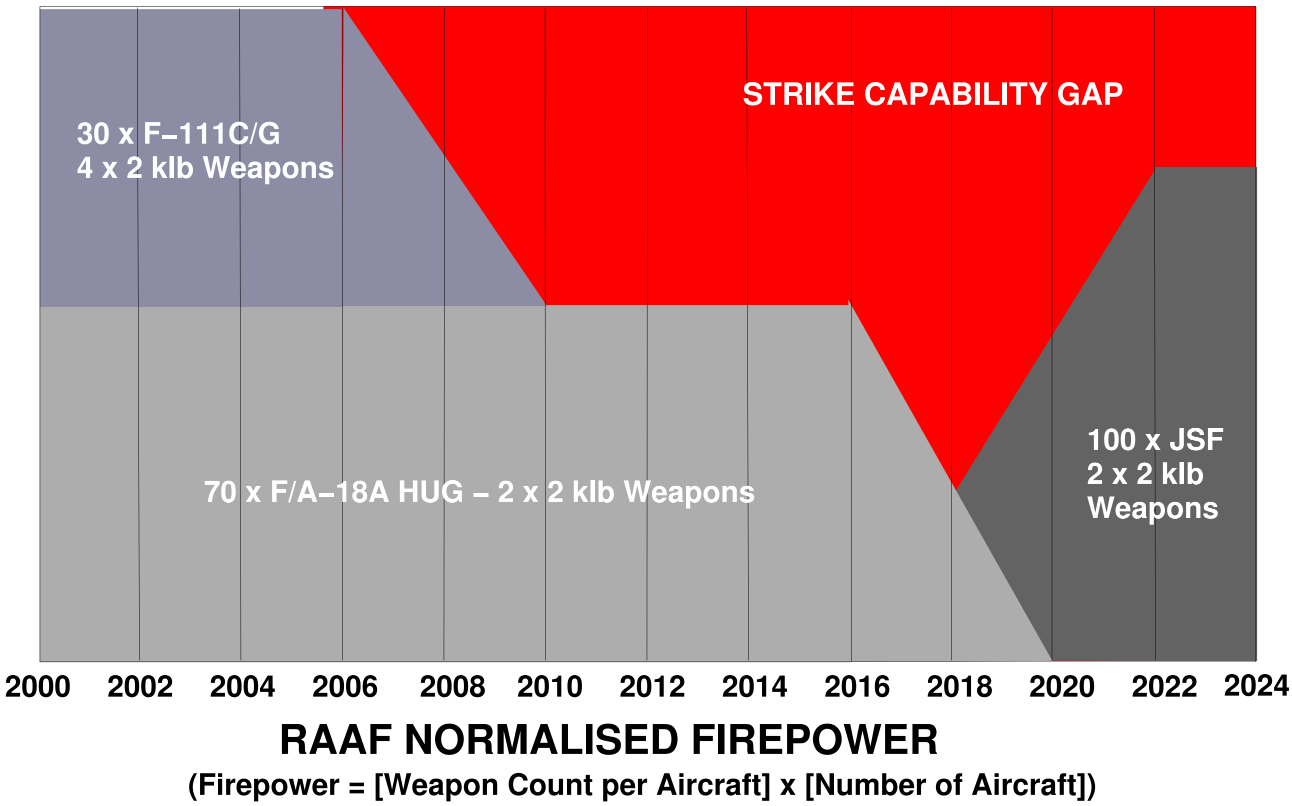

STRIKE CAPABILITY GAP
30 x F–111C/G
4 x 2 klb Weapons
70 x F/A–18A HUG – 2 x 2 klb Weapons
100 x JSF
2 x 2 klb
Weapons
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
RAAF NORMALISED FIREPOWER
(Firepower = [Weapon Count per Aircraft] x [Number of Aircraft])

Figure 16:

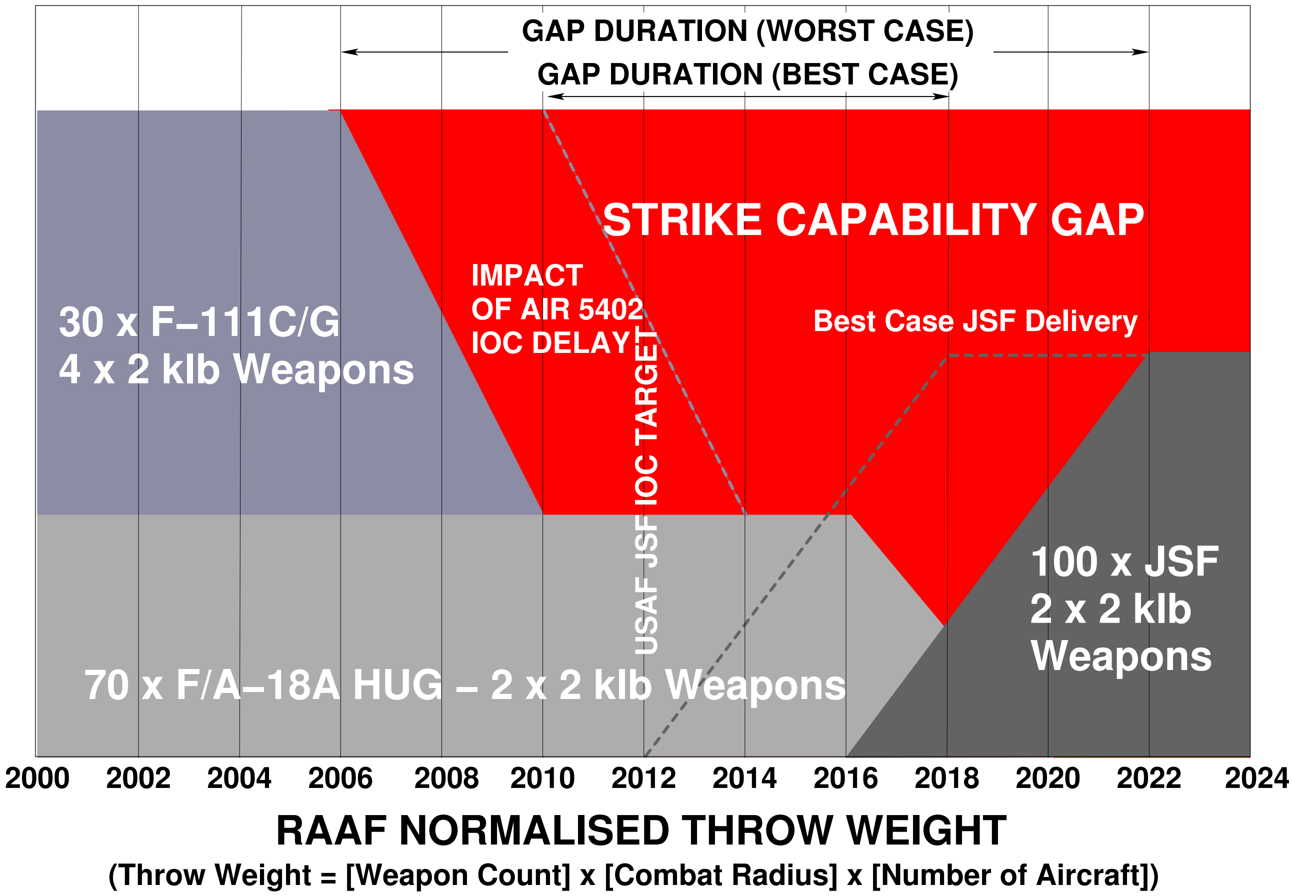

GAP DURATION (WORST CASE)
GAP DURATION (BEST CASE)
STRIKE CAPABILITY GAP
IMPACT
OF AIR 5402
IOC DELAY
USAF JSF IOC TARGET
Best Case JSF Delivery
30 x F–111C/G
4 x 2 klb Weapons
100 x JSF
2 x 2 klb
Weapons
70 x F/A–18A HUG – 2 x 2 klb Weapons
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
RAAF NORMALISED THROW WEIGHT
(Throw Weight = [Weapon Count] x [Combat Radius] x [Number of Aircraft])

Figure 17:

> If the future of the RAAF is being planned on the basis of assumptions which are designed to favour or defend a prior decision rather than yield objective hard measures, we cannot have any confidence that resulting RAAF force structure decisions are objective. Without independent analysis using widely accepted measures of capability, Australia faces the prospect of an RAAF force structure unable to compete in a highly capable regional threat environment, yet publicly presented as competitive. Unlike members of the Australian community who mostly are not equipped to identify Australia's weaknesses in capability, Australia's allies and potential regional foes will be able to understand and quantify weaknesses in RAAF capability.

The claim that the F/A-18A will be able to 'ingress and egress [the target area] at low level and off axis should that be necessary' assumes operations in weather conditions where the pilot of the F/A-18A can perform manual terrain following, as the F/A-18A is not equipped with a redundant automatic terrain following radar system such as the APQ-171 on the F-111. This may not be feasible during the monsoon season, where heavy rain and very low cloudbases will impair thermal imager performance severely. US experience using the LANTIRN navigation FLIR thermal imager indicates that this regime of flight proved very challenging for F-16 pilots, requiring significant qualification time. Even assuming favourable weather conditions, evading hostile SAMs and fighters while attempting to perform manual terrain following places an unreasonable demand upon pilots. Maintaining proficiency in low level penetration technique will impose a large training demand in flying hours, over and above what is required to maintain proficiency in air combat techniques and weapon delivery techniques.

> Air Force claims about low level penetration technique using strike tasked F/A-18A fighters do not accord well with US experience on the F-16C, especially under adverse weather and high threat density conditions. This raises the prospect of combat losses through Controlled Flight Into Terrain (CFIT), as occurred with the loss of the 'nose cold' (TFR/Radar off) F-111G in Malaysia.

The claim that the F/A-18A will 'retain a medium level of situational awareness provided through the networked system of systems supported by AEW&C and other national/coalition assets' assumes no opponent will apply high power jamming to the network, and no opponent will deploy specialised long range weapons to destroy the Wedgetail AEW&C aircraft.

The claim that '... will have a limited capacity to penetrate sophisticated surface to air missile threats even though that capability will be better than today' is difficult to support given the superior low level capability of the F-111 compared to the F/A-18A. With defensive jamming equipment of comparable or equal quality the advantage in low altitude penetration always goes to the aircraft which can fly lower and faster. Historical experience with the F-111A and F-105D in Vietnam, both equipped with identical jamming pod types, is that the F-111 suffered a loss rate around 40 times lower than the F-105D, which was limited to manual terrain following[41] [42].

It is unclear why Air Force are claiming a 'better capability' to penetrate 'sophisticated surface to air missile threats' using the F/A-18A rather than the F-111. Use of the FOSOW will obviate the need to penetrate such defences in many scenarios. Should circumstances require penetration by combat aircraft, the F-111 is inherently better suited to this role with greater low level speed and automatic terrain following capability. The addition of MIDS/Link-16 to the F-111 would further enhance that advantage by providing situational awareness of fighter and missile battery positions.

1.17 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 29.)

RAAF Statement: *When affordability and mass is factored into the argument, JSF is the clear contender for meeting Australia's future air combat needs.*

RAAF Statement: *Air Force is developing a paper to compare the F-22 and JSF capabilities that will be publicly released in August this year.*

The issue of 'affordability and mass' does not necessarily favour a cheaper and less capable aircraft. If we assume two aircraft of similar capabilities, then a large disparity in cost does permit significantly larger numbers of the cheaper aircraft affording more capability per dollar. Where there is a significant disparity in capability per aircraft, this will no longer be true.

The question which Air Force should be asking is the question of 'how do we maximise the capability we can acquire with a finite amount of funding?' rather than 'how do we maximise the numbers we can acquire with a finite amount of funding?'

Maximising capability given finite funding is not a simple problem to solve, and historically there are no case studies to support the proposition that it can be solved using a single type of combat aircraft. Conversely, every example we have in half a century of modern force structure planning points to the success of mixed fleets of aircraft. The reason for this outcome is simple. In adopting a single type model, the great diversity of roles which must be performed by combat aircraft results either in a cheap aircraft which attempts to do everything, but is not particularly good at anything, or a very expensive aircraft which does everything well, and its cost restricts numbers.

To defend the use of the single type model in the F/A-18 and later JSF, Air Force have argued that the use of a networked 'system of systems' will make up for the limitations of the lower capability single type, despite the bounds on capability imposed by the lower capability single aircraft type.

> Air Force, by insisting on a single type combat fleet for the RAAF and insisting on a fleet size of 100 aircraft, have placed Australia in the position where it ends up facing the dilemma of either purchasing a JSF which is demonstrably inadequate in the most difficult roles, or an F/A-22A which is superbly capable in the most difficult roles but too good for the less critical roles. Claims by Air Force that networking can offset the capability limitations of the JSF are not supportable by rational analysis - combat aircraft fleet capabilities are bounded by the capabilities of the platforms in that fleet.

In engineering terms the process of optimisation is one of manipulating the size of variables to effect a desired outcome. Optimising a military force structure is no different, and is achieved by manipulating the relative numbers of combat aircraft of differing capabilities in a fleet to achieve some desired balance in capabilities. A single type fleet replacement for the RAAF's F-111s and F/A-18A amounts to having no variables to manipulate - buying 150 JSFs rather than 100 will not make the JSF any more capable of defeating evolved Sukhoi fighters in air combat, or any more capable of defeating an advanced S-400 Surface to Air Missile system.

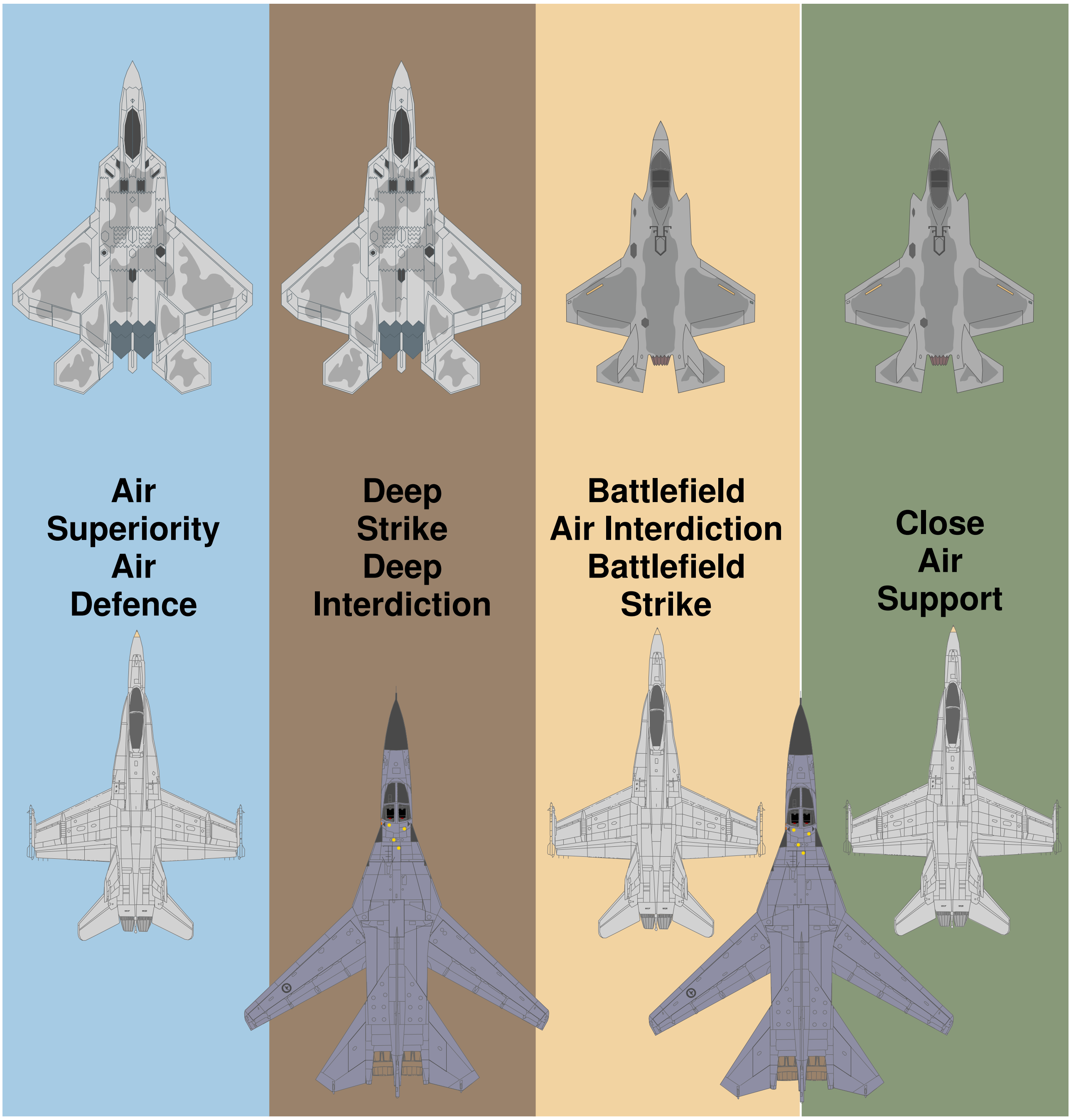


Figure 18: *There are significant disparities in the roles assigned to the JSF and F/A-22A in US service, against the division of these roles in the current RAAF model. The F/A-22A performs air combat roles which F/A-18A is now used for in Australia, and deep strike roles performed by the F-111. The JSF is to be used for the battlefield and close support roles which are shared between the F-111 and F/A-18A in RAAF service. Adoption of the JSF as a single type replacement for the F-111 and F/A-18A leaves capability gaps in air combat and deep strike roles.*

The issue of numbers is only relevant in terms of achieving some 'critical mass' to provide geographical coverage of Australia's north. The RAAF has available basing at Learmonth, Curtin, Tindal, Darwin and Scherger. Only Learmonth and Tindal/Darwin have the infrastructure and accessibility to credibly support tanker aircraft and required fuel replenishment, therefore in practical terms the two 'hubs' for offensive and defensive RAAF operations will be Learmonth and Tindal. Geographically these two bases are best situated to cover the valuable energy infrastructure of the North West Shelf and Timor Sea, and associated population centres, and Learmonth is optimal for launching long range strikes against targets in South East Asia. We can assume two squadrons of combat aircraft per 'hub' to provide credible strike/reconnaissance and air combat capabilities, deployed in a contingency.

> The 'critical mass' numbers for the RAAF will sit around 4 squadrons or about 64 aircraft, plus additional aircraft for operational conversion and combat reserves. In practical terms, the minimal size for an RAAF combat fleet is of the order of 80 combat aircraft.

An issue not addressed to date in public statements by Air Force is the issue of viable numbers of tanker aircraft to support a force structure of 80 to 100 combat aircraft. Comparative ratios of fighters to tankers in the US and UK force structures are of the order of 4 fighters per tanker. For 80 to 100 fighters, this yields tanker numbers of the order of 20 to 25 aircraft, or four to five times the number recently announced by Air Force. The utility of any number of fighters will be bounded by the number of available tankers.

The capability of the aircraft is however no less critical than raw numbers. Perhaps the most widely accepted fallacy about air power is the idea that numbers are more important than the capability of combat aircraft. This model was most deeply espoused by the Soviets and China during the early and mid Cold War, resulting in enormous fleets of cheap short range MiG fighters. Confronted in combat with larger and more capable US fighters, the 'mass centric' force structure model failed dismally. That the Sukhoi Su-27 and Su-30 exist today is testimony to the failure of the 'mass centric' model and the premises behind it. The Soviets had no choice than to compete with large high capability aircraft, and the Su-27 and Su-30 are larger and more agile than the top end US F-15 and F-14 fighters they were built to defeat[43].

There are only three combat aircraft today which fall into this top end bracket of high capability, high performance and large size. These third generation Su-27/30 and F-15E/S/K family of aircraft, and the fourth/fifth generation F/A-22A. All other types are significantly less capable in the critical air superiority role, and the JSF relative to the F/A-22A is no exception. Indeed, the gap in capability between the F/A-22A and JSF is vastly greater than the gaps in capability between their respective generational predecessors, the F-15/F-16, and F-14/F/A-18.

It is important to observe that the design aims of the 1970s Hi/Lo mix fighters were quite different to the design aims of the JSF relative to the F/A-22A. The F-16 and F/A-18A were initially conceived as lightweight air superiority fighters, to supplement the high performance heavyweight F-15/F-14. Over time all four types have been pressed into strike roles, mainly through avionic upgrades. Conversely, air superiority has never been a high priority in the role definition of the JSF - it is primarily a battlefield strike and close air support aircraft. Were the JSF designed with air superiority in mind, as were the F-16 and F/A-18A, it would have agility competitive with the F/A-22A and supersonic cruise capability.

> The preference shown by Air Force for the use of the JSF in air superiority / air dominance roles runs contrary to sixty years of cumulative historical combat experience. All historical precedents indicate the F/A-22A is the proper choice for defeating opposing air power, especially the Su-27 and Su-30. Given the 'critical mass' constraint on force size, the direct consequence of this is that the idea of a single type combat fleet for the RAAF is not viable and should be abandoned immediately.

Australia has successfully operated a two type combat fleet since the 1960s. The difficulties observed today are a consequence of accrued problems in acquisition and management over the last decade and should not be accepted as givens for the future, unless we are to accept that the acquisition and management apparatus in Defence cannot ever be made to work effectively.

Retention of the two type combat fleet model has the additional benefit of permitting staggered funding for block replacements, and mid life upgrades, over time. This avoids the problems inherent in a single type fleet, such as block upgrade costs and block obsolescence. The difficulties with the JSF largely arise from an insistence on using it as a single type block replacement for two types.

The two type combat fleet model also permits aggressive optimisation by altering the ratios of the two types to be acquired. This permits the best possible balance between funding and capability, and is a direct consequence of having a means of optimisation.

> Retention of the two type combat fleet model which has worked successfully for the RAAF since the 1960s affords important benefits in managing acquisition and upgrade budgets, avoiding block obsolescence, scheduling the replacement of the F-111 and F/A-18A, and optimising the total force capability against a finite budget.

It is important to observe that in the framework of the US force structure, the F/A-22A and JSF are considered complementary. The F/A-22A performs the roles now being performed by the F-15C air combat fighter and F-15E/F-117A 'deep strike' fighters, while the JSF performs the roles now being performed by the A-10A, AV-8B and battlefield strike / close air support tasked F-16Cs and F/A-18s. In terms of RAAF roles, the F/A-22A performs the air combat roles now performed by the F/A-18A and the 'deep strike' roles now performed by the F-111, while the JSF performs the battlefield strike and close air support roles now shared between the F/A-18A and F-111. Refer Figure 18.

The 'paper to compare the F-22 and JSF capabilities' to be released in August must be considered in the context of a JSF decision which is now being publicly defended by Air Force against the argument that 'the F/A-22A is a better choice than the JSF'. Unless such a paper is supported by an independent and comprehensive technical and strategic analysis, it cannot be considered an objective document.

1. The starting point for any such paper must be a comprehensive technical and numerical survey of developing regional capabilities in air combat, strike, cruise missiles, AEW& and aerial refuelling. Without a benchmark in capability to compare the future RAAF against, any force structure model is meaningless.

2. The second component must be a technical assessment of technological and numerical growth in regional capabilities, into the 2020+ timeframe. There is little point in building a force structure to defeat a current capability which will have evolved into something more potent over the coming two decades. It amounts to the equivalent of planning to win the last war.

3. The third component must be a comparative technical assessment of the capabilities of the F/A-22A and JSF, as planned for in their respective spiral development paths, in the 2015+ timeframe. Comparing current Low Rate Initial Production F/A-22A Block 10 aircraft against the planned 2015 capability of the JSF is as meaningless as comparing the JSF against a 1999 variant of the Su-30MK.

4. The fourth component must be a parametrised flyaway cost model for the F/A-22A and JSF, encompassing both best case and worst case build numbers of both aircraft by the intended 2012-2016 delivery timeframe. The costs of both aircraft will vary considerably with accrued build numbers, and comparisons which exclude the best and worst cases for both types are meaningless.

5. Finally, the document must aim to summarise the data in a coherent fashion, explore the implications of mixed force structures, and the impact of the probable FB-22 delta wing strike fighter on the JSF and F/A-22A equation.

If Air Force wish to produce a credible 'paper to compare the F-22 and JSF capabilities', this paper will need to be produced by an independent entity, and will need to be supported by very detailed technical analysis, operational modelling and strategic analysis. Such independent technical analytical capabilities are scarce in Australia. Without an independent and comprehensive supporting technical analysis, any such paper will be perceived as a public relations document, not a technical and strategic document.

1.18 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 30.)

RAAF Statement: *JSF characteristics - a.Contain true Low Observable or 'stealth' characteristics.*

RAAF Statement: *JSF characteristics - b.Good mission radius, currently in excess of 600nm for the CTOL variant ...*

RAAF Statement: *JSF characteristics - c.Advanced sensors, comprising the AESA radar, full coverage ESM system, EOTS and DAS as well as active EW systems.*

RAAF Statement: *JSF characteristics - d.High advanced data fusion capabilities to provide unprecedented situational awareness ...*

RAAF Statement: *JSF characteristics - e.Excellent weapons carriage capability both from internal and external weapon stations.*

RAAF Statement: *JSF characteristics - f.A full suite of precision weapons - air-to-air, air-to-ground - with standoff weapons to be cleared in later blocks*

RAAF Statement: *JSF characteristics - g.The ability to carry eight Small Diameter Bombs internally.*

RAAF Statement: *JSF characteristics - h.Enviable communications capability - both voice and data.*

RAAF Statement: *JSF characteristics - i.Other communications/data link capabilities including Link-16 and a high capacity Interflight Data Link*

RAAF Statement: *JSF characteristics - j.F-16/F-18 like manoeuvre performance.*

A detailed comparison of the JSF and F/A-22A is included in Annex C.

a. The stealth capability in the JSF is a departure from previous designs such as the F-117A, B-2A and F/A-22A, in that the JSF's capability is optimised to defeat a much narrower range of threat radars. The JSF will perform best in the forward quarter, and against X-band battlefield Surface to Air Missile systems and fighter radars. It will be much less effective against longer ranging lower band radars carried by AEW&C aircraft, or used for early warning and long range SAM acquisition. This is an acceptable design limitation for the manner in which the US intend to use the JSF; less so for the RAAF's intended roles for which the F/A-22A's stealth is better adapted. Australia will be limited to the export version with further reductions in stealth capability, compared to US models. While the export JSF will have better stealth than third generation fighters, its stealth will be inferior to an export model of the F/A-22A.

b. The cited mission radius of the JSF is for an aircraft carrying internal weapons, and can be regarded to be good compared to an F-16 or F/A-18A, but it is poor compared to an F-111. For typical payloads the JSF delivers about 40% greater radius than an F/A-18A, but only about 60% of the radius of an F-111. Therefore the JSF will require almost as much tanker support as an F/A-18A does, especially if the JSF carries large or draggy external weapons. Refer Figure 19.

c. The JSF's sensor suite is optimised for battlefield strike and close air support, and is well adapted for this role. However, its radar only delivers about 50% of the useful footprint of an F/A-22A radar, its Electro-Optical Targeting System is a derivative of the existing F-16C system, and its ESM is not optimised for long range coverage. The only unique sensor is the Distributed Aperture System which is designed for low resolution imaging of nearby threats. The capabilities in all of the JSF sensors can be retrofitted to legacy aircraft. Refer Figure 21.

d. The data fusion capabilities of the JSF software system are modelled on the F/A-22A design. As a software system, this capability can be inserted into any legacy aircraft equipped with a modern COTS technology computer.

e. The weapons carriage capability of the JSF is better than the F/A-18A, but characteristically about 50% of the F-111. The F-111 internal weapons bay has similar capacity to the two JSF internal bays.

f. Modern Mil-Std-1760 compatible weapons can be carried by any aircraft with this interface capability.

g. The F/A-22A is also capable of carrying eight Small Diameter Bombs internally, and the F-111G has been used in trials to carry at least eight internally. Refer Figure 21.

h. Communications equipment can be retrofitted to any legacy aircraft. The planned JSF suite is similar to the F/A-22A suite.

i. Link-16 datalink capability can be retrofitted to any legacy aircraft. Fighter-to-fighter datalinks are available now on the F/A-22A, F-14B/D, Su-30MK and MiG-31.

j. The manoeuvre performance of the F-16/F-18 was highly competitive against 1960s Soviet fighters like the MiG-21 and MiG-23. The 1980s MiG-29 and Su-27 were designed with agility to defeat the F-16/F-18, especially if the latter are burdened with external fuel tanks. Contemporary Su-30MK variants with current technology engine block upgrades and canard controls will outclimb, outaccelerate, outturn and outdash the F-16C, F/A-18A-F and JSF. Moreover, expected growth in Russian AL-31F family engine performance will see this margin grow over time. The extant weight issues with the JSF may see its agility decline by the time it reaches production. Refer Figure 21 and 20.

> The JSF shows every prospect of being a superb battlefield strike and close air support fighter, where its limitations in radar performance, stealth and agility will be of little importance. However, its size and constrained stealth capability will impair its effectiveness in the 'deep strike' role currently performed by the F-111, while its constrained stealth, limited speed and agility will impair its effectiveness in the air combat role. Equipped with standoff weapons and supported by robust tanking, a pair of JSF could substitute for one unrefuelled F-111, but at higher operational cost. Confronted with the Su-30 series in air combat, the JSF will be largely reliant upon its constrained stealth to survive.

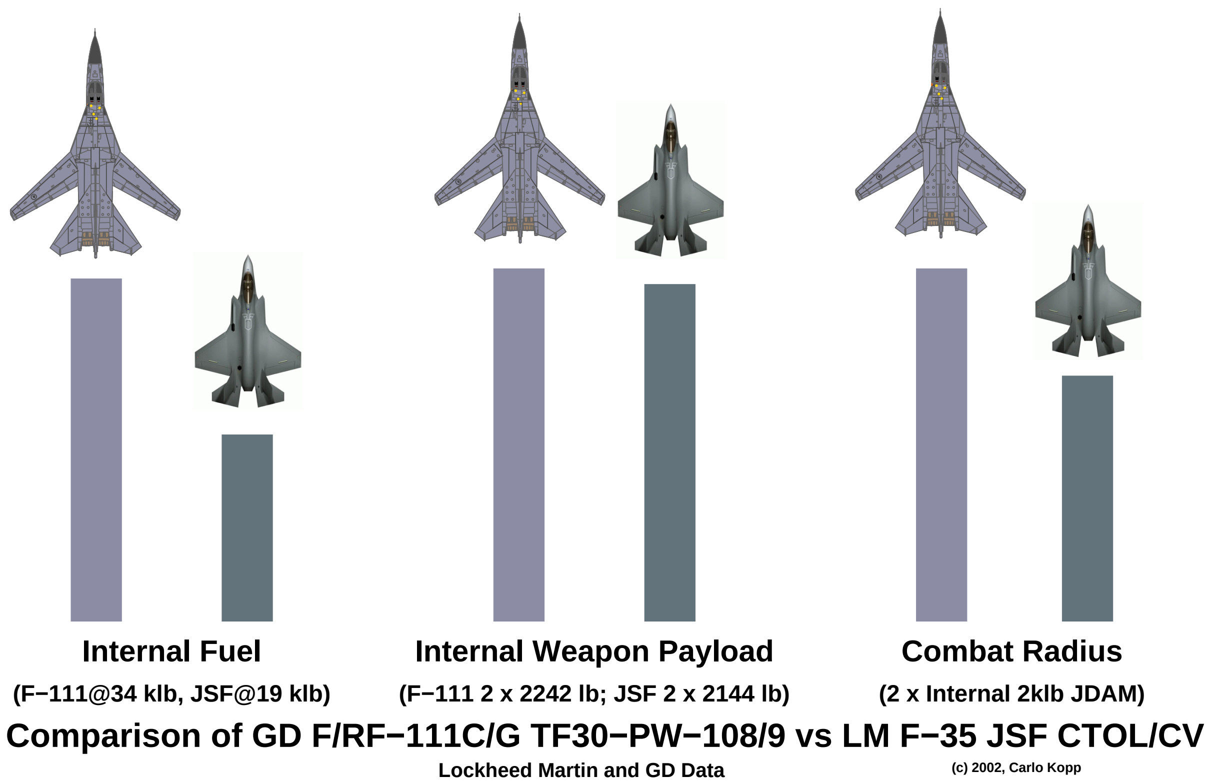


Figure 19:

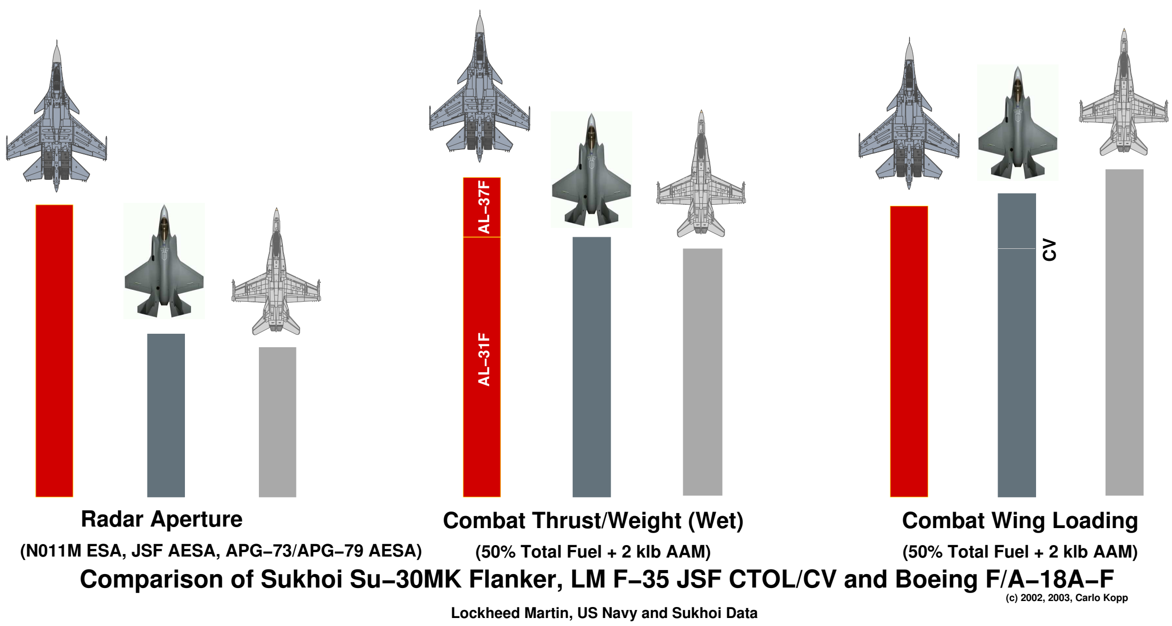


Figure 20:

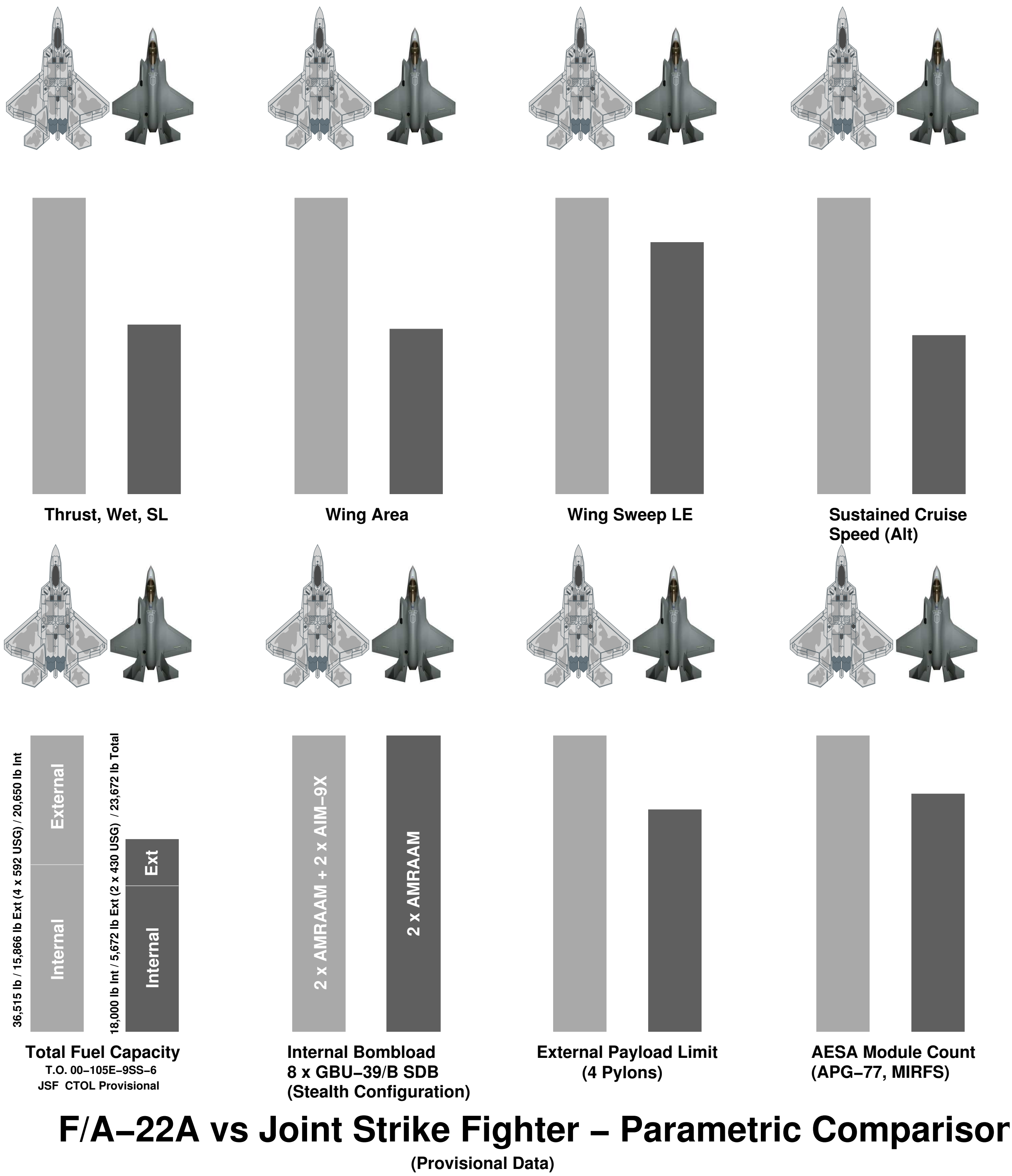

Thrust, Wet, SL
Wing Area
Wing Sweep LE
Sustained Cruise Speed (Alt)
36,515 lb / 15,866 lb Ext (4 x 592 USG) / 20,650 lb Int
External
Internal
18,000 lb Int / 5,672 lb Ext (2 x 430 USG) / 23,672 lb Total
Ext
Internal
2 x AMRAAM + 2 x AIM–9X
2 x AMRAAM
Total Fuel Capacity
T.O. 00–105E–9SS–6
JSF CTOL Provisional
Internal Bombload
8 x GBU–39/B SDB
(Stealth Configuration)
External Payload Limit
(4 Pylons)
AESA Module Count
(APG–77, MIRFS)
F/A–22A vs Joint Strike Fighter – Parametric Comparisor
(Provisional Data)

Figure 21:

1.19 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 31.)

RAAF Statement: *Interoperability - a. ...Link-16...*

RAAF Statement: *Interoperability - b. ...SATCOM...*

RAAF Statement: *Interoperability - c. ...JTRS and JVMF ...*

RAAF Statement: *Interoperability - d. ...Intra/Inter Flight Data Link ...*

RAAF Statement: *Interoperability - e. Basic comm/nav ...*

The datalink and communications capabilities of the JSF are not unique, indeed most legacy US fighters expected to remain in service well past 2010 will receive block upgrades including these capabilities, especially Link-16 and JTRS. The only features unique to the JSF and F/A-22A are the Satellite Communications terminal and covert Intra/Inter Flight Data Links. The latter are retrofit alternatives for legacy aircraft.

1.20 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 32.)

RAAF Statement: *JSF components and systems will be significantly more reliable than equivalent components on legacy platforms.*

RAAF Statement: *Improvements in sortie generation rate over legacy platforms are expected to be in the order of 25%.*

JSF component reliability and achievable sortie rates are specification targets which may or may not be achieved by mature JSF aircraft. While much effort is being invested into designing the JSF for high availability, it will contain the largest fraction of Commercial Off The Shelf (COTS) avionic hardware ever seen in a combat aircraft. This and reported heat management problems will present genuine challenges if the intended specifications for reliability and availability are to be achieved.

1.21 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 33.)

RAAF Statement: *While the Government hasn't made an acquisition decision to sole source for the JSF, Air Force expects that the aircraft will meet our requirements and further expects that an acquisition decision to acquire the aircraft can be made in 2006.*

RAAF Statement: *However, if the JSF does not mature as expected, or fails to meet Australia's requirements, the option remains to recommence the AIR 6000 process for the acquisition of an alternative manned combat aircraft, noting that all the contender aircraft will be quite mature in the 2012 timeframe.*

The statement that 'Air Force expects that the aircraft will meet our requirements' assumes that a formal requirement actually exists, in terms of capability. There is no evidence to date that Air Force have performed a formal analysis of the projected capabilities of regional air forces in the 2015+ timeframe, and thus there is no evidence that a capability target suitably defined to decisively defeat developing regional capabilities actually exists. In fact, the contract for the Operational Concept Document (OCD) and study for the AIR 6000 / NACC effort was only recently awarded, and without a formal OCD document, it is not possible to test the capability of an aircraft against an intended operational concept. Given the cited 2006 Year of Decision, and a reasonable timescale for the production and analysis of an OCD document, there may be very little time indeed for formal evaluation of the JSF and actual validation of the aircraft's performance against required targets.

Gathering technical intelligence and analysing, evaluating and modelling representative regional capabilities, especially advanced Su-30MK variants and AWACS, will present serious challenges in such a constrained timeframe as 2006. Until such analytical effort is performed rigorously and in much detail, it will not be possible to exactly assess how well the JSF will compete against regional capabilities. Publicly available technical material to date does not present a strong case for the JSF.

In 2006 at best a small number of early SDD JSF prototypes will be flying, and these are likely to be so heavily committed with flight testing activities that it will prove very difficult to even get access for RAAF test and operational test pilots to fly them, let alone fly them against the F-15C as a representative emulator for the Su-30MK. It is worth observing that during the acquisition of the F/A-18As, RAAF test pilots flew development aircraft which were not representative of production aircraft. The production aircraft did not perform as well due to modifications required for operational service.

With the prospect of further delays to the JSF program arising due to development problems, especially with weight, this problem may well become exacerbated over the next two years[44].

The timing of the latest reports of expected further delays in the JSF program raises genuine concerns, given the evidence presented by Air Force. If additional delays are being reported in the US, why have they not been presented in evidence[45]?

The intended 2006 Year of Decision for the JSF is too early to assess the air combat performance, reliability, and avionic/software capabilities of a representative production JSF variant. Until Low Rate Initial Production (LRIP) JSF aircraft are available, there will be no opportunity for RAAF pilots to fly a JSF with representative production air combat performance and avionic/software capabilities against an aircraft with representative performance to emulate the Su-30, nor will there be an opportunity to perform an operational evaluation for a representative regional threat environment. Deciding on the JSF in 2006 presents the possibility of a commitment to a production JSF before its limitations can be fully assessed. However, a 2006 Year of Decision is viable if the intended purchase is the F/A-22A, as it is now in Low Rate Initial Production and entering operational service.

The Air Force position that 'if the JSF does not mature as expected, or fails to meet Australia's requirements, the option remains to recommence the AIR 6000 process' understates the difficulties which exist in robustly evaluating the JSF in the 2006 timeframe, but also fails to acknowledge the difficulties which a 'no go' decision will present to RAAF personnel performing the JSF evaluation, given the vocal public support given to the JSF by the Defence Senior Leadership Group and the incumbent Minister.

A safer strategy for the New Air Combat Capability effort is to defer the Year of Decision to 2008 - 2010, and perform a parallel competitive evaluation of the JSF and F/A-22A. This allows a much more detailed analysis to be performed, and representative aircraft to be flown, with a much better knowledge of future regional capabilities. There is no point in evaluating third generation aircraft such as the F-15E/K, F/A-18E/F, F-16E/F or Eurocanards - the authors agree with Air Force statements that only fourth/fifth generation fighters, ie the JSF and F/A-22A, are credible new acquisitions for the future RAAF.

From a cost, capability and maturity perspective, the best time to acquire the JSF will be post 2016, when the aircraft has matured and production volumes have driven down unit flyaway costs.

An even safer acquisition strategy for the replacement of the RAAF fleet is to accept the strategic inevitability of a two type fleet, commit early to replacing the F/A-18A with a smaller number of F/A-22A, and extend the F-111 into the 2020+ timeframe with judiciously chosen upgrades. In 2015, the choices for F-111 replacement will be advanced variants of the F/A-22A, an operationally matured and by then proven JSF, and very likely the 'F-111-like' FB-22, in addition to further life extension of the F-111 through engine replacement, structural rebuilds, and further avionic upgrades. Opting for this acquisition strategy wholly avoids the extremely large risks in the current JSF-centric plan, spreads funding demands over two decades, introduces a far better air combat capability from 2012 onward in the F/A-22A, and provides considerable flexibility in exactly how the F-111 is replaced.

This strategy formed a core element of the 'Evolved F-111' proposals as submitted and briefed to the AIR 6000 Project Office in 2001/2002 and highlighted to the RAAF and Defence, immediately following the JSF decision in June 2002, as a comprehensive risk mitigation strategy. As events over the last two years have shown, this option was appropriate. Defence opted to ignore it.

1.22 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 34.)

RAAF Statement: Level of Capability • *strike a similar number of targets as previously; however, at extended radius of action ranges*

RAAF Statement: Level of Capability • *strike using standoff weapons (once integrated onto the JSF)*

RAAF Statement: Level of Capability • *ingress at all levels and off axis should that be necessary*

RAAF Statement: Level of Capability • *conduct electronic attack against air and surface threats in support of mission objectives*

RAAF Statement: Level of Capability • *retain a high level of situational awareness provided through the networked system of systems supported by AEW&C and national/coalition assets*

RAAF Statement: Level of Capability • *use the doctrine and tactics that have invigorated the system of systems capability*

RAAF Statement: Level of Capability • *maintain an enhanced probability of survivability and success*

- The relative radius advantages of the JSF vs the F/A-18A erode significantly once additional range is added by aerial refuelling. In practical terms this amounts to a striking radius gain between 15% and 25% against the refuelled F/A-18A capability. For comparison, the available aerial refuelling capability used to refuel escorted F-111s would permit 8 F-111s to strike targets at about 1,500 nautical miles, with 8 fighter escorts to the same radius, affording a 50% greater number of delivered weapons against a mixed package of 12+12 F/A-18A strikers/escorts at 1,000 nautical miles or 12+12 JSF strikers/escorts at about 1,250 nautical miles[46].

- Carriage of external standoff weapons on the JSF compromises the JSF's stealth performance severely, and incurs a fuel burn penalty which costs striking radius. The limitations in stealth bandwidth, and reduced stealth capabilities of the export JSF may however necessitate the carriage of external standoff weapons if heavy air defences are to be defeated.

- Penetrating air defences at 'all levels', meaning high, medium and low altitude penetration, will present difficulties for the JSF. The X-band optimisation of the JSF's stealth shaping performs best against fighter radars and Surface to Air Missile engagement radars, it will be much less effective against AEW&C and long range early warning radars, forcing low altitude penetration akin to that of the F-111 if any useful measure of surprise is to be achieved. Low altitude penetration by the JSF will incur a fatigue life penalty. This constraint would not apply to the F/A-22A as its stealth shaping is designed to defeat a much wider range of defending radar types, and it can penetrate at high altitudes and supersonic speeds.

- The utility of the electronic attack capability of the JSF's AESA radar will be limited to the X-band frequencies covered by the antenna design. Most threat radars of interest will remain well outside the frequency coverage of the AESA. A capability to jam engagement radars in the X-band was not introduced in upgrade planning on the EF-111A and EA-6B electronic attack aircraft until the 1990s, as the jamming of radars at lower frequencies was regarded to be much more important. For practical purposes the electronic attack capability in the JSF is limited to a narrow range of threat radars. It is worth observing that the use of the AESA for X-band jamming opens opportunities for opponents to use X-band missile seekers with Home-On-Jam or passive anti-radiation homing capabilities.

- The situational awareness of the JSF in the 'system of systems' will be bounded by the capabilities of the sensors feeding the network, especially the AEW&C aircraft, and the extent to which an opponent attempts to jam the network and threaten AEW&C aircraft with long range missiles. In general there is no reason to believe that a significant advantage in situational awareness will exist against an opponent with networking and AEW&C aircraft capabilities, in the 2020+ timeframe.

- Doctrine and tactics will be constrained by limitations in the capabilities of the JSF and vulnerability of the network and supporting sensor platforms to hostile jamming and attack.

- The correct language is 'enhanced probability of survival P[S]' not the stated term. Given the much more competitive regional environment we can expect in 2020 and later, and the limitations of the JSF in performance and stealth capability, there is no evidence to support the proposition that the RAAF will retain its current relative capability against the region if equipped with JSFs in 2020.

> The stated 'level of capability' resulting from the use of the JSF amounts to a reduction in the number of weapons which can be delivered to a given range, relative to the use of escorted and refuelled F-111s. Moreover, the limitations in stealth 'bandwidth' and radar bandwidth inherent in the JSF design will not provide the broad spectrum survivability gains and electronic attack capabilities this document suggests. The cited 'level of capability' can be considered misleading, especially as it does not compare against alternatives such as the F/A-22A and F-111.

1.23 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 35.)

RAAF Statement: *Over time the level of regional capability will also rise and that will offset some of the gains made with the development of the system of systems.*

RAAF Statement: *Regardless of these offsets, Defence assesses that our level of capability will continue to improve over time and Defence is confident that the overall air combat capability will retain the regional advantage articulated in the Defence White Paper. Figure 3 [Refer Figure 22] provides an indication of the strike capability that can be delivered over time.*

To claim that 'over time the level of regional capability will also rise and that will offset some of the gains made' is a remarkable understatement given the extent of observable growth in air power across the wider region.

Current publicly available data indicates that China will field in excess of 350 Su-27SK and Su-30MKK/MK2 aircraft, with some Russian sources claiming that 500 may be the final figure. China is also introducing into production the agile lightweight indigenous J-10 fighter, similar in concept to the Eurofighter Typhoon, Rafale and cancelled Israeli Lavi. An AEW&C prototype is now being flown at Nanjing, and extensive ground based development facilities have been photographed. China is also modifying existing H-6 Badger bombers into aerial refuellers, providing a capability similar to the now retired RAF V-bomber tanker variants, while negotiating for the Russian Il-78 Midas tanker. Available public materials indicate that a long range cruise missile development program is very active, intended to produce equivalents to the US Tomahawk and B-52H launched CALCM cruise missiles. A modified H-6H Badger variant with four pylons to carry such missiles was revealed two years ago. Within the 2020 timeframe the prospects are very good that China will have the capability to project air power across South East Asia.

India is committed to deploying at least 180 Su-30MKI fighters by 2020, this being the most advanced variant available, equipped with EU and Israeli avionics and expected to be armed with a variant of the AGM-142 missile now being fitted to the F-111, and a licence built Russian Yakhont supersonic cruise missile. India has ordered up to six Israeli A-50I AWACS, using a variant of the radar bid to Australia for AIR 5077. India has taken delivery of six Russian Il-78 Midas tankers, with more being canvassed in the Indian press. The Indian Navy is acquiring a former Russian CTOL carrier, and an air wing of agile MiG-29K fighters, while upgrading its fleet of 4,500 nautical mile radius Tu-142 Bear maritime patrol aircraft to carry cruise missiles. Negotiations continue on the lease of Russian Tu-22M-3 Backfire supersonic strategic bombers, not unlike an enlarged F-111 with 2,500 nautical mile radius capability. The Port Blair runways in the Andamans have been significantly upgraded. Like China, India is equipping itself with the capability to project significant air power across South East Asia, to compete with China's gains in capability. Both China and India are acquiring a wide range of advanced Russian missiles and precision guided bombs to equip their fleets of combat aircraft.

This arms race has had and will continue to have collateral effects in the nearer region. Malaysia has ordered its first batch of Su-30MKM fighters, similar to the advanced Indian variant, with more planned for pending the acquisition of AEW&C aircraft. Indonesia has fielded its first four Sukhoi fighters and stated an intention to deploy around 50 aircraft. Russian sources claim that Indonesia has also sought advanced Russian S-300PMU-3 mobile long range Surface to Air Missile systems.

Historically Australia's force structure planning has been driven by capabilities in the nearer region, and attaining and maintaining an advantage was not difficult. Over the next decade Australia will be confronted with a new reality, in which nations in the nearer region will increase their capabilities to unprecedented levels, while China and India will acquire the capability to directly project air power into Australia's geographical area of interest. Force structure planning yardsticks based on near regional capabilities will inevitably be less relevant strategically than yardsticks based on wider regional capabilities, especially those of China and India. Unless Australia acquires a credible capability to challenge possible future air power incursions into the near region by India and especially China, Australia's strategic influence in the near region will inevitably collapse.

Australia will never have the capability to defeat either regional superpower in a head to head confrontation, but attaining capability levels good enough to deter power projection into the near region and Australia's sea-air gap is feasible, and affordable, should judicious choices be made in air power investments.

Air Force must change its thinking on the relationship between platform capabilities and networking, and accept that top tier platforms such as the F/A-22A are the only way to credibly offset the regional influx of top tier Su-30s and associated weapons. The fragility of the networked systems of systems when confronted with technologically competent opponents must be factored into the equation, and the complete dependency on the network envisaged by Air Force must be accepted as a single point of failure for the whole ADF warfighting system.

Cruise missile defence capabilities do not appear cited anywhere in the Air Force submission, yet this will become a major capability issue over the coming decade, especially in terms of its demand on fighter top speed, persistence and missile payloads. The US have recently initiated large scale planning for enhancements in cruise missile defence capability, centred on the use of the F/A-22A to intercept cruise missiles and their launch platforms[47]

Another outstanding issue will be aerial refuelling capability, as the five A330-200 tankers despite good per unit capability are simply not credible in numbers to support viable numbers in RAAF strike operations across the sea-air gap, while providing for air defence operations across the north of Australia. Affordable options exist in 8 to 10 converted used 747-400 airliners, but Air Force have repeatedly rejected this option[48].

While the recent decision to increase the Wedgetail AEW&C buy from four to six aircraft is a step in the right direction, another one to two aircraft would be required for credible coverage of the north, and to provide redundancy should any be lost in combat. Electronic attack capabilities remain a genuine hole in RAAF capabilities and this must be addressed at some stage. The repeated rejection of the EF-111A suggests that this capability is not well understood in Air Force.

If Australia is to retain its current strategic position across the wider region, significantly more attention and intellectual rigour must be invested into air power. Air Force must change its thinking on networks, accepting their limitations, and more investment must be made into aerial refuelling and AEW&C aircraft. A genuine electronic attack capability should also be pursued.

Air Force claims that 'regardless of these offsets, Defence assesses that our level of capability will continue to improve over time and Defence is confident that the overall air combat capability will retain the regional advantage articulated in the Defence White Paper'.

This claim directly contradicts the strike capability chart provided by Air Force in their submission (Figure 22), which clearly illustrates the large reduction in capability arising from F-111 retirement. No less importantly, the chart does not attempt to quantify the capability level achieved once the JSF is introduced. Analysis using pre-SDD and current figures for JSF capability clearly indicates that strike capability planned for in the JSF era will be little better than that during the planned period of the 'strike capability gap' between 2011 and 2014.

In terms of retaining a 'regional advantage' there is no evidence that Air Force have made any attempt to quantify developing regional capabilities, either in the near region or wider region. Every Su-30 deployed in the region amounts to about 60% of an F-111 or 250% of an F/A-18A, in raw payload-radius or throw weight terms. Fifty Sukhois roughly balance 30 F-111s in raw payload-radius or throw weight terms.

Claims by Air Force that the RAAF will retain a 'regional advantage' in strike capability do not account for planned and expected buys of Su-30 aircraft in the near region, let alone capabilities being developed on the Asian mainland. The advantage held today will rapidly erode with the retirement of the F-111.

DEPARTMENT OF DEFENCE ANALYSIS MODEL (UNDERSTATES F–111 CAPABILITY PER UNIT)

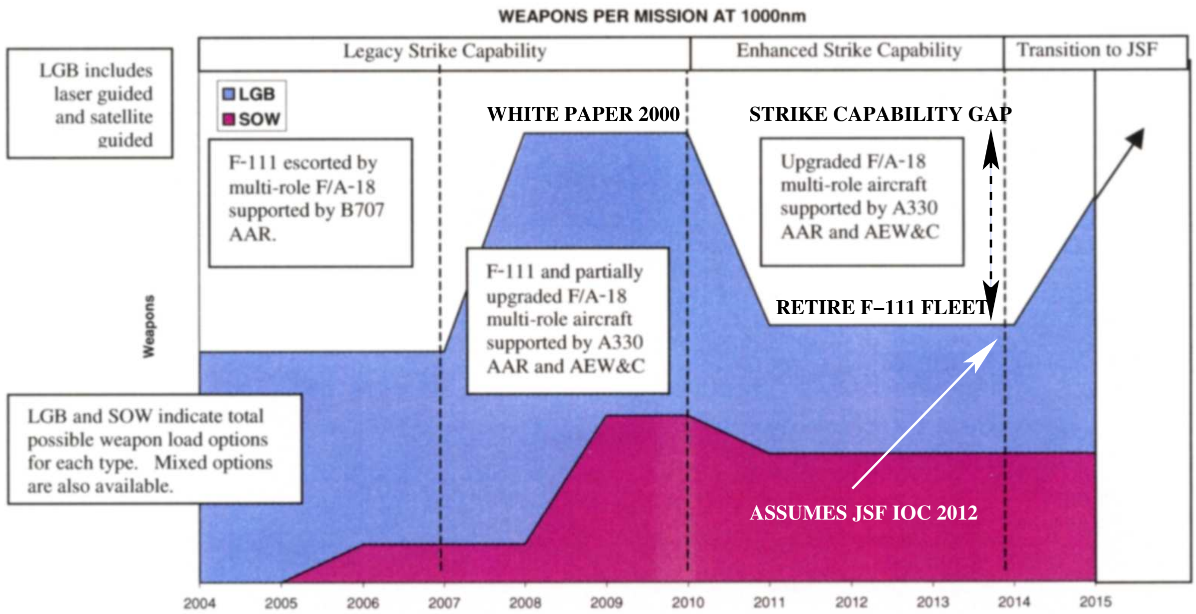


Figure 3 – Level of Precision Strike Capability over Time

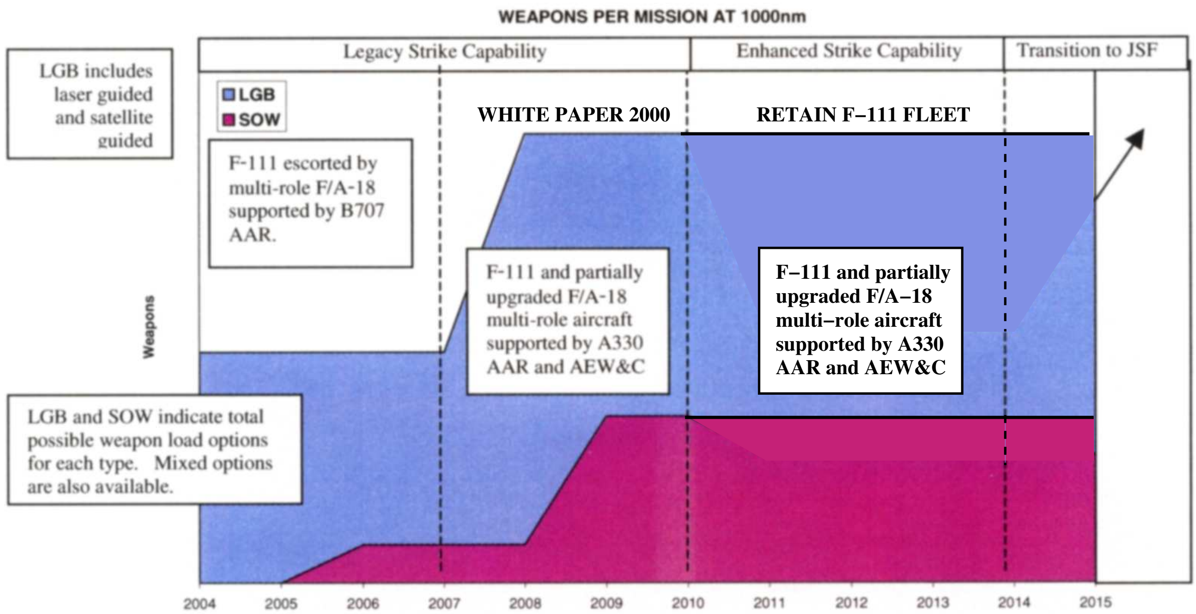


Figure 3 – Level of Precision Strike Capability over Time
(Amended to assume F–111 retention to 2020)

Figure 22: *DoD assessment of strike capability without (upper) and with (lower) the F-111 in service to 2015-2020.*

1.24 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 36.)

RAAF Statement: *F-111 retirement prerequisites - a.AEW&C introduction.*

RAAF Statement: *F-111 retirement prerequisites - b.Air to Air Refuelling aircraft*

RAAF Statement: *F-111 retirement prerequisites - c.F/A-18A HUG EWSP and Link-16.*

RAAF Statement: *F-111 retirement prerequisites - d.AIR 5409 GPS guided bombs.*

RAAF Statement: *F-111 retirement prerequisites - e.F/A-18A AIR 5418 FOSOW.*

RAAF Statement: *F-111 retirement prerequisites - f.F/A-18A AIR 5418 FOSOW.*

The prerequisite measures cited for F-111 early retirement cannot credibly offset the loss of capability arising from the removal of the F-111 with the planned AIR 5409, AIR 5418 weapons upgrades, AIR 5416 EWSP upgrade, AIR 5426 Strike Capability Upgrade, JP 2089 networking upgrade and AIR 5421 reconnaissance equipment upgrade applied.

Moreover, the current windback in deeper maintenance and ongoing effort to 'drawdown on aircraft and engine "hours in the bank", serviceable repairable item stocks and consumable spares stocks' cited in Paragraph 20 will see a progressive erosion in F-111 capability over coming years, as it will be increasingly difficult to ensure F-111 availability levels. The drawdown effort will guarantee that the F-111 will be beyond recovery in the 2010 timeframe, as a result of which any significant delays in the 'F-111 retirement prerequisite' programs will see an even greater capability gap arise[49].

> The claim that the F-111 will be retired only when specific prerequisite programs are completed conflicts directly with the effects arising from the current effort to drawdown F-111 support capabilities. As the drawdown effort is now under way and will impact aircraft availability prior to 2010, the claim that retirement will not occur until specific prerequisite programs are completed is misleading. Retirement is effectively now in progress.

1.25 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 37.)

RAAF Statement: *In the future the region may see the progressive introduction of Russian and Western sourced fighter/bomber aircraft including the Su-30 and Mig-29 derivatives with advanced air to air weapons and advanced ground based air defence systems supported by modern radars.*

RAAF Statement: *While the F-111 is currently assessed as being capable in this environment, when escorted by F/A-18s, the cost of maintaining this advantage is distorting the shape of the force.*

RAAF Statement: *The best way of defeating these systems is by employing a systems of systems, to which the F/A-18 can contribute following the completion of the Hornet Upgrade Program and integration of Link-16.*

RAAF Statement: *But no equivalent (or affordable) program exists for the F-111.*

The claim that 'the region may see the progressive introduction of Russian and Western sourced fighter/bomber aircraft including the Su-30 and Mig-29 derivatives with advanced air to air weapons and advanced ground based air defence systems supported by modern radars' neglects to state that Indonesia has already taken delivery of its first Sukhois and Malaysia has ordered its first batch, and is thus misleading. Moreover, it fails to articulate the impact of the wide range of Russian precision guided bombs, standoff missiles and cruise missiles being supplied with the Su-30, and compatible with mid-life upgrade packages such as the Su-27SKU.

> The claim that the near region 'may see the introduction' of Sukhoi fighters is misleading, insofar as Indonesia has already taken delivery, and Malaysia has placed orders, while planning for a second buy.

The claim of 'while the F-111 is currently assessed as being capable in this environment, when escorted by F/A-18s, the cost of maintaining this advantage is distorting the shape of the force' acknowledges that the F-111 does provide an 'advantage' yet states that the 'cost of maintaining this advantage is distorting the shape of the force'.

> Given that the F-111 provides around half of the RAAF's aggregate combat fleet strike capability, it would be feasible to spend an equal amount on upgrades and support on the F-111 as is intended to be spent on the F/A-18 without a disproportionate imbalance in funding priorities arising. Earlier Defence Annual Reports indicate clearly that total expenditures on the F-111 fleet are well below expenditures on the F/A-18 fleet. There is therefore no basis for a claim that the F-111 is 'distorting the shape of the force'.

Note[50]

The claim that 'the best way of defeating these systems is by employing a systems of systems, to which the F/A-18 can contribute following the completion of the Hornet Upgrade Program and integration of Link-16' is not credible, given the prospect of regional parity in AEW&C and networking capabilities, and especially given the limitations of the F/A-18 in penetrating heavy ground based air defences and confronting Su-30s in BVR combat.

> Air Force claims that the F/A-18 equipped with Link-16 and supported by AEW&C provide the 'the best way of defeating these [Su-30, SAM] systems' is predicated on unsupportable assumptions of asymmetric advantages in AEW&C and networking capability which cannot be expected to be valid beyond 2010.

The claim by Air Force of 'no equivalent (or affordable) program exists for the F-111' is an error of fact. The JP 2089 program could introduce a Link-16 capability for a cost of the order of AU$20 million. Moreover, the budgets cited for AIR 5409, AIR 5416, AIR 5418, AIR 5426 and AIR 5421 provide generously for capability and survivability upgrades to the F-111 making it viable into the 2020+ timeframe.

> The claim that no affordable programs exist to introduce a Link-16 capability, also stated in the public Defence Watch briefing, is highly misleading given the wide availability of competitively priced Link-16 terminals.

1.26 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 38.)

RAAF Statement: *The late delivery of the JSF would require the extension in service of the air control and strike capability that will be inherent in the F/A-18 by about 2010.*

RAAF Statement: *The aircraft systems that are currently being upgraded can be expected to be highly competent until at least 2015.*

There is little doubt that the JSF will be late in delivery, the only question is how late and with what impact on its capability and unit cost at that time.

The bigger issue is the ability of the F/A-18A HUG to compete in the regional environment we can expect between 2010 and 2020. The F/A-18A HUG is not competitive against the Su-30 in BVR combat unless a significant asymmetric advantage exists in both AEW&C and networking capabilities. That advantage cannot be guaranteed given recent regional developments. Some of the most pronounced limitations in the F/A-18A HUG when compared to the Su-30 are shared by the F/A-18E/F, which is often advocated as an 'interim fighter' replacement for the F/A-18A. The return on investment in significant F/A-18A life extension, or 'interim fighter' lease/buys is poor given the uncompetitive performance of all third generation fighters against the Su-30.

1.27 MATURE AIR COMBAT CAPABILITY (CIRCA 2015) (Para 39.)

RAAF Statement: *Fatigue life of the [F/A-18] airframe is the significant factor that could preclude the F/A-18 from being extended beyond 2015.*

RAAF Statement: *Defence has determined that a minimum of 15 aircraft will need to have their centre barrel assemblies replaced to ensure that a viable fleet can be maintained to the planned life of the aircraft. However as a hedging strategy, Defence has set aside funding for a total of 43 centre barrel assemblies to allow the life of the fleet to be extended significantly beyond 2015 should that become necessary.*

Performing rebarrelling on a significant fraction of the F/A-18A fleet is both expensive and time consuming, and incurs a significant penalty in aircraft availability for operational use. Moreover, rebarrelling yields a very poor return on investment as it adds significant additional fatigue life to the aircraft, which would be retired before 2020 even with late JSF deliveries.

Rebarrelling a large fraction of the F/A-18A fleet to effect life extension past 2015 yields a very poor return on investment given the short remaining service life of the fleet beyond 2015, and the inadequacies of the F/A-18 against developing regional capabilities. By insisting on the early retirement of the F-111, Defence have exacerbated this problem by shifting the burden of additional strike roles on to the F/A-18A, and by destroying opportunities to consolidate the F/A-18A fleet to 3 squadrons, and shift the saved flying hours to an additional F-111 squadron.

1.28 CONCLUSION (Para 40.)

RAAF Statement: *The decision to retire the F-111 has been made in the best interests of maintaining a strong capability for the Defence of Australia.*

RAAF Statement: *This will enable the development of a network-enabled capability to be generated to ensure that Australia can maintain parity or better with regional air combat capability into the future.*

RAAF Statement: *While a strike capability reduction will occur following retirement of the F-111, that level of strike capability will be greater than today's level of capability.*

RAAF Statement: *It is the Air Force's view that the level of strike capability available for any contingency will continually develop over time through greater aircraft availability and enhanced situational awareness created through the implementation of the system of systems.*

RAAF Statement: *Australia cannot afford to maintain the F-111 in-service at the level of capability required while developing the future force; therefore the F-111 aircraft will not be part of the future system of systems.*

Given that the capability to perform operations in 'Defence of Australia' roles is severely compromised by the aggregate reduction in RAAF payload radius capabilities arising from F-111 retirement, this claim is a non-sequitur.

The claim that 'a strike capability reduction will occur following retirement of the F-111, that level of strike capability will be greater than today's level of capability' cannot be supported by analysis. The chart presented by Air Force displays selective use of pessimistic assumptions about F-111 availability, and unreasonable assumptions about the ratio of F/A-18As committed to escort tasks compared to the number committed to strike. Moreover, the model is confined to the best case achievable strike capability at 1,000 nautical miles, disregarding the impact on total strike capability at shorter ranges, and availability of F/A-18A aircraft and tankers for air defence tasking. Even so the analysis by Air Force indicates only a 14% increase in their assessment of strike capability provided by refuelled F/A-18As between 2011 and 2014, against unrefuelled F-111s today. The unserviceability or loss of a single tanker aircraft demolishes the 'increase' argued for by Air Force.

The claim that 'the level of strike capability available for any contingency will continually develop over time through greater aircraft availability and enhanced situational awareness created through the implementation of the system of systems' is a non sequitur in two respects. The first is that the overtasking of the F/A-18A and AP-3C in taking on F-111 roles will divert them from air control and maritime patrol roles. The second is that the prospect of extensive ongoing upgrades and structural rebuilds of the F/A-18A will see a larger fraction of the fleet sitting in depot hangars being worked on, than ever before.

The claim that 'Australia cannot afford to maintain the F-111 in-service at the level of capability required while developing the future force; therefore the F-111 aircraft will not be part of the future system of systems' is not consistent with the cited figures for previously planned upgrades and support, nor is it consistent with independent analysis, nor is it consistent with documented trends in availability and the impact of the Sole Operator Program and ageing aircraft engineering program. Given the low incremental cost in adding networking capabilities such as Link-16, incorporating the F-111 into a networked environment is not a obstacle of any substance.

The cited conclusions are not supportable by known facts or by analysis. They are predicated on a range of unrealistic or unreasonable initial assumptions, and non-sequitur arguments. There is no supportable case for early retirement of the F-111.

1.29 CONCLUSION (Para 41.)

RAAF Statement: *Reduction of payload and range will be offset by: a.significantly greater availability of F/A-18s due to Air to Air refuelling capacity.*

RAAF Statement: *Reduction of payload and range will be offset by: b.integration of Link 16 to provide enhanced situational awareness provided from the network through the AEW&C.*

RAAF Statement: *Reduction of payload and range will be offset by: c.integration of an advanced electronic warfare self protection suite [on the F/A-18A].*

RAAF Statement: *Reduction of payload and range will be offset by: e.enhanced strike ranges following the introduction of new A330-200 tanker aircraft and the long range standoff weapon to both AP-3C and F/A-18.*

RAAF Statement: *Reduction of payload and range will be offset by: f.flexible strike options with the integration of the satellite guided weapons and new targeting pod.*

RAAF Statement: *Consequently there will be no gap in strike capability during this transition period.*

a. The availability of the F/A-18A aircraft is determined by the availability of pilots, quality of maintenance and funding for fuel and munitions. It is not dependent upon the presence or absence of tanker aircraft. Therefore this claim is non-sequitur.

b. The presence or absence of Link-16 capability does not impact the payload and range of an aircraft of any type, other than the 40 to 50 kg of Link-16 terminal hardware which must be carried by so equipped aircraft. Link-16 does enhance survivability, but survivability gains cannot make up for a loss in payload and range capability.

c. The presence or absence of advanced electronic warfare self protection equipment does not impact the payload and range of an aircraft of any type, other than the 70 to 150 kg of hardware which must be carried by so equipped aircraft. Electronic warfare self protection equipment does enhance survivability, but survivability gains cannot make up for a loss in payload and range capability.

d. The strike radius achievable by F/A-18A aircraft carrying identical numbers of identical weapons to the unrefuelled F-111 is bounded by the number of tankers available. The five tankers recently ordered are inadequate to offset the loss of 27 F-111 aircraft, in terms of aggregate fleet payload and radius.

e. Satellite aided inertially guided weapons are not 'satellite guided weapons', and the integration of these cannot increase the number carried to a given distance. Delivering a pair of 2,000 lb satellite aided inertially guided bombs requires the same payload and radius capability as a pair of 2,000 lb laser guided bombs. An advanced targeting pod may provide improved target image quality for a given range, but also cannot change the number of bombs carried to a given distance[51].

The statement: 'Consequently there will be no gap in strike capability during this transition period' is a non-sequitur in relation to the cited measures for offsetting the loss of the F-111.

2 Annex A - Endnotes and References

[1] Griffin R.E., Reid D.J. 'A WOVEN WEB OF GUESSES: CANTO ONE: Network Centric Warfare and the Myth of the New Economy', Proceedings of the 8th ICCRTS, National Defence University, June 2003, Washington DC, http://www.dodccrp.org/events/2003/8th_ICCRTS/Pres/track_5.htm. This research paper coauthored by a DSTO researcher, eloquently exposes the fallacy in reasoning underpinning the utility of networking, as espoused in the Air Force submission. The paper refutes the belief that networking provides unbounded growth in capability, and identifies 'Naive Inductivism' as the root of the problem in current Air Force thinking on the value of networks.

[2] Kopp C., 'Reflections on Information Age Warfare', Draft paper, 2003.

[3] Kopp C., 'Regional Capability Growth - A Risk All of its Own', Australian Aviation, date TBD.

[4]Majumdar S., 'AIRBORNE EARLY WARNING TACTICS - An IDC Analysis', INDIA DEFENCE CONSULTANTS, New Delhi, 17 March 2004, http://www.indiadefence.com/.

[5]Szabo S. (Capt), 'Suchoj Su-35/37', http://www.lietadla.com/lietadla/ruske/su-35.htm.

[6] Sayan Majumdar, 'AFTER BRAHMOS MORE COLLABORATIONS?', INDIA DEFENCE CONSULTANTS, New Delhi, 12 April 2004.

[7] Kopp C., 'Replacing the RAAF F/A-18 Hornet Fighter - Strategic Operational and Technical Issues', Submission to the Minister for Defence, May, 1998. The likely arrival of weapons such as the KS-172 and Kh-31 was predicted six years ago in a submission to Defence, however it appears that this advice was rejected by Defence.

[8] India's defence analysts are already canvassing the option of deploying support jamming aircraft, refer Majumdar S., 'IAF Acquires Mid Air Fuelling CAPABILITY - An IDC Analysis', New Delhi, 13 October 2003, http://www.indiadefence.com/.

[9] Letter from the Office of the Minister for Defence, 12th October, 2001, in relation to a proposal to acquire and refurbish 12 EF-111A aircraft.

[10]Kopp C., 'DEF 224 Bunyip and the Evolved EF-111 Raven', Unsolicited Innovative Proposal to the Department of Defence, May 24, 2002.

[11]Kopp C., 'EF-111A/C: Electronic Combat Capability for the Australian Defence Force', Unsolicited Innovative Proposal to the Department of Defence, January 26, 2002.

[12] The Lockheed-Martin video presentation on the 'New Interdiction Fighter - the JSF' presented by Air Force illustrated the interdiction of battlefield ground targets using the JSF and supporting networking, but did not explore the problem of persistence and the relationship between strike aircraft size, weapons payload and required tanker support.

[13] It is worth observing that the cruise fuel burn of the F-111 at 25,000 to 30,000 ft altitude is similar to that of the F/A-18, yet it carries twice or more the fuel of an F/A-18A, or JSF. Refer Kopp C., 'Regional Denial: An Alternative Deterrent Strategy for the ADF', Submission to the Minister for Defence, June, 2000. This submission pointed out the difficulties which will arise for the RAAF in a rapidly evolving region, due to inadequate aerial refuelling capabilities against regional geography, and the value of the F-111 given its range and persistence.

[14] Kopp, C., 'IS THE JOINT STRIKE FIGHTER RIGHT FOR AUSTRALIA? PART 1 - F-35 V F/A-22', Australian Aviation, Page 41 - 46, Aerospace Publications, Pty Ltd, Canberra, April, 2004, Kopp, C., 'IS THE JOINT STRIKE FIGHTER RIGHT FOR AUSTRALIA? PART 2 - JSF V RISK FACTORS', Australian Aviation, Page 29 - 34, Aerospace Publications, Pty Ltd, Canberra, May, 2004.

[15] Figure 3 in the Air Force submission illustrates the large loss in aggregate fleet persistence resulting from F-111 removal quite dramatically.

[16] T. Michael Moseley, Lt Gen, USAF, 'Operation IRAQI FREEDOM - By The Numbers', Assessment and Analysis Division, United States Air Force, 2003.

[17] The design aims of the 125 kg class Small Diameter Bomb are detailed extensively in Knoedler A., Smith T.K., 'Miniature Munition Technology Demonstration', 39th Flight Test Squadron, Eglin Air Force Base, Technical Briefing Paper, 1996.

[18] At the time, one of the authors of this submission produced all of the weapon loadout diagrams for the AIR 5404 proposal under subcontract to the PSP supporting Defence in this effort.

[19] This was proposed to Defence repeatedly by industry, including a proposal by the authors of this submission. Refer Kopp C., 'The F-111F as an Interim RAAF Multirole Fighter', Unsolicited Innovative Proposal to the Department of Defence, 26th April, 2002, Pages 21 - 27.

[20] T. Michael Moseley, Lt Gen, USAF, 'Operation IRAQI FREEDOM - By The Numbers', Assessment and Analysis Division, United States Air Force, 2003.

[21] The AGM-142 missile has been sold to South Korea, and more recently, India to equip the Su-30MKI, refer Sengupta P.K., 'India Inducts Su-30MKIs Into Service', Tempur, Page 53, October, 2002, http://www.indiadefence.com/.

[22] The Elta EL/M-8222 pod will be carried by the Indian Su-30MKI, refer Sengupta P.K., 'India Inducts Su-30MKIs Into Service', Tempur, Page 53, October, 2002, http://www.indiadefence.com/.

[23] Industry offered an alternative configuration for internal jammer integration, intended to avoid the high cost of waveguide integration, but this received no response from Defence. Refer Kopp C., 'F/RF-111C/G: Leveraging Radar, Pave Tack Upgrades and Optical Fibre Technology in AIR 5416 EWSP', Unsolicited Innovative Proposal to the Department of Defence, December 6, 2002.

[24]Kopp C., 'F/RF-111C/G: Radar Capability Growth Options', Unsolicited Innovative Proposal to the Department of Defence, 2002.

[25]Kopp C., 'F/RF-111C/G: Cockpit Supportability Upgrade', Unsolicited Innovative Proposal to

the Department of Defence, December 6, 2002.

[26]Kopp C., 'AN/AVQ-26 Pave Tack: Technology and Capability Growth Options', Unsolicited Innovative Proposal to the Department of Defence, 2002.

[27]Kopp C., 'AN/AVQ-26 Pave Tack: Imaging Reconnaissance Growth Options', Unsolicited Innovative Proposal to the Department of Defence, 2002.

[28]Kopp C., 'AN/AVQ-26 Pave Tack: Counter Air Capability Growth Options', Unsolicited Innovative Proposal to the Department of Defence, 2002.

[29]Kopp C., 'AN/AVQ-26 Pave Tack: Imaging Reconnaissance Growth Options', Unsolicited Innovative Proposal to the Department of Defence, 2002.

[30]Kopp C., 'F/RF-111C/G: Radar Capability Growth Options', Unsolicited Innovative Proposal to the Department of Defence, 2002.

[31] The F-111 Cold Proof Load Test facility at Amberley is used to validate the structural integrity of F-111 airframes. It is the only such facility for any ADF platform.

[32] Survivability is formally defined as the combined effects of 'susceptibility' or the probability of being engaged by a threat system, and 'vulnerability' or the probability of being fatally damaged as a result of a hostile weapon hit. Susceptibility is more important in this context, given the lethality of modern weapons.

[33] The GBU-39/B Small Diameter Bomb and GBU-38 JDAM-ER glide bombs are cited at 40 nautical miles for a high altitude drop, and the latter at 20 or more nautical miles for a low altitude toss.

[34] Dr Kopp has flown the toss delivery and escape manoeuvre on the RAAF's F-111C simulator at Amberley on multiple occasions, and has also flown level overflight 'autobomb' deliveries on the previous simulator.

[35] Refer Gusev A., NII Priborostroeniya, 'Bortovaya aviatsionnaya radiolokatsionnaya sistyema upravleniya "BARS"', Technical Description, 2003, Moscow, also Hughes Aerospace and Defense Sector, Radar Systems, 'AN/APG-73 Radar System', Technical Description, 11/93, El Segundo, California.

[36] Refer Kopp C., 'The F-111F as an Interim RAAF Multirole Fighter', Unsolicited Innovative Proposal to the Department of Defence, 26th April, 2002, Pages 21 - 27.

[37] The most viable candidate HALE UAV is the RQ-4 Global Hawk, which will be available in time with imaging radar and optical payloads, a high power X-band radar payload, and likely also electronic reconnaissance and communications/network relay payloads.

[38]Kopp C., 'AN/AVQ-26 Pave Tack: Technology and Capability Growth Options', Unsolicited Innovative Proposal to the Department of Defence, 2002.

[39]Kopp C., 'AN/AVQ-26 Pave Tack: Imaging Reconnaissance Growth Options', Unsolicited In-

novative Proposal to the Department of Defence, 2002.

[40]Kopp C., 'F/RF-111C/G: Radar Capability Growth Options', Unsolicited Innovative Proposal to the Department of Defence, 2002.

[41] We assume that Air Force have used the term 'penetrate' in the sense of an aircraft penetrating hostile air defences, which is the accepted use of this term in the literature.

[42] Refer Kopp C., 'JSF = Thunderchief II?', Australian Aviation, TBD.

[43] The pattern observed in the late Cold War repeats the pattern observed in World War II - by the end of the conflict the most successful fighters were larger and heavier than their opponents. Case studies are the RAF Tempest, USAAF P-38L, USN F6F, Luftwaffe Me-262 and JNIAF N1K1. Small fighters were mostly relegated to supporting roles.

[44] Refer Robert Wall, 'STRETCHED-OUT - F-35 In-Service Dates Slide', Aviation Week & Space Technology, 06/13/2004.

[45] Refer Proof Committee Hansard Transcript - JSCFADT Hearing 04 June 2004,

Page 3: ". . . . We have invested $300 million in getting ourselves involved in the system demonstration and development phase of the Joint Strike Fighter. We have not made a decision at this stage to buy the aircraft. That decision comes later, after we have done a lot more work in 2006. As John Harvey will tell you, we have 30 scientists currently working on that project in the DSTO and we are also heavily involved in developing our concepts for that aircraft in Air Force."

Page 16: "I have just come back from a series of meetings in the US. There are the three variants of the aircraft, as we said. The undersecretary of acquisition technology and logistics, Mr Mike Wynne, was at the last meeting I went to. The atmosphere in all three services is very positive. They all need the aircraft. It has to go ahead. The CTOL aircraft is much less sensitive to weight and that is pressing ahead quite well. The carrier variant has an approach speed and they are working through weight issues on that. The STOVL is much more sensitive to weight, but they have a way forward with that as well. It is very challenging. In terms of dates, the first aircraft will fly in mid-2006. The first aircraft will be available for USAF service in about 2009 or 2010. It is a big, challenging project, but they need it and it has to work. They are pressing ahead."

[46] Based on EADS, Boeing and General Dynamics data. We have budgeted one spare tanker, and 4 escort fighters to cover the tankers and AEW&C aircraft, providing for a 2:1 ratio between strikers and escorts.

[47] Refer Fulghum D.A., 'Cruise Missile Battle', Aviation Week & Space Technology, May 31, 2004, Page 50.

[48] Kopp C, 'A Strategic Tanker/Transport Force for the ADF', RAAF Air Power Studies Centre, Working Paper 82, March 2000.

[49]Goon P.A., Email Letter to the Office of the Minister for Defence, "Retention of Capability Options as a Risk Mitigation Strategy", 25 February 2004, summarising results of 1999/2000 risk analysis into 'turning the tap off' on the F-111.

[50] Goon, P., "A Farewell to Arms Revisited", 04 January 2004, Extracts from Defence Annual Reports 1998 to 2003 - Financial Analysis (RAAF).

[51] This lack of precision in language is not in keeping with Defence directives eg. Chapter 5 of the Capability Systems Life Cycle Management Manual 2002.

3 Annex B

This annex contains materials supporting the analysis in this submission, extracted from the Evolved F-111 documents.

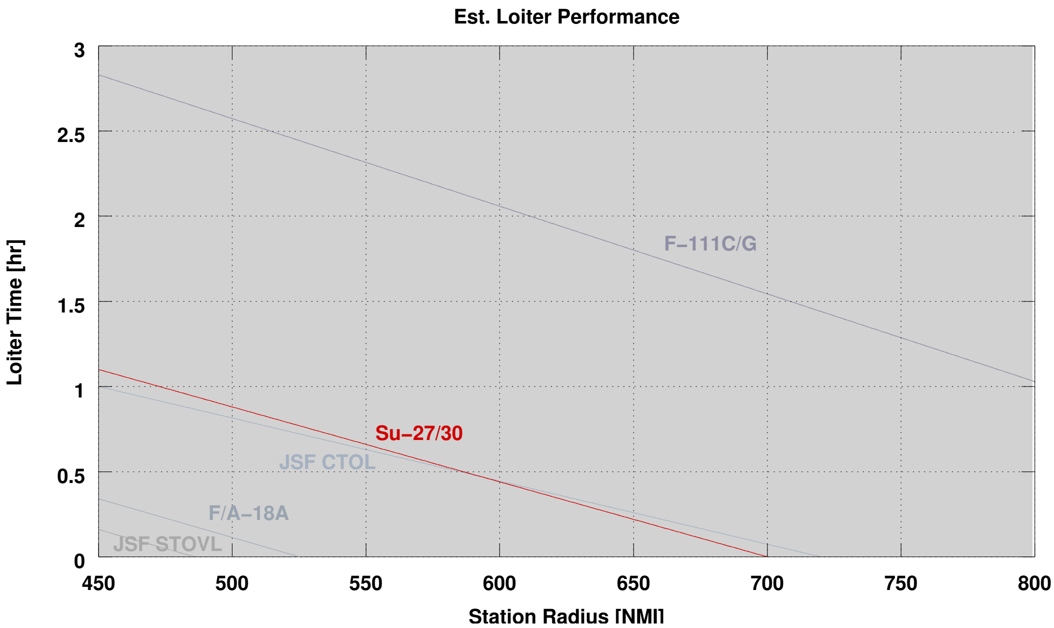


Figure 23: *Comparison of F-111 against JSF variants (C. Kopp/USAF).*

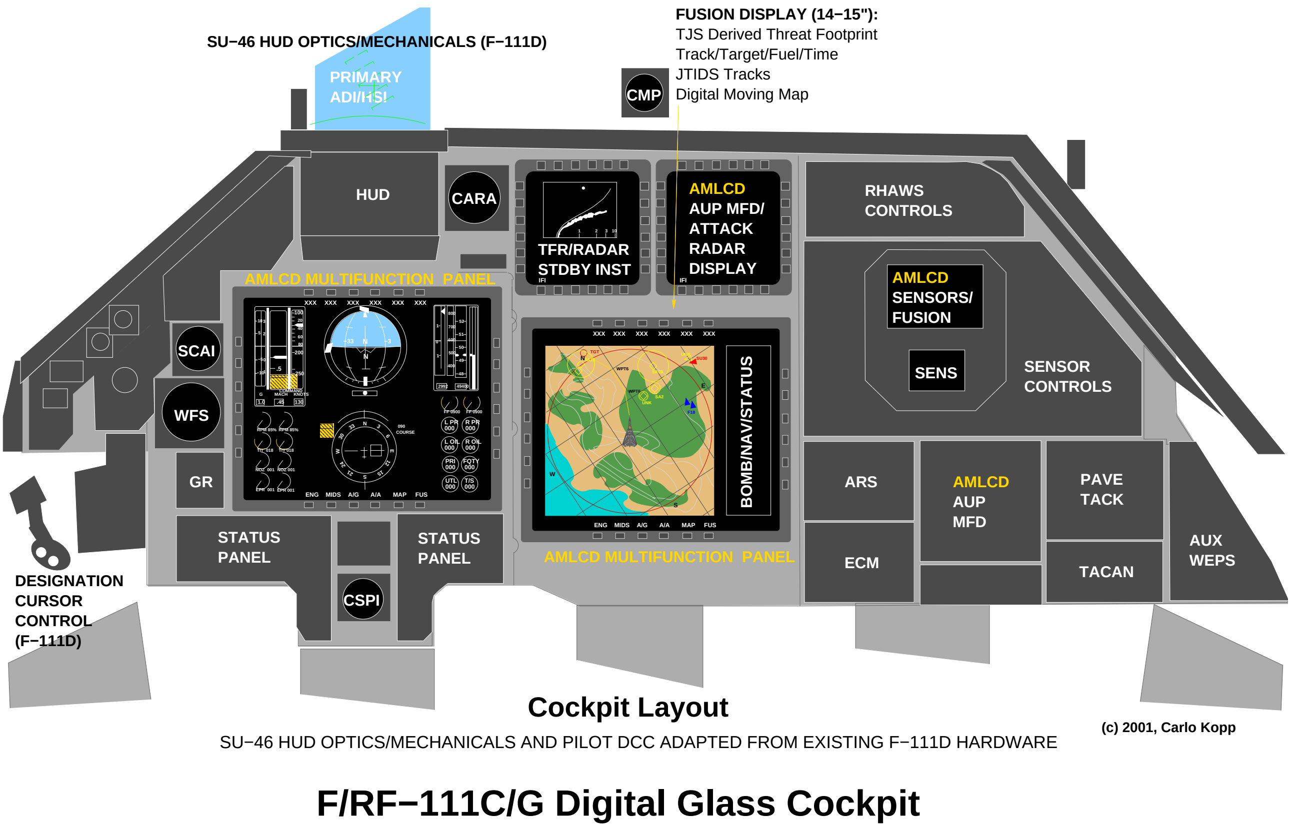


Figure 24: *Significant support cost savings could be effected by retrofitting a 'glass' cockpit to the F-111, emulating US and EU practices in older aircraft. A range of proposals were put to Defence by industry for such an upgrade (C. Kopp).*

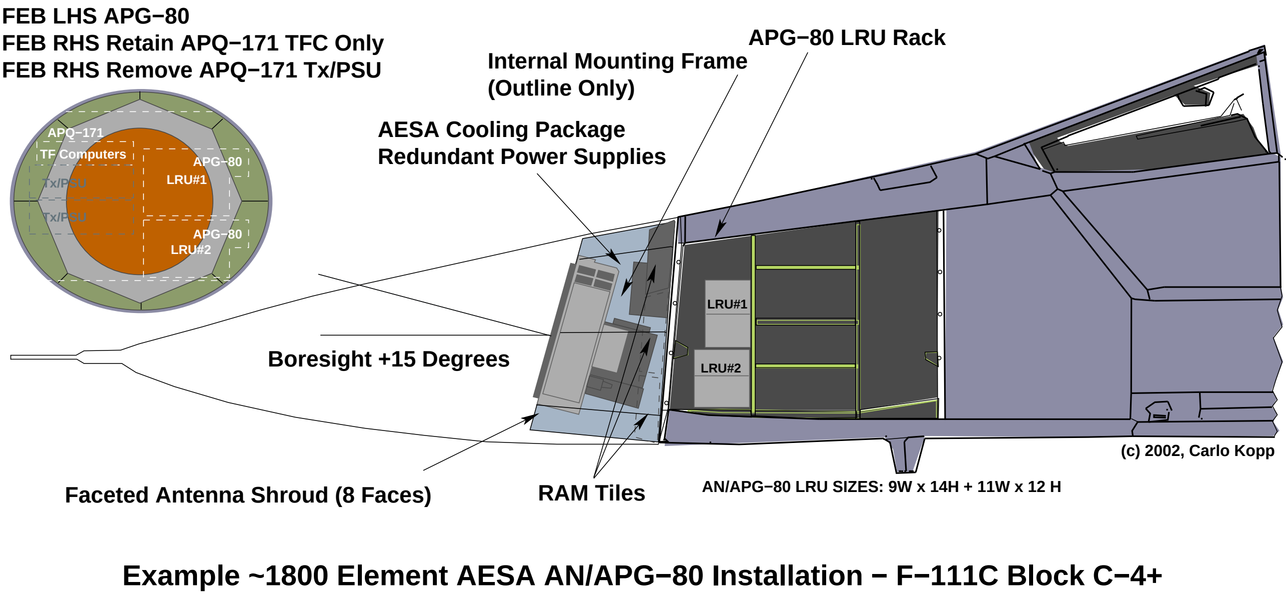


Figure 25: *The AIR 5426 funding base could support a retrofit with a modern active array radar, reducing support costs, improving strike capability and providing a Beyond Visual Range missile capability. The diagram depicts an APG-80 installation, using existing APQ-171 hardware to minimise the integration cost of the terrain following capability (C. Kopp).*

4 Annex C

This annex contains published materials supporting the analysis in this submission.

1. Kopp, C., 'Network Centric Warfare', Defence Today, Vol 2 No 3, Page 28 - 34, Strike Publications, Pty Ltd, Amberley, August, 2003.
2. Kopp, C., 'NCW - buzzwords, bytes and the battlespace', Defence Today, Vol 3 No 1, Page 20 - 31, Strike Publications, Pty Ltd, Amberley, March, 2004.
3. Kopp, C., 'Wedgetail - Australia's Pocket AWACS', Defence Today, Vol 3 No 2, Strike Publications, Pty Ltd, Amberley, June, 2004.
4. Kopp, C., 'IS THE JOINT STRIKE FIGHTER RIGHT FOR AUSTRALIA? PART 1 - F-35 V F/A-22', Australian Aviation, Page 41 - 46, Aerospace Publications, Pty Ltd, Canberra, April, 2004.
5. Kopp, C., 'IS THE JOINT STRIKE FIGHTER RIGHT FOR AUSTRALIA? PART 2 - JSF V RISK FACTORS', Australian Aviation, Page 29 - 34, Aerospace Publications, Pty Ltd, Canberra, May, 2004.

Network Centric Warfare

by Dr Carlo Kopp

The stunning success of the Operation Iraqi Freedom military campaign will be seen by historians as the first full scale demonstration of the power of information age warfighting techniques. Accordingly, 'Network Centric Warfare' (NCW), often termed 'Network Enabled Warfare' (NEW) has become the newest buzz phrase to achieve prominence in Canberra Defence circles.

Network Centric Warfare is much more than that and, not surprisingly, is very demanding technologically. In terms of operational technique the power it offers comes at a price – and that is something that should not be ignored by Defence professionals.

The trauma observed a decade ago in the civilian information revolution is now evident in the transition to NCW in the military domain. The level of trauma often has as much to do with grappling with complex technology, as it is in changing the thinking processes of a great many people.

Over the coming decade we will see the world divide into nations that employ NCW techniques, and others that do not, be it for reasons of ideology or operational/ technological incapacity. It is clearly in Australia's interests that the ADF fall into the former rather than the latter category.

A commonly held view is that NCW is somehow uniquely a feature of modern air warfare or modern naval warfare. The opposite is arguably true since NCW is a combination of technology, technique and warfighting philosophy, which if anything has the potential to bring about levels of cross-Service force integration that were unthinkable a decade ago. NCW is just as valuable to the digger on the ground, as to the sailor onboard ship or the pilot in a fighter aircraft.

NCW - Dispersing the Fog of War

In its simplest terms NCW is the military equivalent of the information revolution, which transformed the business of industry, government, education and entertainment during the previous decade. The first phase of the information revolution was in 'digitisation' or the placement of computers into large scale use for processing information; the second phase was 'networking', which amounts to connecting these computers together. Within the business/government/education/ entertainment domains the information revolution has produced enormous gains in productivity, which grew as global networks expanded and increasing numbers of services became networked.

The experience observed in the civilian world was that this process was neither smooth nor painless, and many organisations came to grief through their inability to adapt. The term 'digital divide' is today popular as a description of the enormous gap between digitised/ networked developed nations, and the developing world devoid of the infrastructure and skills required to make this transition.

The trauma observed a decade ago in the civilian information revolution is now evident in the transition to NCW in the military domain. The level of trauma often has as much to do with grappling with complex technology, as it is in changing the thinking processes of a great many people. It is interesting to hear those in the Defence community grumble about problems heard from industry stalwarts a decade ago.

To understand NCW we need to explore it from several perspectives. These can be summarised as:

1. The strategic and philosophical dimension.
2. The operational dimension.
3. The technological dimension.

All three perspectives are reflections of a single broader reality and focusing on any at the expense of the others is to diminish the whole.

From a strategic and philosophical perspective NCW is about the exploitation of information to compress targeting cycles in combat, and in turn to accelerate the operational tempo to the detriment of an enemy.

Virtually all warfighting is centred in individual or formation engagements, and can be characterised by a construct called the Observation-Orientation-Decision-Action (OODA) loop, devised two decades ago by Colonel John Boyd in the US. In any engagement a commander must observe the situation to gather information, that information must by analysed and understood so that the commander's situation can be understood, thereafter resulting in a decision to act in an advantageous manner, ultimately resulting in action.

Whether we are observing a soldier in a firefight, a fighter pilot in a dogfight, a frigate captain engaging an enemy warship or a bomber package commander penetrating enemy airspace, their activity patterns follow the OODA loop model. It is an inevitable part of reality and has been so since the first tribal wars of 25,000 years ago. Sadly, its proper understanding had to wait until the 1970s.

What confers a key advantage in engagements is the ability to stay ahead of an opponent and dictate the tempo of the engagement - to maintain the initiative and keep an opponent off balance. In effect, the attacker forces his opponent into a reactive posture and denies the opponent any opportunity to drive the engagement to an advantage. The player with the faster OODA loop, all else being equal, will defeat the opponent with the slower OODA loop by blocking or pre-empting any move the opponent with the slower OODA loop attempts to make.

The mechanics of operational tempo and OODA loops apply at all levels of conflict, from individual engagements up to corps or force level engagements.

The four components of the OODA loop can be split into three which are associated with processing information, and one associated with movement and the application of firepower. Observation-Orientation-Decision are 'information centric' while Action is 'kinematic' or centred in movement, position and firepower.

If we aim to accelerate our OODA loops to achieve higher operational tempo than an enemy, we have to accelerate all four components of the loop. Much of 20th Century warfighting technique and technology dealt with accelerating the 'kinetic' portion of the OODA loop. Mobility, precision and firepower increases were the result of this evolution. The steam powered navies and horse drawn armies of a century ago have been supplanted by mechanised and air mobile land forces, turbine or nuclear powered navies, followed by fleets of supersonic fighters and bombers.

There are practical limits as to how far we can push the 'kinetic' dimension of the OODA loop because more destructive weapons produce collateral damage, and faster platforms and weapons incur ever increasing costs. Accordingly, we have seen a slow down in this domain since the 1960s. Many weapons and platforms widely used today were designed in the 1950s and may remain in use for decades to come.

The 'information centric' dimension of the OODA is the target of NCW and remains the yet to be exploited new frontier in warfighting technique.

Observation-Orientation-Decision are all about gathering information, distributing information, analysing information, understanding information and deciding how to act upon this information. The faster we can gather, distribute, analyse and understand information, the faster and arguably the better we can decide how and when to act in combat.

What digitisation and networking offer is a technological means of accelerating the Observation-Orientation-Decision components of the OODA loop. This is a philosophical and strategic dimension of this argument: exploiting information technology to accelerate operational tempo in a manner opponents cannot match.

Networking of information is central to the effectiveness of this philosophy. Its aim lies in providing channels of rapid and reliable communication up and down the chain of command, and between commanders and sources of information - the latter being as much machine sensors as human observers.

Whether the source of vital intelligence is a Special Forces team in a hide outside an enemy base, a satellite in orbit staring down with a 2-foot aperture thermal imaging telescope, or a fighter imaging an area with a 6-inch resolution synthetic aperture radar, that raw data is of no use until it can be processed and understood by a commander who needs to act upon it.

What digitised sensors and networks provide is a means of vastly accelerating the speed with which such information can be made available to support a decision. The ultimate aim in this game is 'realtime' access - the ability for a commander to observe from a distance an opponent's deployment and activities.

There is another dimension to networking. Transmitting information up and down the chain of command, and transmitting information from sensors to decision-makers and, in turn, to shooters is the 'conventional' aspect of this game. It amounts to accelerating the time proven techniques of command and control, and intelligence. The other dimension of the NCW paradigm is the ability to transmit information laterally, and to rapidly concentrate information from many sources.

The latter can be important in its own right, since it provides a means of discerning deeper patterns in an opponent's behaviour, and permits sharing of information at lower operational levels. It is often touted as the essence of NCW, but in reality is a facet of a more complicated problem.

Networking of information is central to the effectiveness of this philosophy. Its aim lies in providing channels of rapid and reliable communication up and down the chain of command, and between commanders and sources of information - the latter being as much machine sensors as human observers.

The Operational Dimension

Arguments centred in warfighting philosophy and strategy are vitally important, especially at strategic and force levels of understanding and conducting wars, but they capture only part of the bigger issue. At a basic operational level NCW yields its own benefits and challenges.

At the level of individual unit or combatant engagements, a key issue is situational awareness. This is true for a platoon about to assault an opponent's urban position, or a warship captain about to shoot a Harpoon into an opposing warship, or a fighter pilot about to pickle a bomb or squeeze off a missile.

Understanding the immediate situation is as important as understanding the broader situation. If the urban position is covered by remote and hidden sniper and machine gun positions, an otherwise optimal assault could become a costly disaster. If the enemy warship is baiting the warship commander to set him up for an air attack, or shore based cruise missile attack, positioning for a shot could lead to different and even costlier disaster. If the fighter pilot cannot see that the enemy stronghold he is about to bomb is filled with human shields, a different but no less disastrous problem could follow.

At the immediate operations level every commander is faced with the reality that an immediate situation fits into some context. Prosecuting an attack directed by his commander successfully requires an understanding of the surrounding environment. Historically that understanding was gained through a combination of intelligence provided by command, and immediate observation of the tactical situation.

The most successful warfighting forces have historically been those that have followed the 'directive control' model, where a front-line commander is given directives which set out aims or objectives, and is given maximum autonomy in planning and executing the operation. Success in execution is then a result as much of the available force at hand, as it is of the commander's understanding of the situation and his ability to exploit it to an advantage. The better the understanding of the broader environment, the greater the opportunities for a talented commander to take the initiative and gain possibly a much greater advantage than set out in his initial command directive. A good case study would be World War II Blitzkrieg advances by the Wehrmacht, the originators of the idea of directive control, or attacks by Allied pilots on high value targets of opportunity.

To successfully absorb NCW into a defence force, it is vital that personnel have appropriate practical skills, but also a proper understanding of the limitations of the machinery. There is no substitute for good human judgement, as yet, and making best use of a powerful NCW apparatus requires exactly that.

What NCW provides is a means of improving the autonomy of commanders in the field. A land force element commander can make much better decisions if he knows the exact disposition of the opposing force, and the disposition of reserves and supporting enemy assets. A naval commander can benefit immeasurably from knowing the whereabouts of enemy combatants within a 300 mile radius. A fighter pilot who knows the exact placement of enemy SAM and AAA batteries has many more options than a pilot flying in blind.

The ability to gather information over large areas or in focal areas of interest, digitally process it to find opposing force elements, and rapidly distribute it to front-line warfighters provides enormous advantages at every level of combat. If an infantry squad commander knows exactly which roofs are occupied by snipers his odds of success go up very significantly, and so on.

There is a darker side to the NCW paradigm (providing high speed digital communications to every front-line shooter) which enables a level of micro-management from headquarters that is unprecedented historically. The temptation for general officers in headquarters to meddle in distant engagements is considerable.

This is a reflection of the other side of the NCW operational equation - the human element. Humans and computers do not always mix well. Frequently humans will either reject the computer, or oppositely treat it as an infallible artifact. Both extremes reflect the reality that information processing and transmitting machines are not other humans, and the machines communicate information in very different ways.

To successfully absorb NCW into a defence force, it is vital that personnel have appropriate practical skills, but also a proper understanding of the limitations of the machinery. There is no substitute for good human judgement, as yet, and making best use of a powerful NCW apparatus requires exactly that. The combination of sensors, computers and networking equipment that makes up the NCW system is ultimately a means to an end, not an end in itself. A commander must still have the ability to rationally interpret the data provided, and to identify opportunities and to creatively exploit them to an advantage.

NCW inherently offers at an operational level the ability to closely integrate air, land and sea forces. Surface bound forces, be they naval or ground forces, are inherently limited to their visual horizon in observing the surrounding environment, and thus see only a small portion of the larger battlespace. Air forces do not suffer this limitation. Their horizon at typical cruise altitudes is over 200 nautical miles away but they are limited by the resolution and capabilities of their onboard sensors.

The quid pro quo is inherent here: air power can provide tremendous wide area situational awareness to surface bound forces, and surface bound forces can provide air power with a detailed picture often impossible to get from 30,000 feet.

NCW provides a mechanism via which such valuable tactical information can be transmitted in either direction to gain an immediate advantage. An SAS team on the ground is apt to always perform better bomb damage assessment than a satellite in orbit. While air power holds a decisive advantage in the game of delivering heavyweight firepower quickly over large distances, and gathering large volumes of realtime information over large areas, it does not have the surgical effect of a sniper's bullet or the ability to climb into a bunker to determine if its occupants have indeed been killed by a strike.

NCW is often portrayed as being primarily of benefit to air warfare and naval warfare. The advantages to be gained by land forces are no less important. Real-time intelligence over wide and local areas is always valuable, and the ability to rapidly transmit aimpoint coordinates for a precision air attack is often the difference between winning and losing.

It is worth noting the numerous reports from Operation Iraqi Freedom indicating that US Marine Corps units accustomed to operating with organic close air support were much better able to integrate in an NCW environment with US Air Force, US Navy, US Marine Corps, RAAF and RAF fighters than were US Army units. This is a direct consequence of a Service culture which aims to break down distinctions between specialisations and a training regime centred in closely integrated all-arms operations. The lesson is that even with a superb NCW system in place, a force which is myopically centred in its own view of reality will not be able to fully exploit the opportunities offered by the technology.

The Technological Dimension

The technology supporting NCW is inherently complex, but not significantly more so than the technology used to digitise and network the civilian world.

A basic prerequisite for an NCW capability is the digitisation of combat platforms. A fighter plane, tank or warship with a digital weapon system can be seamlessly integrated in an NCW environment by providing digital wireless connections to other platforms. Without the digital weapon system, and its internal computers, NCW is not implementable. The growing gap between the US military and the EU military largely reflects the Europeans' reluctance to heavily invest in digitising their combat platforms.

Provision of digital wireless connectivity between combat platforms is a major technical challenge which cannot be understated. While civilian networking of computers can largely rely on cabled links, be they copper or optical fibres with wireless connectivity as an adjunct, in a military environment centred in moving platforms and field deployed basing, wireless connectivity is the central means of carrying information.

The problems faced in providing military networking are generally well understood, but often push the boundaries of available technology.

Key issues can be summarised thus:

1. Security of transmission is vital, since everybody does their best to eavesdrop. Therefore, digital links have to be difficult to eavesdrop and robustly encrypted to defeat any eavesdropping which might succeed. Even if a signal cannot be successfully decrypted, its detection provides an opponent with valuable information on the presence, position and often activity of the platform or unit in question.

2. Robustness of transmission is no less critical in the face of transmission impairments such as solar flares, bad weather and hostile jamming. If a signal cannot penetrate a rainshower or is blotted out by an opponent's barrage jammer, the link is broken and the NCW model also breaks down.

3. Transmission capacity is just as important, especially where digitised imagery must be transmitted. If a 10 Megabyte recce image must be sent, or a 2 Megabit/sec digitised video feed observed, a 9600 bit/sec channel will be nearly useless. A popular misconception is that 'digital data compression' solves this problem - the reality of Shannon's communication theory is very much at odds with this popular fantasy. Robustness against jamming and the overheads of encryption both work at the expense of transmission channel capacity for a given radio communications link.

4. Message and signal routing is an unavoidable evil, insofar as platforms must be able to specifically address and access other platforms or systems in an NCW environment. Just as email on a civilian network must have an address, so must a military messaging scheme.

5. Signal format and communications protocol compatibility is essential to ensure that dissimilar platforms and systems can communicate in an NCW environment. This problem extends not only to the use of disparate signal modulations and digital protocols, but also to the use of partially incompatible implementations of what is ostensibly the same signal modulation or communications protocol. The mutual incompatibility headaches we see in commercial computing are often more traumatic in the challenging military environment.

At present, nearly all military datalinks used in NCW operate at speeds that would be considered intolerable in the civilian/commercial world, reflecting the realities of wireless communications. Moreover, the military world lives with a veritable Tower of Babel in both signal modulations, operating frequencies and digital communications protocols, and variations of nominally standard protocols.

NCW is often portrayed as being primarily of benefit to air warfare and naval warfare. The advantages to be gained by land forces are no less important. Real-time intelligence over wide and local areas is always valuable, and the ability to rapidly transmit aimpoint coordinates for a precision air attack is often the difference between winning and losing.

LWC

Wherein lies the biggest challenge in adopting NCW techniques? Major challenges will lie in formulating strategic doctrine and policy, in developing operational techniques and skills, and in understanding and integrating the technology into existing and future platforms and systems.

To place this in context, Western armed forces currently deploy systems using a wide range of current and legacy signal formats and protocols, examples being:

1. Link 1 at 1200/2400 bits per second used for air defence systems, devised in the 1950s.
2. TADIL A/Link 11/11B at 1364 bits per second used for naval links and ground based SAM systems, using original CLEW DQPSK modulation, or newer FTBCB convolutional coding at 1800 bits per second. It is 1960s technology.
3. TADIL C/Link 4 at 5,000 bits per second in the UHF band, used for naval aviation, AEW&C to fighter links, and fighter to fighter links on the F-14 series. It is also 1960s technology.
4. Link 14 used for HF transmission between naval combatants at low data rates.
5. TADIL J / MIDS/JTIDS/Link 16 which is a jam resistant L-band time division spread spectrum system based on 1970s technology. While its time slot model permits some allocation of capacity, in practical terms it is limited to kilobits/sec data rates, over distances of about 250 nautical miles. JTIDS is multi-platform and multi-service and widely used for transmitting tactical position data, directives, advisories, and for defacto Identification Friend Foe. Its limitation is that it is ill suited to sending reconnaissance imagery and inherently tied to master stations which generate its timebase - reflecting its origins of three decades ago. Satellite link and higher data rate derivatives exist but retain the basic limitations of its time division technique.
6. CDL/TCDL/HIDL/ABIT which are US high speed datalinks design primarily for satellite and UAV transmission of imagery. CDL family links are typically assymetric, using a 200 kilobit/s uplink for control and management, and a 10.71, 45, 137 or 234 Megabit/s high speed uplink, specialised for the control of satellite/UAVs and receipt of gathered data. ABIT is a development of CDL operating at 548 Megabits/s with low probability of intercept capabilities.
7. Improved Data Modem (IDM) is used over Have Quick II spread spectrum radios to provide low data rate but secure transmission of targeting coordinates and imagery. It has been used widely for transmission of targeting data to F-15E/F-16C strike fighters and F-16CJ Wild Weasels. It is essentially an analogue to commercial voiceband modems.
8. Army Tactical Data Link 1 - ATDL 1 used for Hawk and Patriot SAM batteries.
9. PATRIOT Digital Information Link - PADIL used by Patriot SAM batteries.
10. Tactical Information Broadcast System - TIBS used for theatre missile defence systems.
11. PLRS/EPLRS/SADL are a family of US Army/Marine Corps datalinks used for tracking ground force units, and providing defacto Identification Friend Foe of ground units. EPRLs is also used for data transmission between ground units.
12. TCP/IP (Internet) protocol implementations running over other channels, to provide connectivity between platforms and remote ground facilities.

This veritable menagerie of datalink modulations/protocols is by no means exhaustive, but reflects the realities observed in the computer industry in the decades predating the Internet. New protocols like the Joint Tactical Radio System (JTRS) are in part intended to incorporate mechanisms for translating such legacy protocols into formats that can be sent over a common channel.

As yet there has been little effort to capitalise on the new technology of ‘ad hoc’ network protocols, designed for self organising networks of mobile platforms. The DARPA GLOMO program in the late 1980s saw considerable seed money invested, but did not yield any publicised dramatic breakthroughs. Ad hoc networking remains a yet to be fully explored frontier in the networking domain, one which is apt to provide a decisive technology breakthrough for NCW.

Conclusions

The ADF must clearly grapple with the emerging NCW paradigm. The payoffs in mastering it will be invaluable at operational and strategic levels, and the penalties in following many EU nations will be like military irrelevance over the longer term. With Australia’s strong intellectual base in digital communications and networking, it has the potential to be very successful in NCW, providing that the problem is tackled rationally rather than in fad-driven fashion. The Department of Defence should not be shy about enlisting the aid of industry and academia in developing its NCW paradigm.

Wherein lies the biggest challenge in adopting NCW techniques? Major challenges will lie in formulating strategic doctrine and policy, in developing operational techniques and skills, and in understanding and integrating the technology into existing and future platforms and systems. NCW is by its nature intellectually demanding, and will require more than the incantation of buzz words to implement.

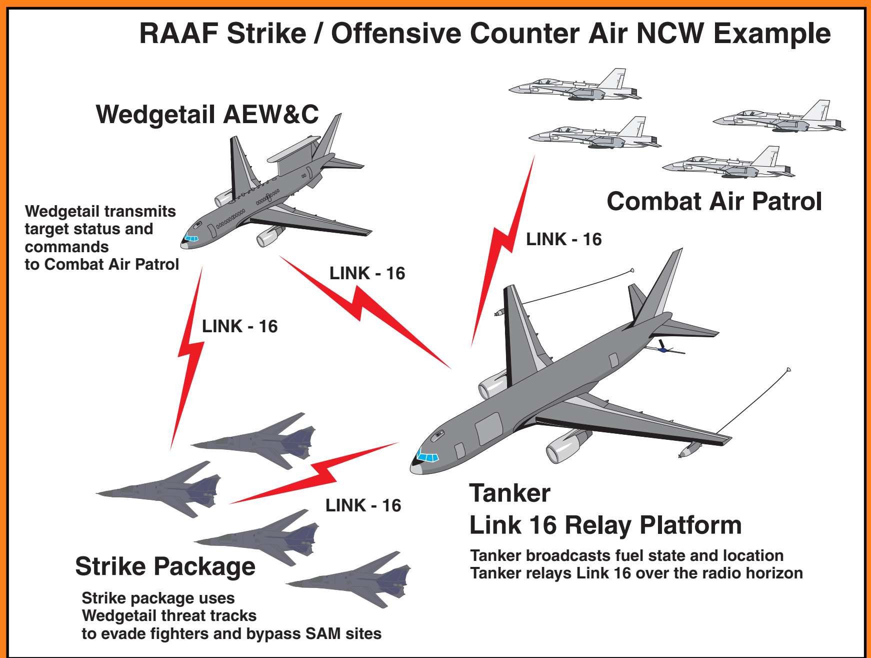
NCW

Network Centric Warfare

NCW

buzzwords, bytes and the battlespace

Dr Carlo Kopp



A 'Wedgetail' AEW&C aircraft relays ISR data and commands to a tanker and multiple fighter CAPs. The RAF first introduced the use of JTIDS on tankers, providing both a relay capability to extend the coverage footprint, but also permitting tankers to advertise their fuel status information to fighters. The model has now been adopted by the US Air Force in the 'SMART tanker' scheme where KC-135R and KC-767 tankers will be equipped with palletised JTIDS and other communications relay nodes. Benefits seen in Defensive Counter Air translate directly into Offensive Counter Air and Strike operations. Strike aircraft equipped with JTIDS/Link-16 can be provided with a continuously updated wide area picture of air defence threats, particularly fighters and hostile radar emitters. This facilitates evasion of these threats, improving survivability.

> "NCW provides a mechanism to accelerate targeting and engagement cycles, but without the Intelligence Surveillance and Reconnaissance assets plus persistent firepower delivery assets to exploit the engagement cycle improvements its utility is of dubious value in itself."
>
> *Dr Carlo Kopp*

NCW in Air Defence Operations

Air warfare is the first area in which we have seen the widespread use of early NCW techniques, both in air defence roles and in strike warfare. The results achieved to date, even with relatively rudimentary capabilities, have been the impetus behind the drive to introduce NCW capabilities on more platforms and also to develop more advanced technology for this role.

Air defence operations were the first to see broader introduction of networked data capabilities, when the Joint Tactical Information Distribution System (JTIDS)/Link-16 time division multiplex system was adopted. Until then interceptors were mostly controlled by voice, but by the 1970s this became unusable for the expected air battles over the NATO-WarPac FEBA in Central Europe due to the intense jamming environment and sheer density of traffic. With the expectation that both sides would put hundreds of fighters up concurrently, voice control of interceptors would be untenable.

The jam resistant JTIDS and its Link 16 messaging format thus became the first 'networking' scheme adopted for air defence operations, as earlier systems were essentially point-to-point uplinks allowing ground control to vector interceptors. JTIDS entered development in the early 1980s.

An AWACS would typically control a Link 16 network, with time slots in the messaging scheme allocated to flights or individual aircraft equipped with onboard terminals. A first generation Link-16 installation would use a dedicated cockpit display which would graphically present the message broadcast by either the AWACS or a ground station. Messages could vary from text strings to Plan Position Indicator (PPI) diagrams showing the locations and states of friendly and hostile fighter aircraft. Many JTIDS terminals fitted to fighters are 'receive only', enabling fighters to listen passively for messages but not send any.

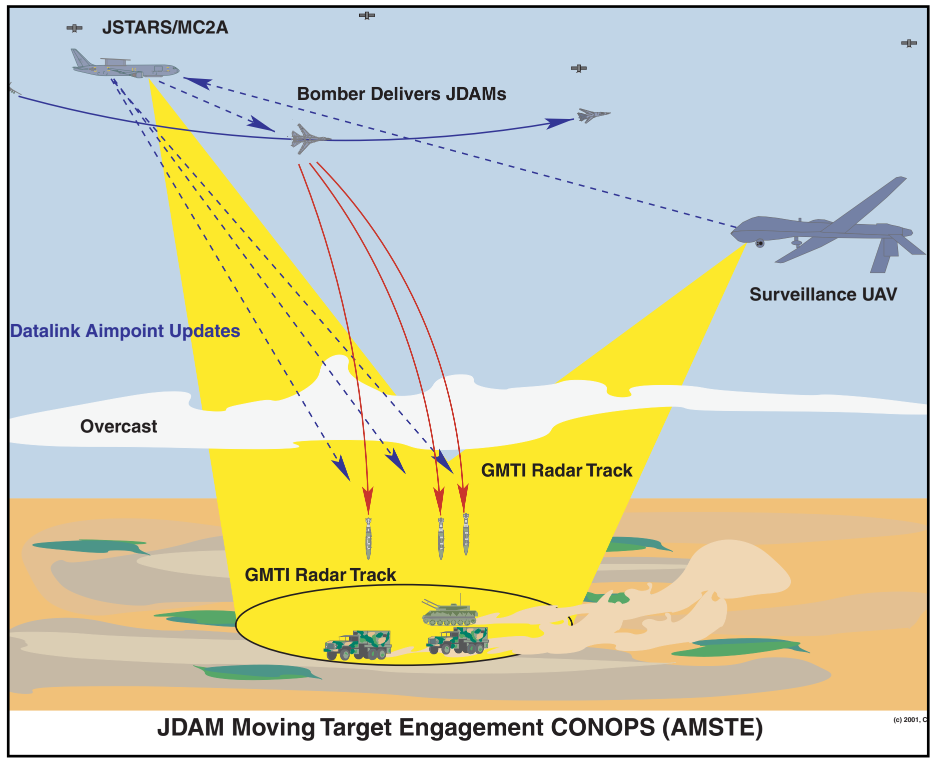
The transition from voice control to JTIDS has produced notable advances in tactics: fighters can operate in radio and radar silence listening for AWACS commands via JTIDS or monitoring the tactical situation via JTIDS. Radars light up only once the fighter is ready to shoot to provide a missile solution and midcourse guidance updates to the missile once it is launched. Many anecdotal tales exist describing exercises in which fighters and AWACS equipped with JTIDS wiped out their exercise opponents using fighters and AWACS not yet fitted with JTIDS.

First generation JTIDS systems present an important advance over voice based communications in terms of jam resistance, unambiguous and complete message transmission, and speed of transmission.

Above: Artist impression of a RAAF AEW&C 'Wedgetail' aircraft destined to play a pivotal role in any future ADF networked force.

Right: Naval ships would not only receive situational awareness information and tactical data from other sources but could also collect, process and disseminate such data across the battlespace. Ships could also provide command & control and other higher level battlespace management functions.

Below: The US Air Force envisages ultimately an NCW environment with digital connectivity through the whole ISR and striking chain, down to the smart weapon. The recent AMSTE trials saw an F-16C drop modified JDAM bombs fitted with JTIDS receivers, against moving ground vehicles. The bombs were guided to impact using JTIDS target position updates transmitted by a remote JSTARS, in effect relegating the F-16 to a UCAV-like 'dumb' delivery role.



One of the current roles envisaged for the F/A-22A is the use of its low probability of intercept (LPI) APG-77 radar and ESM receiver package as a 'horizon extender' for the AWACS, relaying the gathered data over JTIDS. The F/A-22A also carries a covert fighter-to-fighter datalink, but will also now acquire a JTIDS transmit capability to support this role.

NCW

However, many installations are not tightly integrated with the aircraft's weapon system. A pilot or weapons officer must read the JTIDS display, interpret it, and then fly the intercept based on the interpretation of the display. Even if the aircrews are free of error in processing the information, they will have to commit concentration and seconds of time to reading the display.

A second generation JTIDS installation is tightly integrated with the aircraft's mission computers running the navigation and display control software. This permits de facto data fusion by presenting the JTIDS information concurrently with information produced by onboard systems such as radar or radar warning equipment – all on the same display. A tactical situation display layout presented on a cockpit display might overlay a moving map, radar tracks of targets and RWR tracks of hostile emitters, and JTIDS data such as messages and PPI presentations of AWACS tracks with friendly and hostile aircraft positions.

The most recent fighters, such as the US Air Force F/A-22A and F-35 Joint Strike Fighter (JSF) will have such capabilities embedded.

While passive 'receive only' JTIDS terminals provide valuable capabilities in permitting rapid and wide area distribution of tactical situation data to fighters they are limited in terms of exploiting data gathered by fighters. JTIDS terminals with an active transmit capability provide the ability to relay target tracks produced by the fighter back to the AWACS.

One of the current roles envisaged for the F/A-22A is the use of its low probability of intercept (LPI) APG-77 radar and ESM receiver package as a 'horizon extender' for the AWACS, relaying the gathered data over JTIDS. With a 250+ NMI ESM horizon and 200 NMI radar detection range against larger targets, a small number of F/A-22A Combat Air Patrols can largely expand the footprint surveilled by an AWACS. The JSF has nominally such a capability, but is much less effective due to less capable sensors compared to the F/A-22A.

Left: Cockpit multi-function displays in the Gripen fighter cockpit display real-time targeting and situational awareness information to the pilot from which to make decisions about offensive and defensive counter air tactics and weapons employment, or the conduct of attacks against ground targets.

Once fighters are equipped with active transmit capability in JTIDS, the terminal can then double up as a jam resistant and hard-to-intercept supplement or replacement for military secondary radar or IFF equipment. While an IFF code could be spoofed by an opponent, the encryption facilities in JTIDS make it much harder to break into.

In practical terms, widespread introduction of integrated and active transmit capable JTIDS/Link-16 terminal capabilities in fighter fleets will produce a major improvement in air defence capabilities, as the wide area situation picture can be distributed accurately and quickly to all aircraft in an operating area. This will permit significantly greater autonomy by flight commanders or individual Combat Air Patrols.

Other capabilities also accrue. One is that air refueling tankers can be equipped with active transmit capable JTIDS terminals and can broadcast securely their orbit locations and available fuel state. A fighter CAP can quickly determine which tanker in its neighbourhood is the best prospect for a top up. The RAF were the first to introduce this model.

Although a scarce commodity in Australia, tankers are ubiquitous in the real world and this led to RAF proposals during the 1990s to use them as JTIDS relays – effectively 'horizon extenders' for the JTIDS footprint of the nearest AWACS. More recently, the US Air Force has opted to emulate this model with the 'Smart Tanker' scheme using the ROBE equipment package, which is more ambitious in its aims compared to the RAF scheme.

The paradigm produced by a JTIDS net is also valuable for strike aircraft. If equipped even with a basic 'receive only' JTIDS terminal, they can use the situational picture to evade opposing fighters.

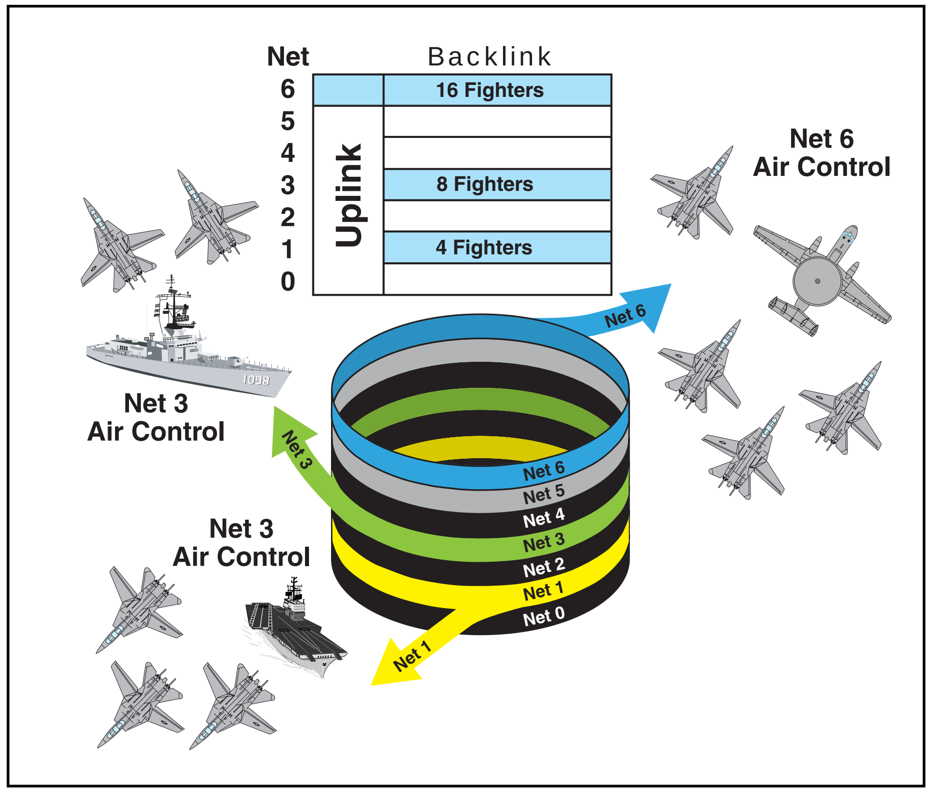
With a 'Gods eye' view of friendly and enemy fighter positions, the safest ingress and egress routes can be rapidly chosen.

The downside of JTIDS operations has proven to be a propensity to saturate individual JTIDS nets with traffic. While this is often a result of poor planning, it also reflects the reality that a significant depth of training is required to support JTIDS operations.

The success of JTIDS has also motivated the adoption of dedicated fighter-to-fighter datalinks - also termed "inter-flight" and "intra-flight" datalinks. While this was first used on the F-14A based on a TADIL C UHF link, the most recent incarnations are much more sophisticated. The F/A-22A uses a Low Probability of Intercept digital datalink to permit F/A-22As to share situation data; target and threat emitter tracks from one aircraft can be relayed to others. A similar capability is now also planned for the JSF.

JTIDS was designed for distributing a situation picture, and coordinating the deployment of assets, especially in complex air defence environments. It is a product of the high-density air land sea battle environment of the Cold War era where 'friendlies' and hostiles were often easy to distinguish, and hundreds of aerial and surface based assets needed to be coordinated. Its limitations in this role lie in throughput and total capacity, as it is designed to best operate with large numbers of short compact messages.

In naval Anti Air Warfare (AAW) or naval air defence JTIDS is no less valuable as it provides a shared channel through which the aerial situation picture can be relayed between missile armed surface warships, effectively permitting all combatants in a Surface Action Group (SAG) to share a common view of the surrounding environment.



Above: An F-111 releases flares as a countermeasure against surface-to-air missile attack. During the 1980s the RAAF's 82 Wing trialled the 'Precision Air Support' model in which F-111s would orbit at higher altitudes over an area of interest and pick off targets using laser guided bombs, directed by a ground observer. This tactic was embryonic to the 'Persistent Strike' techniques used so successfully in Iraq.

Left: A powerful facility in the JTIDS protocol is the capacity to electronically multiplex more than one JTIDS net in a given area. This diagram illustrates the allocation of seven separate JTIDS nets within one operational area.

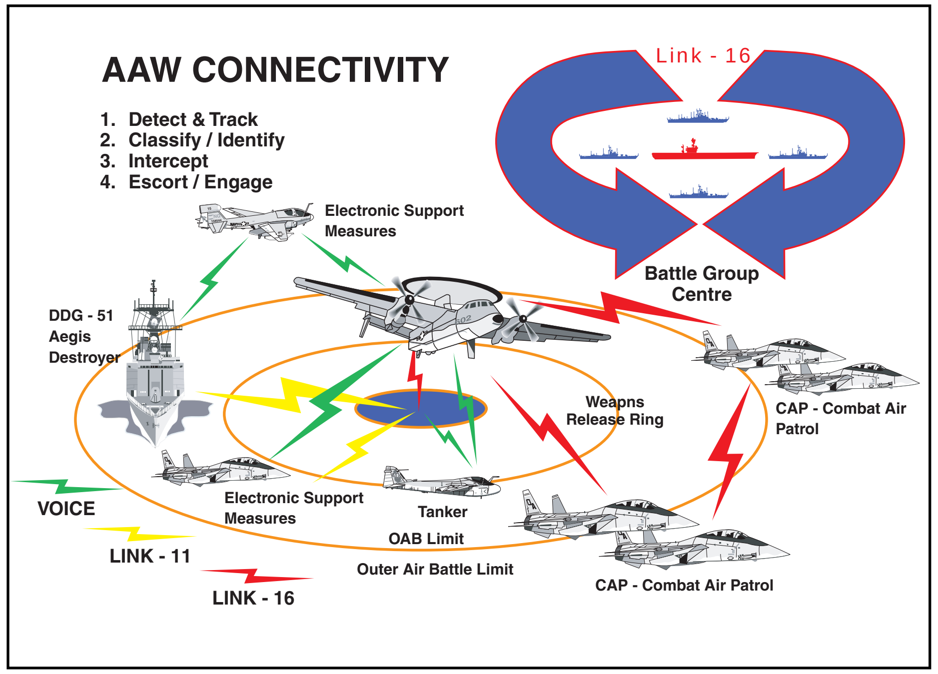
Ship-launched Harpoon Block II missile from the USS Decatur of the type Boeing will supply to Australia. Networking of warships with airborne ISR assets offers important gains in situational awareness and survivability.
(US Navy image)

As with the previous environment in air defence, combatants can passively receive a situation picture from other warships and thus remain radar and radio silent if need be to delay detection.
A major advantage does accrue when JTIDS is used to connect an AWACS and fighter package with a naval SAG. Surface warships suffer an inevitable and basic handicap as a result of a limited radar horizon. Depending on the radar antenna elevation above sea level, and the sea state, this can be between 15 and 25 NMI typically. Low-flying strike aircraft and cruise missiles are effectively invisible to warships until they 'pop-up' over the horizon.
Crossing the 'joint' boundary, an AWACS orbiting overhead with a JTIDS capability permits its 'Gods eye' view to be relayed down to the warship, giving the ship evasive manoeuvre options (circumstances permitting) but also early raid warning of an impending attack. In practical terms a single AWACS can provide a surveillance footprint, especially against low flying threats, vastly superior to even the largest shipboard radars. Physics cannot be beaten here.
The advantages seen in naval AAW resulting from the use of JTIDS are also repeated in land based air defence operations. Radars, missile and anti-aircraft artillery batteries or fire units can be netted together. Again, crossing the 'joint' boundary and netting into a situation picture feed from an AWACS provides like advantages to land based air defenders.
JTIDS is 1970s technology and as such has implicit limitations, especially in flexibility and throughput. Nevertheless, it has proven to be a very effective first generation technology for network centric air warfare, be it in single service or joint service operations. Future technologies such as the US Joint Tactical Radio System (JTRS) are expected to be far more flexible.

NCW in Strike Warfare

NCW technology and technique is much less evolved in strike warfare, compared with air defence environments. This reflects both technological pressures and historical operational pressures.
The digital datalink channel of choice today for NCW oriented strike operations is the Improved Data Modem (IDM) modulation and protocol, running over the Have Quick II jam resistant HF/UHF radio channel modulation. The nearest analogy to the IDM is the conventional voice-band modem running over a telephone line.
The IDM lacks much of the sophistication of the JTIDS scheme and was adopted as a quick gap-filling measure after experience in early Balkans conflicts demonstrated a need to rapidly deliver targeting coordinates from Intelligence, Surveillance and Reconnaissance (ISR) systems such as the E-8 JSTARS and RC-135V/W Rivet Joint to F-16C fighters tasked with interdiction and defence suppression tasks.
In air defence operations only targeting coordinates and target attributes need to be distributed, and in a timely and repetitive manner. In strike warfare the nature of the targets is quite different, be they emitting radars and SAM/AAA systems, or hostile ground forces. Frequently, much more information needs to be distributed to the aircraft tasked with killing the target. For instance, a hostile radar needs to be identified by type and, frequently, qualified with other information on specific operating frequencies and search patterns being emitted, to permit the attacking aircraft to acquire it faster. No differently, an enemy ground unit or camouflaged site/vehicle/position may require a bitmap image (eg JPEG) to permit the striker to unambiguously separate the target from civilian facilities nearby.
A key challenge in strike warfare is thus transmitting what might be a complex package of information required to identify a target without ambiguity. Collateral damage is used by opponents as a weapon in Information Warfare operations; therefore, precision and unambiguous targeting is essential, and not respecting this reality provides an enemy with ammunition.
The earliest implementations of the IDM model were based on the same 'centralised ISR platform plus distributed shooter' scheme seen in air defence operations using JTIDS based technology. As the technology has become more widely used and mature, we have seen other sources of targeting information such as UAVs and distant ground based analysis centres introduced into the system.
This reflects the changing nature of strike warfare. A decade ago most targets attacked by strike aircraft were static or 'semi mobile', regardless of whether they were strategic or battlefield targets. Aircraft would be launched with crews prebriefed on what they were to kill and where it was situated.
Since the 2001 Enduring Freedom air campaign in Afghanistan this has all changed. Evolution in action has seen opponents of the West rapidly shift to mobility to protect their ground force assets.
The time it takes to prepare a sortie and fly a strike aircraft into position to prosecute an attack is typically much greater than the time it takes to rapidly relocate a smaller ground force element and conceal it. The result has been a revolution in strike warfare over the last three years as targeting models built around predominantly static and semi-mobile targets are replaced with one assuming targets to be highly mobile.
This has been reflected in a shift to 'persistent strike' techniques: ISR platforms maintain 24/7 continuous surveillance of areas of interest, with Combat Air Patrols flying 'killbox interdiction' sorties (loaded with smart bombs) maintained on station continuously, waiting to pounce on targets as soon as the ISR machinery can unambiguously identify a target to be killed.
The earliest attempts at 'persistent strike' involved mostly US Air Force B-52H and B-1B bombers, supplemented by US Navy F/A-18Cs and F-14B/Ds over Afghanistan, with targeting data transmitted by voice over radio channels and crews punching the GPS coordinates into the mission management system using the cockpit keypad. Despite this slow and error prone technological limitation, the technique often resulted in targets being killed within minutes of the striker being tasked to attack.
What digital links like the IDM provide is a mechanism to avoid the double handling of targeting coordinates as is the case with voice channels. Targeting data generated typically by a complex and often distant ISR system is transmitted directly into the mission management computer system of the striking aircraft.
Current US Air Force thinking, articulated recently in public by Chief of Air Staff John P. Jumper is 'compressing the kill chain' with the ultimate aim of providing unbroken digital connectivity between the ISR system which finds the targets, through to the strike aircraft which delivers the weapon, even down to the weapon that kills the target.
Adoption of this model will provide a mechanism to minimise the time between a target being detected and killed, with an error free transmission path between the ISR system and the weapon itself.
This model not only reflects the changing nature of opposing target sets but also the deep changes in targeting philosophy. The Cold War era involved opponents on known geographical boundaries, with much known fixed infrastructure and enormous land armies. The military paradigm was one of breaking the opponent's warfighting capability by large-scale attrition using air attack.

The US Navy have a well developed and tightly integrated scheme for Anti Air Warfare (AAW), which uses a combination of JTIDS/Link-16, Link-11 and Voice comms links. F-14D and F/A-18C-F fighters network with the E-2C Hawkeye AEW&C system and shipboard radars to provide a comprehensive layered maritime Integrated Air Defence System. The Outer Air Battle (OAB) zone is primarily covered by fighters and picket warships, the inner zone defences are covered by SAM systems on Aegis cruisers and destroyer escorts. This model evolved from late Cold War pressures to defend against Russian Backfires, Bears and submarines firing supersonic cruise missiles.



Above: A Boeing CH-47F 'Chinook' helicopter, which may be offered to Australia under Air 9000 would be an important troop-lift asset on the networked battlefield. Survivability of helicopters is an ongoing issue, and JTIDS can be used to broadcast threat location data to aid evasion of mobile SAM and AAA systems and hostile helcіopters.

Left: Smaller fighters such as the F/A-18A require intensive aerial refuelling support to provide the persistence required for NCW-enabled strike techniques. With only 4 or 5 tankers planned the F/A-18A and JSF will have difficulty exploiting the targeting cycle improvements from networking.

NCW

The DoD's preferred fighter solution is the F-35 Joint Strike Fighter, designed primarily for battlefield air interdiction and close air support. The JSF will carry a comprehensive suite of digital datalinks and software to permit it to accept targeting data from a wide range of ISR assets and other JSFs.

The current model is much more refined, and involves faster and more concentrated attrition of the opposing nation state's apparatus of power: government leadership, military leadership, command and control facilities, propaganda apparatus, internal security forces, and the most loyal and resilient military and paramilitary combat forces. While this target set is geographically distributed across the breadth and depth of the opposing nation state, it is also mobile and concealed, often exceptionally so.

Historical origins of the 'persistent strike' model lie in Australia . During the 1980s the RAAF's Strike Reconnaissance Force through 82 Wing trialled the 'Precision Air Support' model in which F-111s would orbit at higher altitudes over an area of interest and pick off targets using laser guided bombs, directed by a ground observer. It is little known that a video datalink was trialled to downlink imagery from the F-111 to the ground controller on site. While the scheme did not achieve prominence in Australian military thought, it did migrate to the US via exchange officer postings and ultimately evolved over time into the technique we observed in Afghanistan, with B-52H bombers flying circular orbits over Taliban positions.

Afghanistan also demonstrated the inherent joint warfare potential of this targeting model, as a large proportion of targeting information was generated by special forces units on the ground who identified the targets and then assessed the effect of the attack. This was repeated over Iraq last year. To extract the full potential of this model, however, requires that digital connectivity exists to link together ground force elements and airborne ISR and strike elements. This remains a weakness in the US force structure and an even greater one for Australia. For instance, the IDM is an option on US Army AH-64D Apache Longbow reconnaissance/attack helicopters, permitting the helicopter to accept targeting information on 'over the horizon' targets from airborne ISR platforms and fighters, and vice versa. This is the correct model but it needs to be implemented across a much greater range of land force elements such as tanks and armoured recce vehicles – and infantry units will ultimately require such two-way connectivity.

The Future

There are two fundamental issues that define the future in the NCW game. The technological element is straightforward in concept even if complex in implementation. The first concerns universal high speed digital connectivity between platforms, later including weapons. The second relates to high levels of seamless integration of the connectivity paths with the embedded weapon systems software of platforms. In the US we are seeing this reflected in the software and systems architectures of the F/A-22A and JSF aircraft, the MC2A replacement for the E-8 JSTARS, RC-135V/W and E-3 AWACS, as well in increasing levels of digital integration in naval air defence systems and some Army platforms.

The doctrinal and thought element is reflected in a shifting emphasis in targeting philosophies and in personnel training to support this regime of combat. The US experience has shown that most progress has been achieved in single Service environments, with the joint paradigm lagging quite severely. The well developed and growing intra-Service NCW capabilities of the US Air Force and US Navy reflect this fact: cross-Service doctrine and technique, as well as digital connectivity, lag severely.

In Australia, rhetoric is far more potent than implementation. Many recent decisions indicate that there is little understanding of the deeper relationships between NCW and platform/force structure capabilities. There seems to be a deeply entrenched belief that NCW capabilities, especially connectivity, are a replacement for raw firepower, ISR capability and battlespace persistence. This is a dangerous delusion, insofar as NCW provides a mechanism to accelerate targeting and engagement cycles but without the ISR assets and persistent firepower delivery assets to exploit the engagement cycle improvements its utility is of dubious value in itself.

Three examples of such broken thought processes are evident. A belief seems to exist that the provision of a JTIDS capability can wholly reverse the performance and missile engagement range disadvantages of the F/A-18A HUG and JSF operated with Wedgetail AEW&C against Russian Su-30 fighters and A-50 AWACS now being acquired across the region. Were parity to exist between fighter and AWACS capabilities then the NCW capability of the ADF system could indeed be the decider in a confrontation. But in a situation where the fighters are clearly challenged to outperform opposing aircraft it is unclear how the NCW capability would provide this advantage. If the opponent can shoot much earlier and aerodynamically close or open engagement distances more readily, knowing they are doing this will not prevent them from doing so. The potential for developmental Russian counter-ISR weapons such as the 200 NMI range KS-172 missile to be deployed within the region later this decade raises some very good questions about ISR platform survivability. AEW&C platforms are not throwaway assets.

Another prime example of a broken thought process is the drive for early F-111 retirement and the expectation that four or five medium sized tankers and standoff missiles will offset a de facto 50% reduction in force structure firepower. NCW in strike warfare permits rapid engagement cycles against mobile ground targets, but such engagement cycles can only be executed if strike assets can persist over the target area with large precision bomb payloads. In the absence of plans for two dozen tanker aircraft, the F-111 is the only ADF asset with the on-station persistence and smart bomb payload to effectively make use of an advanced NCW capability - yet it is to be killed off in 2010. The much promoted NCW software and datalink capabilities of the JSF will be of no value if the JSFs are not orbiting the target area since they have run out of gas and smart bombs and have to go home. On balance, the extra NCW processing and bandwidth in a JSF against an IDM and JTIDS retrofitted F-111 is of less value than the inherent persistence and bomb load of the F-111, carrying almost twice the internal fuel of the JSF.

The third example of a broken thought process is the budgetary balance between the RAAF operated Wedgetail AEW&C fleet and the RAN's intended Air Warfare Destroyers. Both have long-range radars but the Wedgetail can acquire and track targets at all altitudes while the destroyers are blind to low altitude targets beyond a very short radar horizon. In effect, the destroyer can only defend a large area footprint properly against representative imported regional threats of Russian design if a Wedgetail is orbiting overhead and datalinking coordinates down to permit missile engagements at maximum range - preferably with the warship radar silent to deny targeting data to the opponent. On balance it makes more sense to invest in more Wedgetails rather than large expensive long-range shipboard radars that drive up the size and cost of the warships significantly. The cost of putting a naval SAM seeker compatible X-band illuminator radar on the belly of a Wedgetail to permit it to provide terminal phase SAM guidance over the radar horizon of warships, and buying more Wedgetails, is cheaper than overinvesting in larger and vastly more expensive warships of dubious survivability.

An issue in its own right is supporting the technological capability in Australia. The policy, not always followed, on ADF Electronic Warfare systems being supplied with software source code and development systems should be extended to encompass all NCW systems, such as datalinks and mission computer integration software. The issues behind this are no different for NCW systems as for EW systems.

In summary, NCW offers enormous potential for the ADF, but it is not a substitute for proper force structure planning. Until this is recognised, rhetoric about NCW will achieve nothing of significant value, and often provides excuses for dubious force structure planning.

Above: Australia seems certain to buy the RQ-4A 'Global Hawk' UAV seen here landing at RAAF Base Edinburgh. Long-range UAV platforms such as 'Global Hawk' would be an important Intelligence Surveillance and Reconnaissance asset. A Global Hawk role seldom discussed in Australia is the 'pseudolite' role in which a Global Hawk carries a communications relay and networking payload rather than ISR sensors, providing persistent airborne 'satellite like' wireless network coverage in areas where proper satellite coverage is absent.

Left: The Australian Army is close to making a decision on a replacement Main Battle Tank (MBT) for its 'Leopard' fleet. With its inherent firepower and mobility the MBT would gain great advantage from target and tactical information plus command & control within an NCW environment.

Wedgetail

Australia's pocket AWACS

Dr Carlo Kopp

With the first flight of Australia's first Wedgetail AEW&C prototype recently, and the aircraft now entering flight test in the United States, the issues surrounding this critical program deserve scrutiny. Despite the Wedgetail's pivotal long-term importance to the Australian Defence Force this program has received, until recently, neither the level of funding nor the public attention it truly deserves. Key questions surrounding the RAAF's AIR 5077 Wedgetail program remain, even though the number of airframes has now been increased from four to six.

Why is Wedgetail critically important?

Perhaps the single most important strategic change Australia has observed in this region since the end of the Cold War is the ascendancy of India and China as regional superpowers. Both nations are aggressively industrialising, and no less aggressively investing in what will become the two largest modern air forces in Asia over the coming two decades. The unrestricted availability of post Cold War Russian technology has provided the materiel base for Asia's arms race - much of this technology being of the same generation as contemporary Western systems. Smaller regional nations are following the two large players, often with 'copycat' buys of identical equipment.

This investment is being focused into achieving, where possible, technological parity or force structuring parity with Western nations. To that effect, hundreds of advanced Sukhoi Su-27/30 fighters are now in service with or ordered by India, China, Indonesia, Malaysia and Vietnam. The Sukhois are Russian analogues to the Boeing F-15 series, but larger and more agile. China is also well on the way to full production of its J-10 Lavi-analogue, and is evidently investing heavily in developing a significant indigenous cruise missile capability.

Across the region we have seen buys of Russian subsonic and supersonic cruise missiles, including the 3M-80/82 Sunburn/Moskit, Kh-61/PJ-10 Yakhont/Brahmos, Kh-35U Uran/Kharpunski, 3M54 Alfa/Club/Kalibr, Kh-59M Ovod and others. Of particular concern is evidence of China's effort to deploy strategic land attack cruise missiles suitable for aerial, submarine and ship deployment. Many sources claim that the PLA now operates the indigenous HN-1 (320 NMI/600 km), HN-2 (800+ NMI/1,500+ km) and the HN-3 (1,350 NMI/2,500 km) cruise missiles.

Reports have emerged claiming China has actively shopped in South Asia for debris from expended or failed Tomahawk rounds. Available imagery of a Chinese cruise missile suggests it is indeed a clone of the BGM-109 Tomahawk - a 1999 report in Hong Kong's 'Sing Tao Jih Pao' claimed a Tomahawk-like cruise missile with 1,080 NMI (2,000 km) range, a CEP of 5 m/16.4 feet using high-technology "map matching" + topography matching + inertial guidance + GPS auxiliary correction + other auxiliary guidance, the missile was claimed to cruise at 15-20m/49-65ft AGL.

More recently reports have emerged claiming China has purchased tooling for the Raduga Kh-65SE, the reduced range export variant of the Kh-55 (AS-15 Kent), which is Russia's answer to the Boeing AGM-86B ALCM. Reverse engineering the Kh-65 to make an Kh-55 clone involves mostly fuselage plugs for more fuel. The recently unveiled H-6H variant with four wing pylons carrying what appear to be four Kh-55/65 ALCMs is clearly intended to provide a long range cruise missile strike capability.

Cruise missile technology acquisitions have been paralleled by an effort to field aerial refuelling. India recently took delivery of its first Il-78MKI tankers while China continues its program of converting H-6 Badgers into V-bomber analogue tankers. With over 120 Badgers built since 1970, there is no shortage of raw airframes.

There can be no doubt that over this coming decade India and China will acquire a significant capability to project air and missile power into South East Asia.

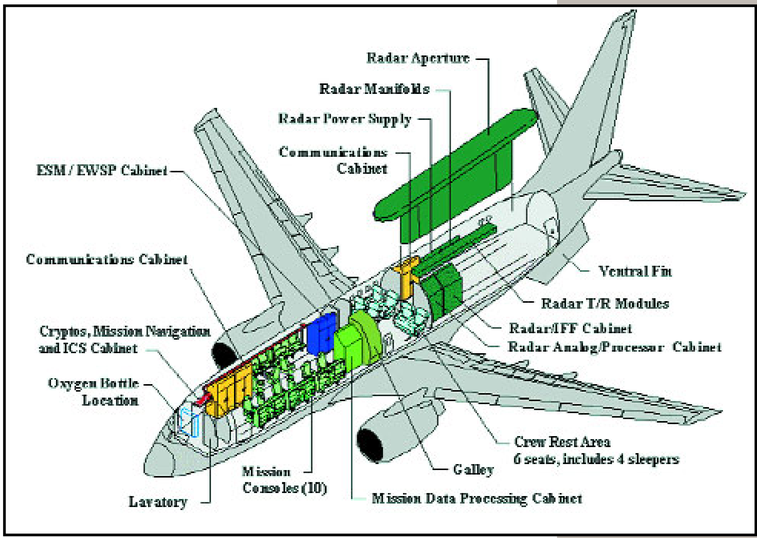
The drive to equip Asian force structures with modern fighter, tanker and precision weapons capabilities is paralleled by an ongoing focus on fielding AEW&C capabilities within the region. AEW&C aircraft are seen as much as military capabilities as they are seen as a status symbol: if you have them you are a serious regional player, if not you are a pretender. The pivotal role of AEW&C aircraft in the Desert Storm, Desert Fox, Allied Force, Enduring Freedom and Iraqi Freedom campaigns has been well understood across Asia and this is reflected in purchases since then.

China's PLA-AF entered a multi-billion dollar deal with Israel to integrate a variant of the Elta Phalcon phased array radar on the Russian Beriev A-50/Ilyushin Il-78M airframe, and at that time also bid for Australia's Wedgetail on the A310 airframe. The Russian A-50 AWACS system was to be removed and replaced with the three sided L-band AESA (active phased array) radar and supporting systems, providing the PLA-AF with one of the most advanced systems worldwide.

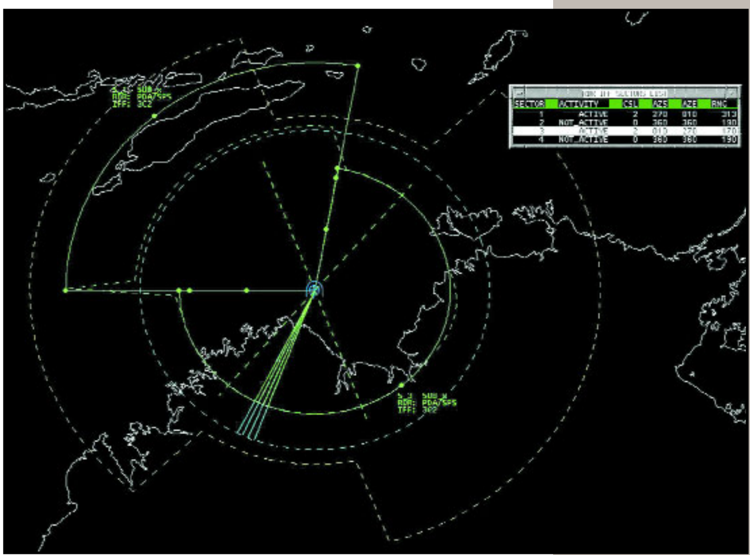
This ambitious plan collapsed in July 2000 when the US objected. This effectively killed the deal at the Israeli Cabinet level. Amid much face saving rhetoric about 'humiliation', the Chinese declared that the Russian A-50U/E would be acquired instead. The radome equipped A-50I prototype has been since observed flying over Nanjing, presumably without the Phalcon installation. While the issue has been quiet in the press, there is no doubt that China will field an AWACS over the coming decade - the only uncertainties being in timing, numbers and type.

India reciprocated, with quiet US approval, and earlier this year signed with Israel for several Phalcon equipped A-50I AWACS to be delivered later in the decade. The exact configuration has not been disclosed but we can expect these aircraft will carry a comprehensive package of Israeli ESM and communications hardware.

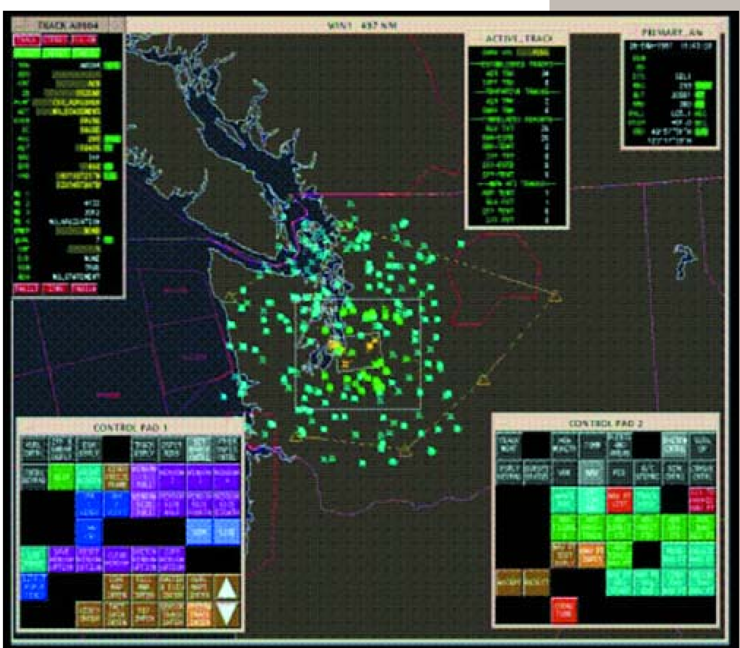
PLA-AF propaganda photo of a pair of Sukhoi Su-30MKK long range strike fighters. This aircraft provides similar strike capabilities to the F-111, but has only about 2/3 of the combat radius. India, Vietnam, Malaysia and Indonesia are acquiring similar Su-30 variants (PLA).



The Wedgetail system has grown since the 1999 proposals were published, with ten multi-function consoles for operators, a similar number to the E-3 AWACS. This provides significant growth potential for the system's roles and missions. A rest area is included to permit operator rotations on extended duration sorties (Boeing).



The Wedgetail's software intensive system will permit the use of a wide range of flexible, graphics intensive synthetic display formats, which can fuse radar, ESM, datalink and digital mapping outputs. These demonstrator displays illustrate the style of presentation to be used. This technology permits rapid growth to incorporate offboard data sources such as UAVs, satellites and ground-based databases (Boeing).



In the nearer region, Malaysia declared its aim in June last year to acquire four AEW&C aircraft, with reports indicating that the Embraer EMB-145/Erieye, Northrop-Grumman E-2C Hawkeye 2000 and the Boeing 737 Wedgetail were under consideration. Malaysian reports claimed the requirement to be urgent enough to delay the buy of additional Sukhois to cover this need.

The pattern of Asia's Sukhoi buys was that small initial batches were ordered, followed by much larger follow-on buys. This can also be expected for both China's and India's AEW&C fleets, as both try to match or exceed each other's capabilities. There can be little doubt that by 2020 almost every regional nation of strategic interest to Australia will have AEW&C fleets, some of which might be numerically quite significant.

In summary, if the RAAF is to have any hope of being competitive in this region, it must have a highly capable and numerically adequate fleet of AEW&C aircraft.

What is Australia buying?

The Wedgetail AEW&C aircraft configuration ordered for the RAAF is the most advanced design worldwide and more than a match for its regional competitors. Based on the Boeing 737-700 IGW, essentially a -700 fuselage mated with stronger -800 wings and undercarriage, this airframe is also the basis of Boeing's MMMA proposals for the AP-3C replacement. The aircraft has a cited dash speed of 460 KTAS, range of 3,000 NMI, time on station without refuelling in excess of eight hours, and an aerial refuelling receptacle to extend time on station.

With turbofan propulsion the Wedgetail has a station altitude between 30,000 and 40,000 ft, providing an important advantage in low-level radar horizon distance against turboprop competitors. Low-level footprint is a critical parameter in both maritime air defence and cruise missile defence roles.

The configuration of the mission system has evolved since the time of the tender. While the basic layout is retained (a forward fuselage mission deck with six operator consoles and cabinets with racked crypto, communications, ESM and data processing equipment, a centre fuselage crew rest area, and an aft fuselage radar/IFF equipment area), current diagrams indicate that 10 operator consoles will be used. The original E-3A AWACS configuration had 9 to 11 consoles while smaller AEW&C platforms like the E-2C have 3 to 4 consoles. Additional consoles provide for additional growth in roles. The console design is a new COTS based 'soft' design where all display formats are produced in software, permitting instant reconfiguration to whatever mode is desired.

In the future a Wedgetail could absorb the battle management roles now planned in the US for the MC-2A series of AWACS / JSTARS / Rivet Joint replacements. The networked and racked open systems based COTS computing package will permit much evolution over the service life of the system.

The core of the mission avionic suite is the Northrop Grumman MESA L-band (1.215-1.4 GHz) surveillance radar with an integrated IFF capability, feasible due to the overlapping radio frequency band coverage of the radar function. The MESA is an active array (AESA) - an integrated Transmit-Receive (TR) module with internal phase shift and RF gain controls drives each antenna element. This provides the type of time-sharing and sector scan capabilities most widely

seen today in the Aegis destroyers' SPY-1 series phased array, but the MESA does so with significantly lower sidelobe performance of an active array and the inherent reliability which comes with over a thousand independent solid state TR modules.

The MESA is an important innovation in the airborne AESA game as it provides 360-degree coverage in a compact and low drag lightweight package. Beam aspect coverage is provided by left and right looking 'slab' array apertures, while fore and aft aspect coverage is provided by endfire mode 'top hat' aperture, in the surfboard shaped upper structure. Best radar performance is in the beam sectors, used most frequently in AWACS style orbit orientation. The TR modules are racked in the upper fuselage for ease of maintenance, with feeds running into the external antenna structure. With no moving parts the MESA will be exceptionally reliable in service - unlike troublesome mechanically steered AEW&C radar antennas with rotational couplers.

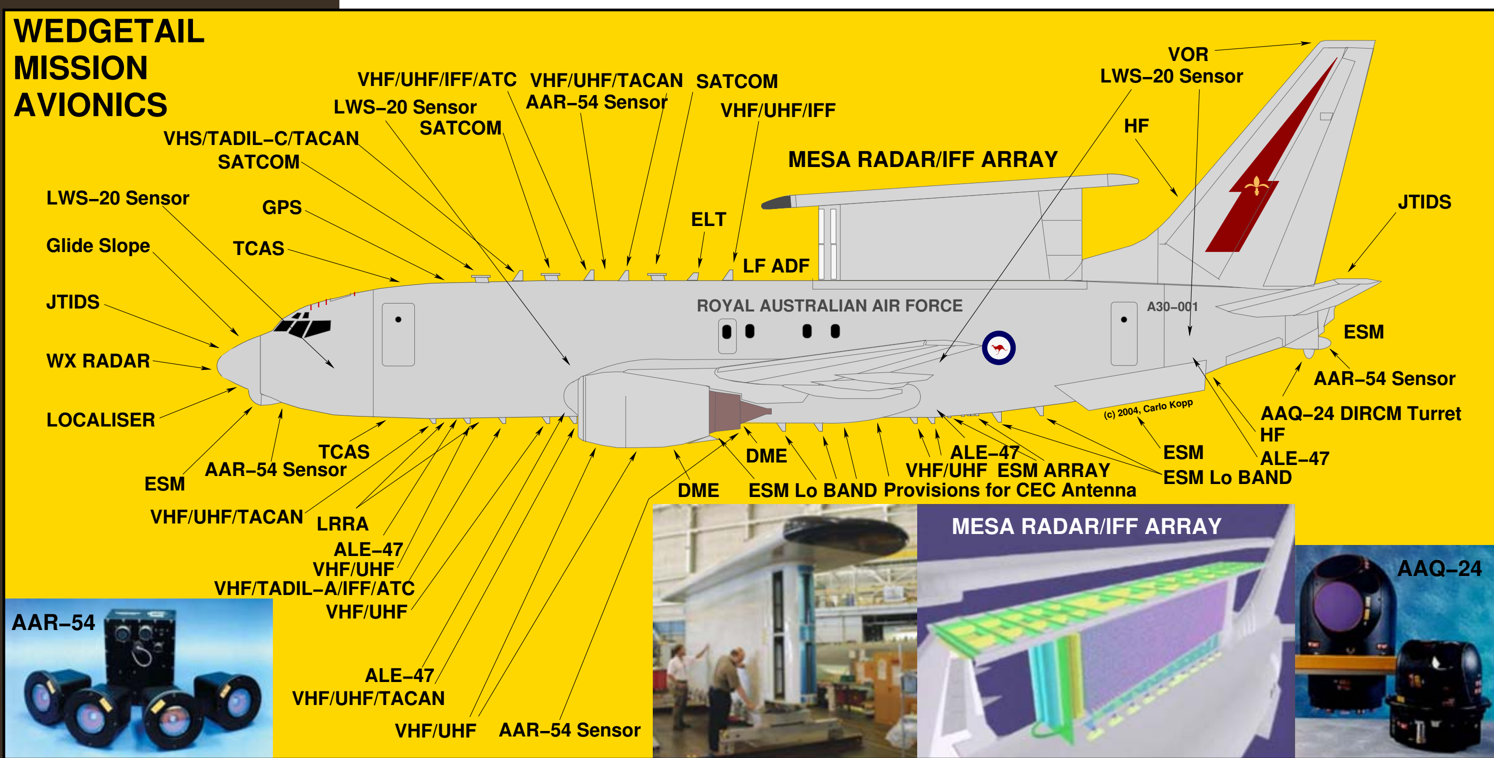
The MESA is well suited to the developing regional environment. The use of the L-band wavelength provides excellent penetration of heavy (cyclonic) weather, an issue for shorter wavelength radars. This radar band also defeats many 'add-on' stealth coatings and shaping measures that are optimised for the centimetric bands. L-band wavelengths resonate nicely with many feature sizes on combat aircraft, as distinct from centimetric band JSTARS like radars optimised for ground vehicles. In cruise missile defence, L-band is not always considered optimal, but the phased array and good station altitude can offset to some extent radar physics - a much increased number of radars pulses over time can still effect good detection performance against such small targets.

The phased array configuration permits highly flexible allocation of radar dwell time in space - basically permitting more energy to be put into specific areas of interest. While the radar can be used to sweep 360 degrees like a mechanically steered design, it can also focus all of its energy into a narrow threat sector to increase effective range performance, or it can timeshare between these two regimes to maintain 360 degree background coverage while increasing detection and tracking performance in a narrow sector of interest. The latter regime has proven very useful in naval Aegis radar operations in complex littoral environments.

The ability to focus energy into sectors permits higher update rates on target tracks, and higher track confidence levels against distant or faint targets. In an environment where larger supersonic combat aircraft and supersonic cruise missiles are common, this is a valuable capability.

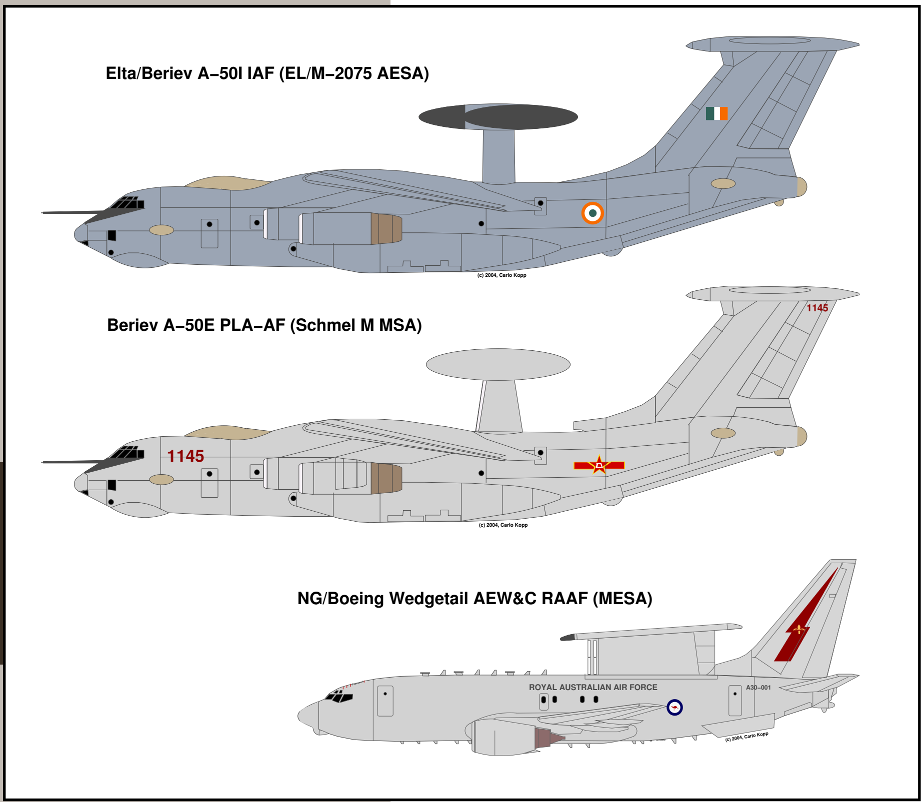
The MESA is supported by a communications/datalink suite and the ALR-2001 Electronic Support Measures (ESM) used to passively detect hostile emitters. Three HF voice/data channels, ten VHF/UHF (Have Quick II) frequency-hopping radio channels, four UHF voice/data channels, UHF MILSATCOM voice/data, Link-11, OTCIXS and JTIDS/Link-16 provide a comprehensive package permitting connectivity with air, land and maritime surface assets. Space is provided for a UN Navy-style CEC antenna for maritime operations. The system best compares to the late model E-3 AWACS suite.

The defensive package is also comprehensive by established standards, including an ultraviolet band Northrop-Grumman AAR-54 Missile Warning Receiver coupled to an AAQ-24 Directed



The Wedgetail will be equipped with a comprehensive mission avionic suite, rivalling that of the late model E-3 AWACS, but more compact and cheaper. The L-band MESA radar/IFF array is likely to be the basis of the US Air Force's AWACS replacement early in the next decade. The extensive defensive suite is the first on an AEW&C/AWACS platform (Author, Northrop-Grumman).

IR Counter Measures turret in the tail, an Elisra LWS-20 Laser Warning Receiver, and multiple ALE-47 countermeasures dispensers, capable of carrying flares, chaff or expendable radar seduction jammers such as the AM 6988 POET or RT-1489/ALE Gen-X. It has not been disclosed whether the AAR-24 is a lamp or laser equipped variant. Absent in the defensive suite is an internal microwave band track-breaking jammer, which might become a necessity in the future as long range counter-ISR missiles such as the Kh-31 and KS-172 series proliferate.



The region is seeing ongoing orders for AEW&C capabilities. Japan, Singapore and Taiwan operate E-2C Hawkeye variants, Japan the E-767 with an E-3 AWACS mission package, and India this year ordered the A-50I with a variant of the Phalcon phased array radar originally bid for the Wedgetail program. The PRC is expected to buy the Russian A-50U/E, and are now flying the recovered A-50I prototype depicted at a flight test centre (Author, PLA).

How many Wedgetails suit Australia's needs?

In a recent editorial, Australian Strategic Policy Institute Director Hugh White pointed out the unfortunate reality that Defence remains on track to purchase only four Wedgetail AEW&C aircraft and two additional mission packages for $3.6B, not taking up the option to add two airframes at an additional seven per cent increase to get six complete systems. As he observed, a 50 per cent increase in capability for a seven per cent increase in buy price is hard to argue against.

What the Wedgetail provides is a system which combines: 250 NMI class 360 degree all altitude radar and ESM surveillance coverage, comprehensive digital and voice connectivity, and battle or mission management functions – all in a single rapidly deployable and persistent package. Within the footprint of the Wedgetail all airborne traffic, maritime surface traffic and most emitters and cruise missiles can be detected and tracked. While JORN provides long range wide area coverage, it cannot provide the accurate height finding and position tracking, passive detection, communications and rapidly updated tracking functions of the Wedgetail - the two systems are complementary, not mutually exclusive.

In modern military terms the Wedgetail provides a comprehensive situational picture within its footprint, and the voice/data communications required to manage any ADF assets within reach.

In classic land and maritime air defence operations the Wedgetail, in concert with fighters and tankers, would be used to support intercepts by RAAF fighters against hostile aircraft and where applicable, cruise missiles. Moreover, its situational picture can be relayed to RAN surface assets, Army missile batteries and distant ADF headquarters. In the air defence game, early warning is one of the most precious commodities as it permits assets to be marshalled and readied for engagements. Every conflict since the Battle of Britain proves this beyond a shadow of a doubt.

In strike warfare the Wedgetail is no less valuable. Other than fulfilling the air control functions seen in air defence, it can be used for air traffic control management of strike aircraft but also to relay a situational picture of hostile surface air defence (via ESM) and fighter (via radar and ESM) dispositions to penetrating strike aircraft. Bypassing defences always beats shooting your way through them.

In purely surface-bound maritime warfare, the Wedgetail provides the RAN with a complete picture of opposing assets, vital in littoral combat, blue water surface operations and convoy escort. Consider a Timor-like or Falklands-like contingency with anti-ship cruise missile firing warships, patrol boats and helicopters targeting troop transports. Analogous gains arise in land warfare, as enemy heliborne and seaborne forces can be tracked in real time.

To these wartime uses we can add a range of peacetime roles that are no less vital. Wide area surveillance of air and sea traffic permits interdiction of people/contraband smugglers, movements of insurgents and terrorists, 'factory ship' poaching of fisheries and search and rescue operations. The large footprint of a Wedgetail compared to the lower power radar on a UAV or maritime patrol / coastwatch platform permits a single Wedgetail to surveil several times the area in much more detail, much faster.

China's emerging program to deploy cruise missiles competitive against the US Navy Tomahawk and US Air Force CALCM will transform the regional strategic landscape. Available evidence indicates that these weapons are likely to be based on a cloned Tomahawk, and a licenced Russian Raduga Kh-55/65, the carried by the new H-6H Badger variant. The only viable defence against such weapons requires high performance AEW&C aircraft in adequate numbers (China Defence Forum, Russian MoD).

The Noble Eagle operation post-911, when the USAF bolstered its E-3 AWACS fleet with NATO E-3s to ensure interception of hijacked airliners, is another contingency where Wedgetails would prove invaluable - be it for surveilling Australian airspace or on loan to allies such as the US.

In coalition warfare campaigns the US Air Force has repeatedly run short of E-3 AWACS and trained crews, frequently borrowing from the UK E-3D fleet to augment its own. With the US facing 'global overstretch' in coming decades, every Wedgetail we have is a politically and strategically valuable ADF campaign contribution without the political encumbrances which come with dropping live munitions. It takes no genius to observe that Prime Ministers of either political persuasion will be attracted to the high payoff, high visibility, low risk Wedgetail as a coalition campaign contribution.

The reality is that once the ADF has operational Wedgetails, the aircraft will be in high demand for peacetime surveillance and coalition warfare operations, aside from their important deterrent effect across the wider region. Were they operational in 2001, odds are much of the fleet would have been deployed to the US or Afghanistan.

This brings us to the key question of how many Wedgetails should the RAAF be operating: six, seven or more.

Conclusions

With four aircraft the RAAF could not have provided continuous 24/7 air defence coverage between the North West Shelf and Darwin areas. At least seven aircraft would be required to be effective against an air or submarine launched cruise missile armed opponent. With four aircraft the RAAF could not have provided AEW&C support for strike operations if on demand air defence coverage is required between the North West Shelf and Darwin areas. At least six aircraft are required, assuming threat strike aircraft with shorter ranging weapons. Should Australia need to provide short notice on demand air defence cover to protect all capitals against the threat of hijacked airliners, as has occurred in the US, then four aircraft would have permitted coverage for only three capitals.

It is clear that if the Defence of Australia is the priority, then a fleet of seven or more Wedgetails is the appropriate number. If coalition warfare is the priority, while retaining contingency coverage for the eastern seaboard capitals, or on demand coverage for the north, then more than four aircraft are required - assuming a coalition deployment of three to four Wedgetails, the total comes in at seven to eight. The `critical mass' number for a well sized Wedgetail fleet is above six aircraft, with eight being more flexible than seven. Six aircraft provides enough for 24/7 coverage of three orbits, without the essential one or two spares to robustly guarantee that coverage.

There is clearly an overwhelming case to get the six or more Wedgetails, regardless of the ideological and military/strategic doctrines used to define the ADF's long term force structure.

The decision to field six Wedgetails is clearly a good one but it brings the fleet size to just over the critical mass number. Wedgetails 7 and 8 remain an unfilled need.

Observations:

- A single Wedgetail aircraft can continuously surveil a circle of about 450 nautical miles diameter for low altitude airborne and maritime surface targets.
- To provide 24/7 coverage of single immediate area of operations requires a pair of AEW\&C aircraft, plus an additional spare should one of these aircraft experience technical difficulties. Full 24/7 coverage would be essential if an opponent used sub-launch cruise missiles, as these may be launched with no warning, or longer ranging air launched cruise missiles. Both categories are proliferating across the region at present.
- To provide on-demand coverage of single immediate area of operations, launching on a JORN track, requires one AEW\&C aircraft, plus an additional spare should this aircraft experience technical difficulties. This is required for a fighter or bomber threat, without longer ranging cruise missiles.
- The air defence of the North West Shelf area, the Darwin area and the Timor Sea would each require a pair of aircraft for 24/7 coverage, with one spare aircraft shared between the three areas. This requires a total of seven aircraft.
- The air defence of the North West Shelf area, the Darwin area and the Timor Sea would each require one aircraft for on-demand coverage, with one spare aircraft shared between the three areas. This requires a total of four aircraft.
- Any major strike operation performed in the region would require at least one aircraft, plus an available spare. Conditions may require that the spare is airborne for the mission. It is unlikely that such a contingency would arise without the risk of opposing air strikes against the continent.
- In practice, one aircraft might be in the depot for airframe maintenance, hardware and software upgrades and testing. Therefore, full fleet availability could not be guaranteed at very short notice, but is feasible with several months of warning time.

by Dr Carlo Kopp, PEng

IS THE JOINT STRIKE FIGHTER RIGHT FOR AUSTRALIA?

PART 1 – F-35 V F/A-22

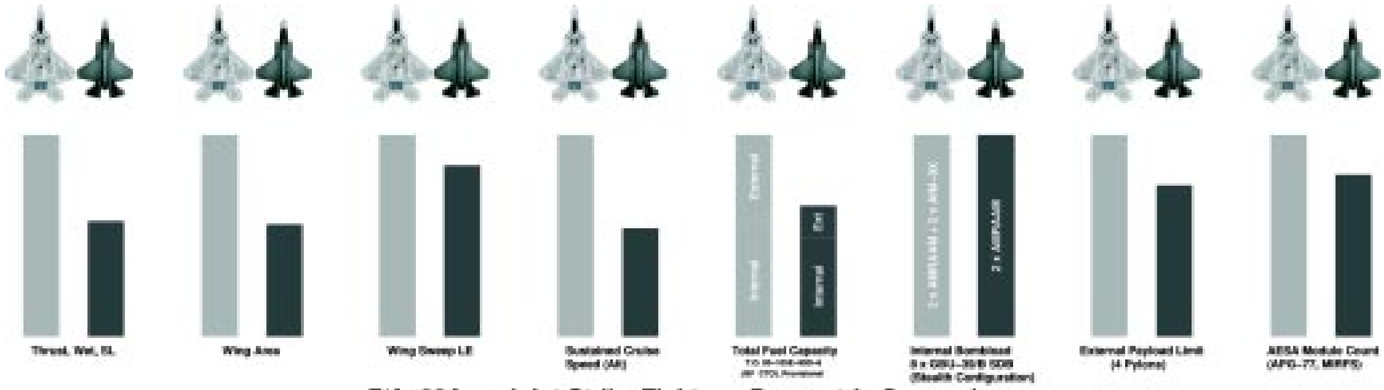
In recent testimony to the Joint Foreign Affairs, Defence and Trade Committee of Federal Parliament the Defence Department leadership asserted that the "the really big difference [between the F/A-22 and Joint Strike Fighter] is in cost". This remarkable statement, and others of a similar ilk, explains much of the enthusiasm surrounding the Joint Strike Fighter in Defence leadership circles – the Joint Strike Fighter is effectively perceived to be a single engine F/A-22. Given the design aims, development histories and characteristics of these aircraft, this belief is not supportable by available evidence.

This two part analysis will delve deeper into the differences between the JSF and its more capable sibling, the F/A-22A Raptor, and explore recent developments in the JSF program.

Both the F-35 JSF and F/A-22A reflect a process of strategic and technological evolution which began during the 1980s. This was a period during which the Soviet empire reached the peak of its military power before its economic and political collapse, a period during which the high performance Sukhoi Su-27 and Mikoyan MiG-29 entered large scale production, and massive Soviet tank armies presented the benchmark of land power worldwide.

During this period the US Air Force relied upon its fleet of F-15A/C Eagle air superiority fighters, supported by the smaller but highly agile F-16A/C, as the means of breaking the back of Warpac air forces in the pivotal Central European theatre. Soviet land forces were to be broken by a mix of F-111, A-7D, A-10A and later, F-16C strike aircraft.

The F-15A was primarily aimed at air superiority, although the weapon system supported a range of modes for dumb bomb delivery, used extensively by the Israelis in combat. The enhanced F-15C gained Conformal Fuel Tanks (CFT) to push internal fuel up from 6110kg (13,455lb) to 10,535kg (23,200lb), and avionics and engine enhancements. The F-16A was, like the F-15A, aimed at air superiority, but limited by radar to mostly day VFR combat. While exceptionally agile, the F-16A's 3085kg (6800lb) internal fuel



F/A–22A vs Joint Strike Fighter – Parametric Comparison

(Provisional Data)

capacity severely limited it.

Growing Soviet airpower, especially the new Sukhoi Su-27 and Mikoyan MiG-29 fighters, provided the impetus for further air superiority fighter development. The US Air Force launched the Advanced Tactical Fighter (ATF) program aimed at replacing the F-15 with an aircraft providing an overwhelming capability margin over the Su-27 and MiG-29 – similar to that held by the F-15A over the MiG-21 and MiG-23. A key feature of the ATF was the addition of a supersonic cruise or 'supercruise' capability – the ability to remain supersonic on dry thrust as long as the fuel payload permitted.

Supercruise was intended to provide an unbeatable energy advantage over fighters with conventional propulsion which are limited to mere minutes in full afterburner before exhausting their fuel. A side benefit was the ability to transit from bases in Holland and the UK to the battlespace in half the time the F-15 required. Considerable R&D investment was made very early into the supercooled turbine engine technology required to support this regime of flight – stealth became a feature of the ATF program only after the F-117A proved to be viable.

The ATF flyoff saw the stealthier and faster Northrop/McDonnell Douglas YF-23A pitted against the Lockheed/Boeing/General Dynamics YF-22A, with Pratt & Whitney and General Electric bidding their respective YF119 and YF120 engines. By 1991, the respective winners were the Lockheed led team and P&W, in a large part due to their more conservative and thus lower risk designs.

The then F-22A ATF had evolved into the technological flagship of the 4th/5th generation fighter class – now embodied in the technologies in the F/A-22A and JSF. The aircraft has supersonic cruise engines, thrust vectoring, all aspect stealth, a large active phased array radar, and the innovative Pave Pillar avionics architecture, which shifted all signal and data processing into a group of centralised multiple processor chip computers.

With the Soviet empire's collapse the role of the F-22A evolved to encompass the 'deep strike' mission of the current F-117A (and earlier the F-111) – destroying heavily defended ground targets using smart bombs. The 250lb class GBU-39/B Small Diameter Bomb came into existence as a weapon to increase the firepower of the F-22, limited then to a pair of internal 1000lb GBU-32 JDAMs. The current F/A-22A is a genuine multirole fighter, with high resolution Synthetic Aperture Radar capability and will be tasked as much with air superiority as with killing SAM sites, radars, airfields, bunkers, command posts and other high value assets. The planned US Air Force Global Strike Task Force (GSTF) will comprise 48 F/A-22As and a dozen B-2As, and is intended to break the back of any opponent, globally.

Penetrating defences at 50,000ft and sustained supersonic speeds, the F/A-22A defeats most SAMs by kinematic performance alone – its stealth capability defeating the top tier S-300/S-400 series systems. The F/A-22A will remain the most survivable strike fighter in existence for decades to come – and the most lethal air superiority fighter.

The JSF evolved from a completely different set of needs and strategic pressures, and occupies a completely different niche in the US force structure. While the JSF program has its origins in the early 1990s, the philosophical thinking in many of its design features dates to a similar era to that of the ATF program.

The problem of breaking Soviet ground forces increased in difficulty during the 1980s. As the Soviets introduced night vision equipment on tanks and fielded the highly mobile SA-12 (S-300V), SA-11 (9K37), SA-15 (9K330) battlefield air defence weapons, it became evident that the existing fleet of A-10A and A-7D close air support and battlefield interdiction (CAS/BAI) aircraft would be hard pressed to survive, let alone provide the numbers to break the Soviets in the Fulda Gap. While the USAFE F-111E/F deep strike force was being supplemented with 200 of the new F-15E 'Beagle' Dual Role Fighter and the 60 F-117A stealth fighters, Tactical Air Command's close air support (CAS)/battlefield air interdiction (BAI) force was sorely in need of improvement.

A flyoff was started between an upgraded A-7D Corsair II, the YA-7F with the F-16's P&W F100 afterburning fan, and an enhanced F-16B variant. Concurrently, trials commenced with dual seat YA-10Bs fitted with the then new LANTIRN package of pods – one pod carrying a terrain following radar and 'look into turn' steered thermal imager, the other a laser/thermal imager pod most akin to a miniaturised Pave Tack.

This ambitious plan for enhancing the CAS/BAI fleet collapsed with the Soviet Union, but important lessons were learned, all reflected now in the JSF program. The A-7F was found to have inadequate fuel capacity for the role though its mildly supersonic speed was suitable, while the A-10A's low speed remained a problem. The F-16 equipped with the LANTIRN system was found to be cumbersome – the pod set was designed for the 'deep strike' F-15E/F-16E (XL) and intended for strikes on prebriefed targets rather than searching for difficult to spot ground targets in proximity to friendly troops.

Perhaps the most significant technology then trailed on the F-16B was a head steered helmet visor projecting thermal imaging turret mounted in front of the windshield. This was found to be very effective, as the pilot could look around the aircraft, in any direction, to find targets and spot incoming SAMs and gunfire. In conventional low level close support work, fighters ended up orbiting the area of interest while ground Forward Air Controllers (FACs) relayed the enemy force position. Being able to look 'over the shoulder' to locate targets proved invaluable.

This experience was prominent in the minds of US force

Both the F/A-22A and JSF use similar planform alignment and stealth shaping rules, reflecting a common design heritage. In the critical forward sector, the much more refined design of the F/A-22A is evident especially in the edge aligned inlet configuration and cleaner chining. The F/A-22A scatters into a smaller number of lobes over a much wider frequency band, reflecting its all aspect 'wideband' stealth requirement. (USAF & LM)

planners during the early 1990s, as the JSF was born, and LANTIRN equipped F-16CGs absorbed the role performed by the A-7D. The A-10A soldiered on, only recently acquiring Israeli built Litening II targeting pods.

During this period the US Air Force deep strike fleet retained the F-111F, the new F-15E and the stealthy F-117A, backed up by the B-52G/H and the new B-1B and B-2A heavy bombers. The then recent Desert Storm campaign illustrated that the key weakness in the force structure was the battlefield strike fleet – not only was the survivability of the slow A-10 a problem, but the range/endurance of the F-16C was inadequate even for the modest 400 to 600nm (740 to 1110km) radius needed. The US Navy and Marines experienced similar troubles with the F/A-18s, while the Marines' AV-8B Harriers suffered disproportionate losses to heatseeking SAMs.

As the JSF program materialised from the JAST technology demonstration effort, each of the respective US players brought their own wishlists to the table.

The US Air Force wanted a better CAS/BAI package than provided by the existing mix of F-16CGs and A-10As, one which absorbed all of the valuable lessons of the late 1980s and Desert Storm. This meant more fuel and weapon stations than the F-16C, stealth to beat radar guided battlefield SAMs and AAA, all round night vision to improve survivability against ground defences, and the ability to find immediate ground targets hidden from the view of a FAC.

The F-16 community insisted on good close-in air combat capability – a hedge against enemy fighters breaking through top cover CAP defences. While early proposals were devoid of an expensive radar, intended to rely on ground target coordinates provided by E-8 JSTARS, UAVs and satellites, the demand for air combat capability and more autonomy saw this idea die very quickly.

The politically vocal and influential US Marines wanted a replacement for their F/A-18s and AV-8Bs, which meant a V/STOL capability, but faster and more survivable than the Harrier. The Marines, like the F-16C community, insisted on close-in air combat capability, and wanted an all weather day night avionics package better than their two seat F/A-18D Night Attack fleet had. Tasked with close air support, the Marines needed an aircraft capable of surviving SAM and AAA defences at low level, and capable of autonomous target acquisition, absent capabilities like the E-8 JSTARS.

The US Navy at that time suffered significant losses in the budgetary game. The A-12A Avenger II ('Dorito') died at the hands of Defense Secretary Cheney, in an acrimonious dispute over performance and price, leaving them without a replacement for the 'deep strike' A-6E Intruder fleet. With much investment in the collapsed A-6F upgrade and the A-12A avionics suite, the Navy wanted a bomber which could absorb as much as possible of the capability planned for the A-12A.

What is significant is that the US Navy had a large investment in air-to-ground radar technology. The capability for simultaneous Synthetic Aperture Radar (SAR) high resolution groundmapping and Ground Moving Target Indicator (GMTI) mobile target tracking had its origins in a Norden radar planned for the A-6, which later became the basis of the APG-76 radar fitted to Israeli F-4Es. This capability was to be absorbed in the A-12A's active phased array which was also cancelled. It has rematerialised now in the JSF's APG-81 radar system – the higher power rating of this radar against the F/A-18 radars reflecting the power-hungry GMTI mode.

These diverse needs coalesced in the JSF program, which attempts to reconcile them with further and much broader aims. The stated service needs for the JSF, as per the JSF website, are thus:

• USN – 'first day of war, survivable strike fighter aircraft to complement F/A-18E/F' (This provides the stealth capability lost in the A-12A bomber, and the strike radius capability and the all weather strike avionics capabilities lost in the A-6/A-12A).

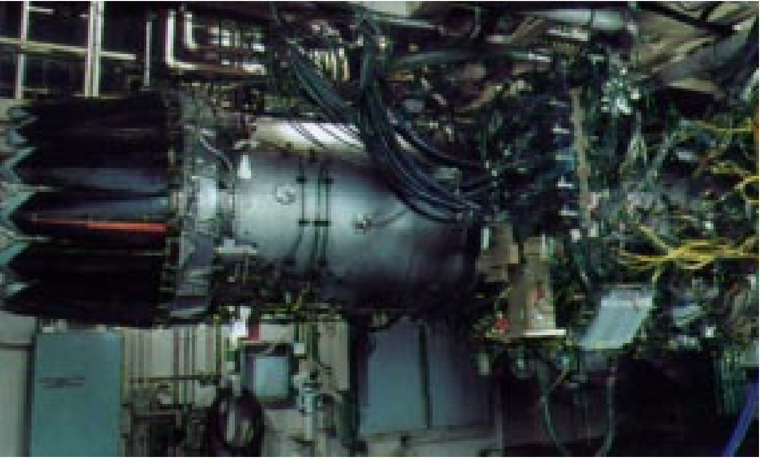
• USAF – 'multirole aircraft (primary air-to-ground) to replace the F-16 and A-10' (This absorbs the existing capabilities of the F-16CG and A-10A but incorporating the CAS/BAI avionics lessons of the late 1980s).

• USMC – 'STOVL aircraft to replace the AV-8B and F/A-18' (This replaces the capabilities in the basic and radar equipped AV-8B variants, the night strike F/A-18D and basic F/A-18C).

All three primary users plan to fly their JSFs with stealthy internal weapons during the initial phase of a conflict, shifting to larger payloads of non-stealthy external weapons once the primary radar directed air defences are broken.

Two other factors had a decisive influence on the JSF as we see it today. The first is that much of the avionics, stealth and engine technology first seen in the F-22A program was absorbed, but adapted for higher volume production and lower costs where achievable. The second was the adoption of a Cost As an Independent Variable (CAIV) design philosophy, intended to trade off capabilities and performance as required to achieve very ambitious cost aims - the simplest US Air Force model was originally to come in at $US38m flyaway each.

The common thread running through all of the US service roles is a primary strike optimisation, reflected in the JSF's avionics and airframe design. Single service roles have been clearly traded down to achieve commonality. The JSF will not provide the payload-radius of the Navy A-6/A-12A deep strike aircraft, nor will it provide the relative agility advantages of the Air Force F-16A against its original Soviet opponents. The aircraft has a more complex and expensive avionics suite than would be required for any of the single service roles, as it rolls all three requirements into one



While nominally both 'stealth fighters', there are important distinctions in stealth performance between the F-35 and F/A-22A. To save weight and costs, the JSF will use a 'narrowband' serrated circular engine nozzle (left), as compared to the highly stealthy 'wideband' edge aligned thrust vector nozzle used in the F/A-22A (right). This reflects the F/A-22A's roles of air superiority and penetration of heavy air defences, against the JSF's main role of battlefield interdiction and close air support. (LM)

package. The JSF's stealth capabilities are more narrowly optimised than those of the F-117A and F/A-22A, reflecting the need to survive mobile battlefield and littoral defences rather than penetrating an Integrated Air Defence System in depth.

The JSF is thus a radically different aircraft to the F/A-22A, in its primary design aims, capabilities and performance. Against its mid 1990s role definitions, the JSF is a very good fit, but with the evolution since 2001 toward persistent battlefield strike tactics, the JSF falls short in both fuel capacity and weapon payload. Were the JSF defined and sized today, the CTOL/CV variants would be larger twin engine fighters closer in size to the F-111 – the only viable commonality with the VSTOL roles would be in avionics and engine cores.

While the CTOL/CV JSF carries an 8170kg (18,000lb) class internal fuel load and the F/A-22A 9375kg (20,650lb), the 11,800 to 13,620kg (26,500 to 30,000lb) class empty weight JSF employs a single engine rated in the 40,000lb (178kN) wet thrust class, against the F/A-22A's pair of 35,000lb (157kN) wet thrust class engines. This results in an enormous difference in achievable thrust/weight ratio, both dry and wet, as the larger and heavier F/A-22A has almost twice the engine thrust available. Engine optimisations are also quite different, as the JSF's F135 uses a larger low(er) altitude optimised fan, compared to the high altitude optimised fan of the F/A-22A's F119-PW-100. The JSF trades away high altitude supersonic engine performance to achieve better cruise and loiter burn, and extract as much thrust as possible at lower altitudes, essential for it primary design role of battlefield strike.

The design optimisations of the 42.8m^2 (460sq ft) (CTOL/STOVL) and 57.7m^2 (620sq ft) (CV) JSF wings and the 77.2m^2 (830sq ft) class F/A-22A wing also differ radically. The JSF wing, with a sweep of around 34 degrees, falls in between the F-16's and F/A-18's, and is nearly identical to the battlefield strike optimised A-7D/E series. The F-16, F/A-18 and JSF however use vortex lift to further enhance low speed high alpha turning performance in subsonic engagements. The F/A-22A's wing, at around 40 degrees sweep, is closer in concept to the F-15 and Su-27/30 series – a tradeoff between supersonic drag and turning performance. Unlike the F/A-22A wing, which is designed around 9G supersonic agility, the JSF wing trades away supersonic performance to maximise subsonic cruise/loiter efficiency – an optimisation for subsonic manoeuvre and maximising subsonic cruise performance.

The basic aerodynamic and propulsion optimisations of the JSF against the F/A-22A reflect their original airframe design aims – the F/A-22A to kill other fighters and penetrate air defences at supersonic speeds, the JSF to hunt battlefield ground targets, and evade missiles and fighters. Like the F-15, the F/A-22A can be swung to strike roles without sacrificing its supersonic performance, but the JSF's wing and engine optimisations preclude it from ever achieving high supersonic performance, vital for running down supersonic opponents like the Su-27/30 – or supersonic cruise missiles.

The stealth design optimisations of the F/A-22A and JSF also differ markedly. The deep penetration and air dominance roles of the F/A-22A dictated all aspect capability, resulting in the expensive edge-aligned thrust vector nozzle design, which provides good 'wideband' frequency capability. The JSF is optimised for best stealth in the forward sector, sharing general airframe shaping rules common to the F/A-22A. The notable difference is in the serrated edge circular nozzle of the JSF, which is clearly optimised for best performance in the X and Ku-bands, typical of fighter radars, SAM/AAA tracking systems and missile seekers.

To achieve lower costs the JSF accepts notable aft sector stealth limitations, especially when tackling deep or layered air defences with fighter threats – an acceptable tradeoff for 'shallow' littoral and FEBA area battlefield strikes against predominantly short range mobile air defence systems. The aim in the JSF is to use newer materials technology than the F/A-22A does to reduce stealth costs, although we are likely to see this technology migrate across to the F/A-22A in later blocks.

The core avionics systems of the JSF and F/A-22A share a common architectural model – sensors are 'dumbed down' and signal/data processing is performed on software running on general purpose high performance computer processors in central processing boxes, rather than specialised hardware. This very powerful model permits rapid evolution in signal and data processing techniques, within the limitations imposed by the sensors used to gather information. Both the F/A-22A and JSF are to now use cheaper commercial processing chips and optical bus technology. The distinctions in onboard computing power between both types will be given by the immediate block upgrade configuration at that time – both using multiple commercial PowerPC chips.

The sensor suites of both fighters differ strongly, reflecting their different roles. The F/A-22A's APG-77 active array radar with 1500 modules of higher power rating than the 1200 module APG-81 radar of the JSF achieves significantly better detection range against airborne targets, and by default greater standoff range in synthetic aperture groundmapping – and any growth GMTI/MMTI modes.

The APG-77 also has growth provisions for sidelooking cheek arrays. The JSF radar is conversely designed around simultaneous SAR/GMTI strike capability, but providing air-to-air detection capabilities much better than the F/A-18A-F and F-16C. The fundamental differences between the radar packages lie not only in the F/A-22A's much superior air-air range performance, but also in their long term growth potential. While radio-frequency modifications and software growth permit the APG-77 to acquire the capabilities in the JSF APG-81, the JSF's nose size, power generation capacity and cooling capacity will set limits on the achievable air-to-air and air-to-ground range growth in the JSF.

Recent reports indicate that a second generation F/A-22A antenna, using common modules to the JSF but of higher power rating, will be phased into later block production.

The passive electronic detection suites in both aircraft differ, although few details have been disclosed. The JSF system is claimed to incorporate a passive emitter location capability (passive rangefinding of threat radars), effectively absorbing the role of the F-16CJ. Given the F/A-22A's demand for higher operating altitudes and threat radar geolocation for deep penetration, we can safely assume that its passive detection system will be much more sensitive – the radar horizon at 50,000ft is much further away than at 25,000ft.

The F/A-22A was to have been fitted with the Advanced Infra-Red Search and Track (AIRST) system, provisioned for in the avionics. This has not materialised as yet for funding reasons. The JSF on the other hand will be equipped from day one with two optical systems – the Electro-Optical Targeting System (EOTS) and the DAS (Distributed Aperture [InfraRed] System). The EOTS is a repackaged growth derivative of the latest Lockheed Martin Sniper XR laser/TV/thermal imaging pod, fitted inside a faceted sapphire window chin fairing. It will provide TV and midwave infrared imaging with multiple fields of view, and increased range laser designation, spot tracking and ranging capability over most existing podded systems.

The JSF's DAS is a radically new idea, using six fixed thermal imagers to provide spherical coverage around the aircraft, and digital processing to provide not only missile threat warning, but also a 'look anywhere' Helmet Mounted Display System (HMDS) capability for the pilot. The DAS combines the ideas trialled in F-16 head steered FLIRs for battlefield strike, with an all aspect IR Missile Approach Warning System (MAWS) capability – the latter reflecting ongoing losses of A-10s and AV-8Bs to low level infrared manportable and mobile SAMs. While an EOTS equivalent for the F/A-22A has been repeatedly discussed in the US press, it is unlikely to be added until later blocks due to existing cost caps.

The JSF cockpit is newer technology to that of the F/A-22A, using a single panel redundant projector rather than individual active matrix liquid crystal display panels. Production cost pressures may see the JSF display technology absorbed in later blocks of the F/A-22A. Integrated capabilities for networking with other platforms are similar for both, driven by the need for intra-type, and intra and inter service interoperability – with the caveat that the larger sensor footprint of the F/A-22A makes it a very much better 'information gatherer' compared to the JSF.

The weapons capabilities of the F/A-22A and JSF are similar, but the JSF is designed to carry larger 2000lb JDAMs internally, compared to the F/A-22A's 1000lb JDAMs. Both carry eight GBU-39/B Small Diameter Bombs internally – an equal payload of the 'standard' new smart bomb. With eight internal GBU-39/Bs each, the F/A-22A carries two AMRAAMs and two AIM-9Xs, while the JSF is limited to two internal AMRAAMs.

From a 'bombing productivity' perspective, armed with the GBU-39/B, supercruise in the F/A-22A provides a unique advantage. At ranges where the transit time between runway and target dominates the sortie duration, the ability of the F/A-22A to cruise supersonic at around twice the subsonic cruise speed of the JSF permits it to perform more sorties – at some ranges this becomes twice as many sorties, effectively doubling the potential 'bombing productivity' of the F/A-22A vs the JSF.

Both aircraft are equipped with external wing pylons to carry external weapons and/or fuel in scenarios where stealth is no longer required, and both will suffer range penalties due to external stores cruise drag when carried. The F/A-22A has four jettisonable pylons with paired AMRAAM rail launchers, each rated to 2270kg (5000lb), the JSF four pylons, inboard at 2270kg (5000lb), outboard at 1135kg (2500lb), with further outboard auxiliary pylons rated at 135kg (300lb) for AAMs. An external stores pod was in development for the F/A-22A.

While the JSF is funded for external air-to-ground stores clearances, at this time the F/A-22A remains limited to external tanks and air-air missiles due to the funding cap. With similar subsonic cruise range performance given similar internal fuel, both types will require generous tanker support in stealthy air-to-air and strike regimes of operation. Neither can compete with the F-111 for payload radius.

In comparing the JSF and F/A-22A in air combat roles, the F/A-22A is vastly superior. In long range BVR combat the F/A-22A has major advantages in sustained energy performance, stealth, radar range and missile kinematic performance – an AMRAAM goes a lot further if launched from twice the altitude at supersonic speed. In close-in combat the F/A-22A's greater agility cannot be contested – on dry thrust the F/A-22A out climbs and out accelerates an afterburning F-15. The JSF is designed to achieve similar performance to the F-16C, itself inferior to the F-15. In any Combat Air Patrol scenario, supercruise permits the F/A-22A to cover four times the footprint of a JSF. It can engage and disengage opponents at will, unlike the slower and less stealthy JSF. The F/A-22A outclasses the JSF across the board and is several times as effective in most air combat regimes.

In comparing the JSF and F/A-22A in strike roles, the divergent deep strike optimisation of the F/A-22A and battlefield strike optimisation of the JSF are telling. The F/A-22A is much more survivable as it is stealthier and su-

Side by side the aerodynamic differences of the F/A-22A against the JSF are prominent, especially the larger wing area, larger tails, larger leading edge sweep angle, and high alpha inlet configuration. The F/A-22A is built for supersonic cruise and high G manoeuvre, distinct from the JSF which is built for subsonic cruise and supersonic dash only. The F/A-22A on dry thrust alone outperforms an afterburning F-15C, whereas the JSF is designed around the agility and manoeuvre envelopes of the 1970s era F-16 and F/A-18 – both inferior to the F-15 family (LM).

The new 285lb Boeing GBU-39/B is the weapon of choice for stealthy strikes on battlefield, urban or other smaller targets. The JSF carries eight weapons internally, with growth up to 20 – the F/A-22A also carries eight (depicted), with growth to 12 weapons.

percruising. However, the F/A-22A in its current configuration lacks the extensive electro-optical suite and radar modes of the JSF, required for battlefield interdiction and close air support. The JSF will have better loiter performance, especially at low altitudes, and carries a larger internal bomb payload. Yet on long range strike profiles, the F/A-22A achieves similar 'productivity' in bomb deliveries as the JSF as it can transit to and from targets twice as fast, both requiring generous tanking to achieve F-111 class strike radii or on station persistence.

In comparing the JSF and F/A-22A in Intelligence Surveillance Reconnaissance (ISR) roles, the F/A-22A does much better for a number of reasons. Both aircraft will have a respectable capability for high resolution SAR ground mapping and electronic intelligence gathering built in - adaptation for ISR requires an internal digital recorder and datalink transmit capability, neither expensive.

High quality optical and thermal imaging reconnaissance would require specialised payloads for both types – the JSF EOTS is not competitive against even current multi-Megapixel focal plane imagers, as would any F/A-22A growth equivalent. Payloads such as thermal imaging strip mappers, visible/IR digital framing cameras and hyperspectral imagers would have to be carried in the internal bays of these aircraft. In this respect the F/A-22A's Sidewinder bays are much better situated geometrically, compared to the JSF's main ventral bays, permitting oblique imaging without a stealth reducing faceted bay door bulge. In the ISR game, timeliness and survivability are top considerations, and the supercruising F/A-22A wins this game without question. Future ISR payloads are likely to evolve for both types as depot fit weapon bay payloads, with additional software added.

In comparing overall evolutionary growth potential, the F/A-22A wins decisively over the JSF. A plethora of historical case studies of multirole aircraft indicate that the two decisive drivers of evolution into alternative roles are size and raw aerodynamic performance. The F/A-22A with a larger airframe, wing, internal volume, radar bay, total engine/electrical power and better stealth design has an unassailable lead. This is true for a comparison of the basic F/A-22A vs the basic JSF. An unknown at this time is the proposed deep strike FB-22A – an 'F-111 like' deep strike optimised F/A-22A derivative. This paper aircraft uses an F/A-22A fuselage and tail section, with a large fuselage plug and a highly swept delta or cranked arrow wing planform. Designed for 1000nm (1850km) class radius supercruising strikes, the FB-22A is a 'new technology F-111' intended to fill exactly that niche, but with potential to be a long range/endurance interceptor and deep escort for the B-2A.

Comparing unit flyaway costs of the F/A-22A and JSF is complex, insofar as technology migration from the high volume JSF into the lower volume F/A-22A could significantly impact next decade cost structures. Currently likely candidate technologies will be antenna modules, computer components, internal data networking, engine hot end components, stealth materials and production processes especially for composite parts. Build volumes for both types longer term remain unclear, as the US Air Force wants more F/A-22As more than it wants extra JSFs, while JSF numbers for the Navy, USMC and export may decline if current trends continue.

The current US Air Force contracted build for 287 to 332 F/A-22A Raptors is capped by political edict, while lobbying continues for an increase to 380 aircraft, and ultimately 500 plus. This follows the historical pattern seen with the F-15A-E. Unit flyaway costs at the end of the current build are expected to be in the $US80-90m bracket, with downstream technology insertion favouring the lower numbers. With follow-on builds, the numbers are likely to fall into the US$70m to 80m bracket. It is important not to misrepresent F/A-22A 'program' costs which include R&D expenses as 'unit flyaway' or FMS prices, as this results in grossly inflated and sensational numbers.

The JSF has seen a steady growth in its target costs over time. Early in its evolution is was to cost the same as an F-16C, but that soon crept up to $US38m for the cheapest basic (CTOL) model and by 2002 US reports indicated about $US50m. Now many US analysts predict a flyaway unit cost in the $US65m bracket. Where the cost of the JSF ends up will depend on a range of technological factors as well as total build numbers.

A mature production F/A-22A in the 2015 timeframe, one which has absorbed avionics, engines, materials and production technologies paid for by the JSF program, will incur its principal production cost differences against the JSF in additional structure, and an additional engine/nozzle. The order of magnitude difference in cost between F-35 and more mature JSFs and F/A-22As could be as little as $US10-15m flyaway – this estimate fitting very closely to cited flyaway numbers for F/A-22As post the current build number cap, vs the more conservative JSF estimates. If the then JSF comes in at 50 to 75 percent of the flyaway/FMS cost of the then F/A-22A, buying the much less capable JSF would be a folly.

Given what is known about both the JSF and F/A-22A, Department of Defence assertions claiming 'the really big difference is in cost' are little more than nonsense.

Next month's analysis will explore NACC and JSF program issues in closer detail.

Both the F/A-22A and the JSF are built to carry weapons internally and if required, externally. Internal carriage is used to achieve full stealth during the opening phase of an air campaign, once opposing defences are broken, larger and more diverse stores can be carried externally. While the JSF matches the internal GBU-39/B payload of the F/A-22A, it can carry only 75% of the F/A-22A's external payload. (US Air Force/LM)

ANALYSIS

by Dr Carlo Kopp, PEng

IS THE JOINT STRIKE FIGHTER RIGHT FOR AUSTRALIA?

PART 2 – JSF V RISK FACTORS

The F-35 Joint Strike Fighter (JSF) is one of the most technologically ambitious aircraft development programs ever seen, in many respects more ambitious than the TFX program which realised the F-111.

This ambition offers the promise of a battlefield interdiction and close air support optimised fighter with survivability and lethality well beyond that of the F-16C, A-10A, F/A-18A-D, AV-8B and UK Harriers it is designed to replace. The flipside of this payoff is that a considerable number of risk factors come into play, potentially affecting costs, timelines and the ultimate capabilities of the production JSF.

For Australia these risk factors combine with the deeper and more fundamental issues arising from the intended use of a survivable battlefield interdiction and close air support fighter in the more challenging roles of 'air dominance fighter' and 'deep strike fighter', missions which impose their own unique needs on combat aircraft. As Sukhoi numbers grow across Asia, Australia will face over coming decades the most competitive region worldwide, with the statistically newest fleet of third generation fighters in service worldwide.

There can be no doubt the strategy of early commitment to a new fighter has its merits as an ambit claim to lock down future defence funds, which otherwise could be gobbled up by competing programs from the Army and Navy. Buying into SDD – System Development and Demonstration – provides some sectors of Australia's industry, especially in component manufacture, access to a potentially huge market. Australia also gets to sit in on development team meetings, gaining an opportunity to learn much about the technology base used in the F/A-22A and JSF.

The early commitment strategy however has its drawbacks as well. The first is that the RAAF must politically defend a massive burst of single service expenditure in the 2012 to 2020 timeframe – with early outlays beginning post 2006. In the face of intense inter service budgetary competition, other parts of the RAAF could suffer badly as a result, sacrificed to protect the JSF. To what extent the early F-111 retirement is a result of this is yet to be known.

A second problem is the degree of access Australia actually gets by SDD buy-in, especially in key areas like stealth, engine hot end technology, AESA (Active Electronically Scanned Array) radar and software. Unless personnel with suitable engineering/science backgrounds and experience are engaged to exploit the gathered data in depth, it may contribute little useful value.

The industry benefit may also prove illusory, in that the highest value added systems integration and software sector of the industry gets a much smaller bite than the hardware manufacturing sector, who in turn must compete against overseas peers to retain their workshare. The worst case outcome – a risk in its own right – is that the manufacturers end up with very little, the Commonwealth with little technology transfer, and the RAAF gets stripped to the bone over the next decade fending off Army and Navy demands for budget.

The RAAF has lost out in the internal budgetary game in recent times – last year's Defence Capability Review saw the RAAF lose the F-111 for no gain in AEW&C, tankers or other 'tier one' assets. The Army gained Main Battle Tanks, the Navy's air warfare destroyers and support ships were confirmed, but the RAAF lost the F-111.

At the most fundamental level the RAAF faces two key challenges in replacing the F-111 and F/A-18. The first is in choosing technology which is relevant 40 years hence, effectively ruling out evolved third generation fighters like the Rafale, Eurofighter, F-15E and F/A-18E. The second is in maintaining the relative advantage Australia enjoyed over the broader region for the last 20 to 30 years, by virtue of the F-111 and F/A-18A in its earlier life. In an increasingly competitive region aiming for a low target capability in replacing the existing fleet will guarantee an inferior strategic position in one to two decades' time, if not earlier.

STEALTH CAPABILITY ISSUES

The JSF is the first 'stealth fighter' intended for export, and we can expect that production F-35s will be delivered in 'high stealth' (US) and 'low stealth' (export) configurations, differing in the performance and application of radar absorbent and lossy materials. In an environment where every ally is clamouring for the 'high stealth' model, it might be politically very tricky for Australia to get access to the full stealth potential of the aircraft when other US allies are barred from doing so.

The stealth capability in the JSF is designed for low cost and maintainability, rather than best possible stealth performance at any cost. Stealth is achieved by a combination of shaping, detail design and absorbent/lossy materials. While detail design and materials can evolve over the life of a design, and be upgraded incrementally to match an evolving threat, airframe shaping is fixed and whatever limits it imposes are unchangable.

The JSF's stealth design is optimised by shaping for the 'narrowband' X-band and Ku/K/Ka-bands, which fits the most likely threats US operated JSFs will encounter – highly mobile battlefield air defence weapons and fighter air intercept radars. The serrated nozzle and inlet design reflect this optimisation – with increasing radar wavelength both will progressively lose effectiveness. The inlet tunnels use S-bending and absorbent materials, while the tailpipe is claimed to use a blocking structure, both most effective against the X-band. The planform and edge alignment is much less disciplined than that in the F/A-22A or YF-23A, again less critical for an X-band threat confined mostly to the fore/aft sectors.

US Air Force thinking is that the JSF is used to demolish battlefield ground targets once the F/A-22As have broken the back of the air defence system and opposing fighter force – in effect the long range S-band, L-band, UHF and VHF radars have been killed off by F/A-22As, as have the opposing L-band or S-band AEW&C systems.

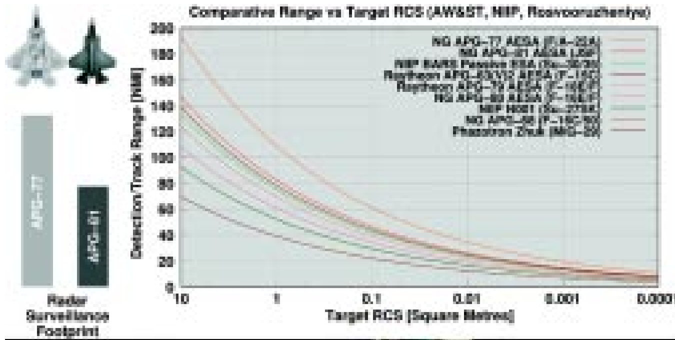
In this environment the greatest risk is presented by opposing fighters hunting with minimal or no ground radar or AEW&C support, and mobile AAA and SAM systems like the Roland, Crotale, Rapier, 2K12/9M9 (SA-6), 9K33 (SA-8), 9M37M (SA-11), Tor M1 (SA-15) and ZSU-23-4P. Such SAM/AAA systems typically use the C, X and Ku bands for their search and engagement radars, and X or Ku bands for missile guidance. For such 'shoot and scoot' high mobility surface threats and fighter threats the JSF's stealth optimisation will work very nicely.

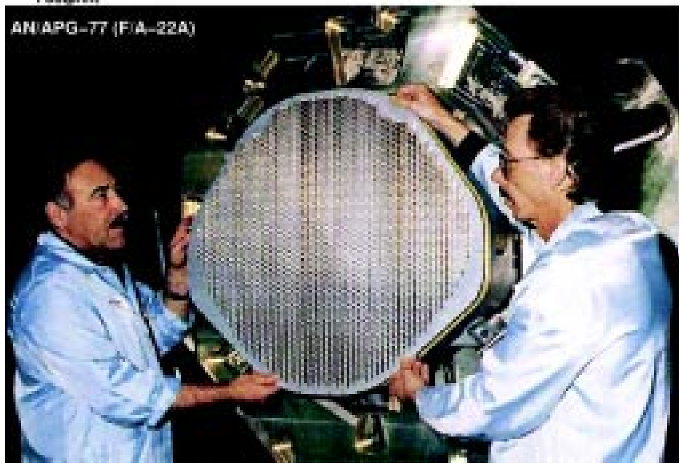
The technological design features of a fighter can be divided by the rate at which they evolve over time. The smartest long term choices are always those which put the highest priority on design features which cannot be altered once the aircraft is in service, accepting that rapidly changing technologies will be replaced over the life of the aircraft. The most attractive aspects of the JSF are all in areas which rapidly evolve, whereas its least attractive aspects are in areas which cannot evolve. From a technological strategy perspective the JSF is a very poor choice long term compared to the F/A-22A (Author).

Lowest Priority – Can Change Quickly By Upgrades

Rapidly Evolving Design Features	Slowly Evolving Design Features	Fixed Design Features
Computer Hardware	Engine Technology	Airframe Size/Weight
Computer Software	Stealth Materials	Aerodynamics
Cockpit Displays	Fuel Systems	Stealth Shaping
Weapons	Hydraulic Systems	Int Fuel Capacity
ElectroOptical Sensors	Structural Materials	Radar Aperture
Datalinks/Nav/Comm	ECS/Cooling Systems	EO Apertures
Radar Processing	Electrical Pwr Systems	Engine Massflow

Highest Priority – Cannot Change Once Acquired





This chart compares publicly available performance figures for a range of current radars, including intended performance for the JSF's APG-81 AESA. While the higher power rating of the JSF radar makes it highly competitive against the older technology passive array in the current Su-30, the introduction later this decade of active array technology in the Sukhoi will tip this balance decisively. The F/A-22A's APG-77 has an unassailable lead which it will retain longer term (Author).

For the RAAF, which intends to use the JSF to replace the F-111 in its 'deep strike' (strategic land strike) role and the F/A-18 in the air combat role, the X-band oriented optimisation of the JSF is a poor fit. In both roles this optimisation will frustrate opponents using X-band engagement and fire control radars, but leaves a major vulnerability in the lower bands, occupied by static or semi-mobile early warning, ground control intercept and acquisition radars, as well as AEW&C radars.

The availability of Russian beyond visual range missiles with very modern infrared seekers and heatseeking adaptations of area defence SAMs like the SA-6 presents a situation where the JSF could be engaged at a respectable distance, despite its good X-band stealth capability. Sukhoi Su-27/30 fighters could be vectored into a firing position without having to light up their X-band radars, or SAM sites cued in a similar fashion.

This is the pitfall of economy 'narrowband' stealth – it can defeat upper band radars used for the engagement control, but is much less effective in defeating the long range systems used to acquire targets. If an Su-30 can be positioned close enough, it can engage the JSF regardless of stealth, and with a kinematic and missile performance advantage the odds are unlikely to favour the JSF.

While having any real stealth always beats having no stealth, Australia should not develop unrealistically high expectations of the JSF's stealth capability, especially in relation to the principal regional capabilities like the Su-27/30, A-50 AEW&C, S-300 and supporting long range radar systems. The only fighter optimised for that threat environment at this time is the F/A-22.

The big wildcard in longer term US Air Force force structuring will be the FB-22A, currently a theoretical concept for a stretched delta wing F/A-22A derivative heavy strike fighter. Sized around the F-111, with a 1500nm (2780km) class radius, the FB-22A would achieve a high level of commonality with the basic F/A-22A. At the recent AFA symposium Gen J P Jumper, US Air Force CAS, presented a scenario in which FB-22A development would start in FY 2004, initial deliveries happening in FY 2011, and full rate production in FY 2016, with an initial build target of 150 FB-22As to supplement the currently planned 381 F/A-22A strike fighters – all 381 now counted as strike assets (Author/USAF).

AVIONICS CAPABILITY ISSUES

The JSF builds extensively upon the experience gained with the F/A-22's JIAWG (Joint Integrated Avionics Working Group) core avionics system, an implementation of the Pave Pillar model. It is built around three liquid cooled fault tolerant Raytheon Common Integrated Processors (CIP), each originally using a mix of DoD VHSIC custom processors and i960 chips on SEM-E format modules. The system effectively absorbs all of the processing tasks historically distributed across boxes in the radar, EW equipments, comm/nav equipment, main mission computers and cockpit display processors where used.

The aim of this model was to produce a system which could be rapidly upgraded in processing power by the addition or replacement of standardised processing modules, yet providing the ability to flexibly allocate processing power as needed by specific system functions, all implemented in software. The F/A-22A system set a record for software complexity in a fighter, with around 2.5 million lines of software source code cited. The system departed from the historical use of low speed Mil-Std-1553B busses, using the high speed Fibre Channel-Avionics Environment (FC-AE) serial bus for high speed internal interconnects.

The F/A-22A is the first aircraft to exploit this highly flexible and powerful avionics model, one which is inherently designed to ride on the back of Moore's Law (of processor speed doubling every three years). It has also been the first design to fall foul of processing chip evolution outrunning the system's development cycle, and the sheer complexity of the software creating major delays to production in its own right.

The recently redesigned 'CIP 2000' configuration uses up to 66 commercial based Motorola/IBM PowerPC RISC (ie Apple Mac compatible) and Intel i960MX processor chips and is aimed at cost reduction and supportability, with a follow on upgrade planned to further increase computing power. Since the 'G4' variant, PowerPC chips typically include an embedded 'Altivec' short vector processor which is exceptionally well suited to signal processing tasks, as found in radar, comms and EW processing.

The JSF avionics suite is built around an evolution of the F/A-22A model, but is much more complex in implementation due to the additional, and extensive, electro-optical suite and digital 'soft' cockpit. Its liquid cooled Integrated Core Processors (ICP) are intended to be a cheaper equivalent to the F/A-22A CIP, relying to a greater extent on commercial packaging technology. Like the F/A-22A, the JSF is expected to use high speed FC-AE serial buses (replacing the originally planned IEEE SCI/RT – a commercial flop) in the JAST Pave Pace model, supplemented by Firewire bussing (also used in Apple computers) in the Vehicle Management System (VMS).

For JSF System Development and Demonstration, the Mercury RACE++ Powerstream processor will be used for signal processing and I/O processing functions (this is a 9U VME format packaged multiprocessor, built around PowerPC RISC processors – essentially a bigger and faster cousin to the 6U VME packaged PowerPC processors now being used in F-15E, F/A-18E/F and F-111C Block C-4).

The core avionics system, centred in the Integrated Core Processors and their software, will present some significant development risks. While VME packaged PowerPC hardware is now widely used, it has not been used on the massive scale of the JSF to date. The large number of interconnects, density of hardware, and the demanding thermal cycling and vibration environment has the potential to produce reliability problems, especially of the intermittent variety, in the ICP subsystem. This may not become statistically obvious until a good number of systems are operationally deployed – cyclic wearout problems in printed circuit boards and connectors often resemble the

The JSF's Electro-Optical Sensor System (EOSS), comprising the ventral Electro-Optical Targeting System (EOTS) and spherical coverage Distributed Aperture System (DAS), coupled via digital processing to the Helmet Mounted Display System (HMDS) and single panel cockpit display, represents the most comprehensive – and complex – electro-optical package ever installed in a combat aircraft. While the EOTS is a repackaged Sniper XR pod derivative, conceptually closest to the F-117A's DLIR/FLIR package, the EO DAS is entirely new. Its aim is to provide spherical day/night IR coverage to facilitate target acquisition and evade threats, especially heatseeking missiles. The EOSS is primarily aimed at close air support and lower altitude battlefield interdiction roles, a result of US Air Force and Marine Corps inputs to this traditionally dangerous regime of operations (LM/CMC/VSI).

From a simple risk perspective, the much more mature F/A-22A presents far fewer headaches than the JSF does – both in terms of meeting long term capability needs, and in terms of program stability post 2010. Currently in low rate initial production, most of the initial build of around 300 F/A-22As will be completed in the 2012 to 2015 timeframe. At the time of writing the F/A-22A had just been cleared for Dedicated Initial Operational Test & Evaluation (DIOT&E), with deliveries underway to the first operational squadron, at Tyndall AFB, Florida. (LM)

behaviour of airframe fatigue damage and will not manifest until some number of cycles is accrued.

The F/A-22A's Milspec hardened SEM-E packaged system was reported to have had a number of hardware reliability problems, initially misdiagnosed as software faults – the JSF's more complex and softer commercial derived ICP has the potential to do the same on a larger scale.

A less obvious issue for the JSF will be achieving genuine 'open systems' standards compatibility throughout the ICP package and bussing. There will be a temptation to get better performance by using proprietary enhancements to commercial standards, opening a Pandora's box of longer term support issues with single source Silicon and interfaces embedded in the system.

Software has proven to be the single biggest headache in the F/A-22 development program, and the JSF with twice as much, is apt to make for twice or more the headache, regardless of lessons learned in the F/A-22. Large realtime systems on multiprocessing computers present some interesting theoretical and practical problems, especially in scheduling computing tasks and guaranteeing shared data consistency and synchronisation – many are considered analytically intractable (the author has both practiced in industry and lectured at university level real time software system design, software/systems reliability engineering, and computer internal architectural design).

Sheer complexity is a problem in its own right, typically software bug counts in systems of this complexity increase at a rate faster than the increase in the size of the code, as more software components have opportunities to interact adversely. While cockpit control, radar signal processing, EW processing, and comm/nav functions are likely to be less troublesome, the big question will be the bugginess or otherwise of the DAS (Distributed Aperture Systems) functions, data fusion functions, and offboard data networking software. Additional difficulties will arise in testing technique to validate the system. Odds are the software will be one of the biggest sources of development cost and time overruns in the latter phase of SDD and LRIP.

A related risk factor will be whether Australia is permitted access to the full software functionality, and whether source code and development systems will be provided for local enhancements and bug fixes.

The primary sensors, the APG-81 AESA radar and EOTS (electro-optical targetting system) present much lesser risks as they ride on the back of the F/A-22A APG-77, F-16E/F APG-80 and F-16/F-15E Sniper XR programs – the bigger issue for both is long term growth potential. Aperture size in the EOTS will set bounds on growth in long range detection performance. For the AESA, the bigger issue for growth will be the aircraft's cooling capacity – the physics of high linearity RF amplifier design in AESAs result in around 55% or more of the power pumped into the AESA coming out as waste heat via the liquid cooling system. Waste heat management has been an ongoing and frequently reported issue in the JSF program. Significant detection range improvements, or X-band jamming power improvements, may well be limited by the aircraft's systems rather than available AESA technology.

The X-band jamming capability planned for the APG-81 may run into similar issues as expected with the X-band optimised stealth capability – most key regional threat systems may sit well outside the frequency band coverage of the antenna design.

AIRFRAME AND PROPULSION ISSUES

As with the avionics suite and stealth capability, the airframe and propulsion package of the JSF faces some technological risks in implementation, yet concurrently the role specific optimisations of the design may not mesh well with the much broader range of roles to be performed by the RAAF using JSFs.

In terms of the airframe, the biggest development issue will be in containing the empty or basic weight of the aircraft (refer March AA Newsdesk). Excess dead weight will exact penalties in performance, be it agility, range or weapon payload at range. Techniques for reducing excess weight can include reductions in structural weight, at the expense of G-limits or airframe fatigue life, reductions in internal fuel payload at the expense of range/endurance, or reductions in the size of the avionics suite. All essentially amount to reductions in aircraft capability.

The alternate path is the use of stronger, more exotic and expensive structural materials to retain capability at the expense of cost. Both the Su-27/30 and F/A-22 use large amounts of titanium alloy for this reason.

US reports published late last year indicated that a worst case 2270kg (5000lb) excess weight could have arisen – during that period aggressive weight reduction measures are claimed to have slashed 1545kg (3400lb) of excess weight. One weight saving measure cited was achieved by changing the assembly technique, at the expense of increased assembly time and cost in production.

The latest reports indicate that the design remains around 450kg (1000lb) above intended weight targets. In an interview published last September, Rear Admiral S L Enewold, deputy program director of JSF, indicated that weight reductions would be achieved by reducing the performance envelope, ie "take some corners of the envelope and shave them off". This is consistent with the Cost As Independent Variable (CAIV) design approach, in which capability is traded down to maintain a target unit cost.

For US users of the JSF, who will task it mostly with battlefield interdiction and close air support, reductions in the aircraft's performance envelope, especially speed and agility, will be of marginal relevance – a stealthy equivalent to the F100 powered afterburning A-7 Corsair II interdictor prototype will be more than adequate.

If the USAF F-35A CTOL JSF ends up a 7.5G rated, Mach 1.3 dash speed fighter with a sea level wet thrust/weight ratio of 0.9:1, the aircraft will still be a major improvement over the types it replaces in this role. Recent statements by US Air Force Secretary Roche indicate many US Air Force JSFs may be delivered in the least agile STOVL (USMC/RN) configuration. An aircraft in this performance bracket would not be competitive in air combat roles in the Asia-Pacific environment of post 2010.

To date there have been no adverse reports on the P&W F135 and GE F136 engines, both using enhanced derivative cores from the respective F/A-22A engines, the F119-PW-100 and YF120. Both of these 'supercooled' engines have the hottest running cores to date, even hotter than the F119-PW-100 which has yet to accrue significant operational hours.

The big issue for the JSF engines will be durability – not designed for dry supercruise, the JSF will need to use afterburner in combat more frequently than the F/A-22A, presenting a more aggressive thermal cycling environment - durability of the F/A-22A's engine hot end could be a poor indicator of JSF hot end durability. Historically more aggressive operating cycles proved to be a major issue for durability in the hot end of the F-15A and F-16A F100 engine, with a number of hot end fires and written off aircraft.

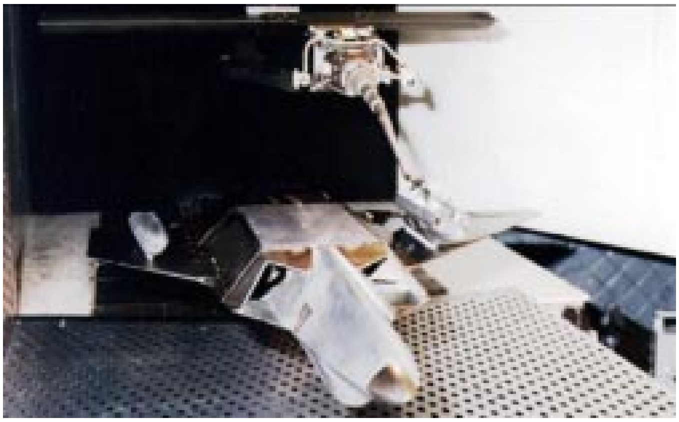
If durability issues arise, they may not become apparent until low rate initial production aircraft are in early service, and the typical measure to deal with this is derating the engine. This costs top end performance, again a non critical issue for US users, yet a problem for Australia. An issue in its own right will be the durability of any stealth coatings used in the nozzle and tailpipe areas.

External and especially internal munitions clearances could also present risks, and problems may not be solved until late in the program. The drag increasing pylon toe-out in the F/A-18E/F presents a good example. Internal release of smaller weapons like the GBU-39/B or GBU-38 500lb JDAM can be challenging, as ejection velocities in excess of 20ft/sec could be required. While the use of pneumatic ejectors will address this for the basic payload of eight GBU-39/Bs, growth configurations may present genuine problems.

JSF GROWTH POTENTIAL ISSUES

For Australia another key long term issue will be the growth potential of the JSF design. Additional engine thrust for a given core technology is usually achieved by increasing engine massflow – informed sources indicate the current inlet design has only a very modest growth margin in available massflow. Whether a 50,000lb (222kN) class F135/F136 derivative can be used with this inlet has not been disclosed to date.

Another growth issue will be available internal volume for avionics, and especially waste heat management capacity. Any increases in ICP capacity and AESA power rating will be reflected in significantly greater waste heat to be dumped from the systems, already reported to be an issue at this stage. Again, for US users targeting interdiction and support roles avionics growth limits may be largely irrelevant – more radar range and a larger information gathering footprint are not critical factors. For Australia, competing with Sukhois in air combat roles, and using the JSF to provide ISR and long range strike capabilities, growth will be a decisive issue.



The F/A-22A is not just a dedicated and specialised air superiority fighter – the US Air Force Global Strike Task Force will use its F/A-22A component mostly for trucking smart bombs. Depicted (top) is USAF AEDC wind tunnel testing of a developmental external stores pod for the F/A-22A, intended to reduce the radar signature of additional external bomb payloads. The jack of all trades JSF is part intended to replace the A-10A and AV-8B Harriers in close air support roles (bottom), and is not optimised to fulfil 'air control' or 'air dominance' roles. (USAF/LM)

The design of the EOTS window fairing and nose radomes will impose hard limits on any aperture size growth in these key sensors, in turn setting bounds on achievable sensitivity growth. This is especially a problem for advanced IRST capabilities, which require also an expensive replacement of the Sapphire windows with a longwave transmissive material.

There are many as yet unresolved technological risks in the JSF, and many of these may not be manifested until later this decade – potentially impairing the performance of the JSF in areas where Australia needs to be highly competitive longer term.

BUILD NUMBERS, TIMELINES AND COSTS

Other major risks will arise in relation to build numbers, delivery timelines and costs. We have already observed a 12 month delay introduced into the program to manage risks, while $US5bn was shifted from the low rate initial production budget into the development budget late last year.

While full scale production is almost a decade away, any schedule slippages will impact on production costs. Flyaway costs of aircraft are highest at the start of full scale production, and progressively reduce as cumulative build numbers accrue, production investment is amortised, and component manufacture matures.

Current Defence planning sees Phase 1/2 JSF deliveries starting around 2012 and ending later that decade. If the JSF production schedule is delayed significantly, Australia buys more expensive JSFs sitting earlier on the production cost curve. In plain dollar terms, buying JSFs in 2020 is cheaper than buying them in 2012.

With similar internal fuel loads in production models (differing from demonstrators), the larger but cleaner F/A-22A (left) provides similar combat radius to the F-35 JSF. Both types will suffer combat radius loss with draggy external payloads, and both types require extensive aerial refuelling support to compete with the existing F-111 in both range/payload and on station persistence. The F/A-22 can however carry more than twice the external fuel payload of the F-35 in drop tanks, giving a total fuel payload 6% greater than the F-111's. (USAF)

Cost related risks fall into three broad categories. The first is that resolution of technological problems drives up the build cost. The second is that schedule delays put any Australian buy into an earlier portion of the cost curve, assuming current schedules for F/A-18A replacement. The third is that US and export clients buy lesser numbers.

The third is potentially the most problematic, as it is driven by overseas budgetary politics and evolving strategic needs. It could manifest itself very late in the program. Since Australia joined SDD we have seen the US Navy and Marines trim back their buys, with the current total sitting around 2500 aircraft. Only the Marines and the UK are technologically locked into the JSF as they use STOVL carriers. The US Navy could bail out and buy more F/A-18E/Fs if the going gets too tough for them at any stage.

The US Air Force is F/A-22A centric in its thinking, for good strategic reasons. The JSF provides a mechanism to drive down the cost of radar, engine and avionic technology used in the F/A-22A, like the high volume F-16A drove down engine costs for the F-15A. No less importantly the JSF presents a big chunk of reserved funding for the ACC fighter fleet, one which might be redirected at a future date into funding more F/A-22As. Given the choice of putting the money into more F/A-22As and FB-22As, or JSFs, there is no contest once the US Air Force has covered its most critical replacement needs in close air support tasked A-10As and older F-16s.

Shifting strategic needs could have the greatest impact on US Air Force numbers, as its targeting model is reoriented from predominantly static to mostly mobile ground targets. Even at the JSF's nominal 600nm (1110km) radius, a lot of tanking is required to achieve significant persistence. An F-111 sized FB-22A works much better as a battlefield interdiction asset than a JSF does, and if the FB-22A does materialise it will subsume over time much of the battlefield interdiction role, driving the JSF into the specialised lower altitude close air support role which it is superbly adapted to.

As yet an unknown is the pricing and numbers impact arising from the likelihood of the US Air Force splitting its JSF buy into CTOL and STOVL variants – a proposal revived by SecAF James Roche at the recent Air Force Association symposium in the US and intended to bolster close air support/battlefield air interdiction strength in expeditionary forces. If this occurs, build numbers of the CTOL F-35A JSF will go down, driving up flyaway costs, and build numbers of STOVL F-35Bs go up, driving down flyaway costs. Out of a finite budget a smaller total number of JSFs is bought for the US Air Force, in turn impacting flyaway costs across all three variants. The US Air Force is already hedgeing its bets on JSF timelines by planning engine and avionic upgrades for many A-10As in its fleet.

Long term export numbers for the JSF remain unclear. Many European F-16 operators will simply opt to swap their existing fleets for JSFs, in a truly benign post Soviet local strategic environment.

WHAT NEXT FOR AUSTRALIA?

Australia's interest in using the JSF for air control/air dominance and long range strike roles does not fit well with the basic design optimisations of the JSF, or the outcome of likely cost driven downstream performance/cost tradeoffs in the JSF program. In distant historical terms it is akin to using a P-40 to do the jobs of a Beaufighter and P-38.

In its core role of 'classical' battlefield interdiction and close air support, the production JSF is apt to be a superb performer, more lethal and survivable than the F-16C, F/A-18A-D, A-10A and AV-8B it replaces. Its effectiveness in the air combat role, against the ever evolving capabilities of the Sukhoi fighters and newer Russian missiles, is very much open to debate and clearly problematic. In the long range strike role, around 60 JSFs with generous tanking could match the aggregate punch of the F-111 fleet, but the 'narrowband' stealth optimisations of the design will not provide the kind of unchallenged survivable deep strike capability Australia gained in 1973 with the F-111, pitted against then regional capabilities.

The big question for Australia is whether the JSF is suitable as a single type replacement for the F/A-18A and F-111. Aside from the fractional battlefield interdiction and close air support roles, the JSF falls well short in the prime air control and deep strike roles, compared to the alternative F/A-22A and likely future FB-22A.

Even at this early stage in the New Air Combat Capability/Air 6000 program an overwhelming case can be made for restructuring the program to focus on the F/A-22A rather than JSF, with a decision deferred to 2008. While the F/A-22A is more expensive, it is also more mature and much more capable permitting smaller numbers to achieve better combat effect.

A package of 36 F/A-22As is more lethal and survivable than 72 JSFs, especially in the critical air control and deep strike roles. An 'F/A-22A centric' NACC solution involves a mature production fighter after 2010 and incurs none of the schedule, technology and cost structure risks, or longer term strategic and technological risks associated with the JSF – an 'F/A-22A-centric' NACC is a very safe solution.

The current plan for early retirement of the F-111 is particularly unhelpful in terms of providing long term options for the NACC program. Retention of the F-111s past 2020 would permit spreading the expense of F/A-22A, JSF or mixed buys over a longer timeline, without any capability gaps arising. The current plan simply forces the replacement buys into an earlier and more expensive time window, while incurring a large capability gap and wastage of prior taxpayer's investment.

The stark reality is that whatever aircraft is chosen, Australia will have to live with it into the 2040 timescale. Choices which might look just good enough against the region today will not be competitive two to three decades hence, as a wealthier Asia invests increasingly in modern airpower.

End of Submission