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

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Analysis Findings

Finding 1: The Defence Senior Leadership Group does not appear to understand the magnitude or the impact of the risk factors arising in the Joint Strike Fighter program.

Finding 2: The Defence Senior Leadership Group appears to be confusing the characteristics and design aims of the smaller Joint Strike Fighter with the characteristics and design aims of the larger and more capable F/A-22A fighter.

Finding 3: The Defence Senior Leadership Group does not appear to understand the respective cost structures of the Joint Strike Fighter and F/A-22A fighter programs, and the export pricing models which apply.

Finding 4: The Defence Senior Leadership Group does not appear to understand the capabilities in the F-111, especially in terms of the aircraft's capacity for the carriage and delivery of precision guided munitions which the F-111 has been doing since the early 1980's.

Finding 5: The Defence Senior Leadership Group does not appear to understand modern strategic and battlefield strike techniques, especially persistent strike techniques required for the engagement of mobile ground targets.

Finding 6: The Defence Senior Leadership Group does not appear to understand the operational economics of the existing RAAF force structure, and their proposed RAAF force structures.

Finding 7: The Defence Senior Leadership Group excluded the F/A-22A fighter from evaluation against the Joint Strike Fighter before detailed briefing materials on F/A-22A capability and cost were available.

Finding 8: The Defence Senior Leadership Group does not appear to understand conventional Measures of Effectiveness used to compare the relative capabilities of air power force structures.

Finding 9: The Defence Senior Leadership Group does not appear to understand the characteristics of modern precision guided munitions, especially the relationships between weapon explosive payload size, weapon guidance accuracy, Designated Mean Point of Impact accuracy and target type.

Finding 10: The Defence Senior Leadership Group does not appear to understand the relationship between aircraft payload range characteristics and the resulting combat effect.

Finding 11: The Defence Senior Leadership Group does not appear to understand the relationship between combat aircraft thrust to weight ratio and the suitability of an aircraft for air combat engagements against agile fighter aircraft.

Finding 12: The Defence Senior Leadership Group does not appear to understand the differences between intended United States Air Force roles for the Joint Strike Fighter and intended RAAF roles for same.

Finding 13: The Defence Senior Leadership Group does not appear to understand the operational limitations arising from an AEW&C fleet size of only four aircraft.

Finding 14: The Defence Senior Leadership Group failed to articulate the scope and importance of the respective tasks in the AGM-142 program, and their implications for the carriage of other new generation weapons.

Finding 15: Injudicious early choices by DMO in the Stand Off Weapon (now AGM-142) program and the F-111 Interim EW program led to significant delays and higher costs in these projects, for little gain in planned capability.

Finding 16: The Defence Senior Leadership Group does not appear to understand the strategic impact of developing regional capabilities, especially the Sukhoi Su-30 fighter, the Il-78MK aerial tanker, the Beriev A-50 AWACS and Russian precision guided munitions.

Finding 17:

The reported 6% cost increase in operating the F-111 over recent years is less than one third the rate of increase in Total Costs over the period for the whole of the RAAF. Were this much lower rate of cost increase sustained, the F-111 would consume a progressively smaller fraction of RAAF Operating Costs over coming years, relative to the F/A-18A and other force elements.

Finding 18:

1. The Defence Senior Leadership Group accepted an inappropriate cost prediction model for the F-111, one which inherently inflates long term costs.
2. This cost prediction model was used inappropriately, further contributing to an inflated long term cost estimate.
3. Then available data from the F-111 engineering community was not exploited to build an accurate long term cost prediction model, one which fits with engineering data indicating longer term cost reductions. Establishing the competencies and skill sets of the personnel who developed this model will show why the appropriate engineering data was not used.

Finding 19:

1. The Defence Senior Leadership Group made public statements and provided advice to Cabinet based on a defective and inflated estimate of long term F-111 operating costs.
2. Any decisions about F-111 (Life of Type) withdrawal dates based on the inflated estimate of long term operating costs are defective and should be reversed.
3. The Planned Withdrawal Date of 2020 for the F-111 could be exceeded without prohibitive costs being incurred.

Finding 20:

The Defence Senior Leadership Group failed to follow the Defence Industry Policy in not considering the effect on Industry, in particular, the strategic importance of the extensive aircraft maintenance, engineering and systems integration capability at RAAF Base Amberley, of their recommendation to Cabinet to retire the F-111 fleet early.

Key Items Omitted by Defence in Evidence

Evidence Item 1:	An explanation of why no risk mitigation strategy, such as the evaluation of alternative solutions, exists to protect the Commonwealth against risk factors inherent in the Joint Strike Fighter program.
Evidence Item 2:	An explanation of why the superior F/A-22A was not evaluated in detail to establish the cost/benefit ratio and unit production costs relative to the Joint Strike Fighter, prior to the decision to exclude it from further evaluation.
Evidence Item 3:	Foreign Military Sales (FMS) pricing schedules for an export model of the F/A-22A, detailing the unit flyaway costs to Australia of this aircraft (not the total unit program cost to US taxpayers which is higher). The specific advice on unit flyaway costs provided by Defence to Cabinet at the time of the Joint Strike Fighter decision. If Defence was advised by Cabinet that the F/A-22A was unaffordable, any then dated documents detailing this advice to Defence.
Evidence Item 4:	An explanation of why Defence intends to use the strike optimised Joint Strike Fighter aircraft for air combat roles in which the US Air Force intends to use the high performance multirole F/A-22A fighter.
Evidence Item 5:	An explanation of what Measures of Effectiveness (MoE) Defence employed to conclude that no strike capability gap would arise as a result of arbitrary early retirement of the F-111 fleet; and whatever dated analysis reports might exist to support this conclusion.
Evidence Item 6:	An explanation of what Measures of Effectiveness (MoE) Defence employed to conclude that the AP-3C Orion was a viable strike asset in a regional environment equipped with long range Su-30 fighters.
Evidence Item 7:	An explanation of why Defence did not perform a comprehensive reliability and wearout analysis of the F-111 airframe and systems prior to recommending to Cabinet early retirement of the fleet.

Evidence Item 8:

All Defence internal studies and analyses employed to support the recommendation to Cabinet for early retirement of the F-111; These analyses including the risk analysis which claims a high risk of 'loss of capability' post 2010.

Evidence Item 9:

All studies and analyses which support the claim by Defence that an increase in empty weight in the Joint Strike Fighter would not degrade the aircraft's capability in air combat roles, especially against the Sukhoi Su-30 fighter.

Evidence Item 10:

A detailed accounting of costs incurred in the AGM-142 upgrade project, year by year, and specifically where these costs were incurred (contractors, DMO, consultants, munition warstocks etc).

Evidence Item 11:

An explanation of why the Office of the Chief of Air Force has, through internal defence and public pronouncements, in effect accepted responsibility for the developmental risks inherent in the Joint Strike Fighter program.

Notes[1]

1 Analysis in Detail

Mr BEVIS On the final matter, you have addressed an aspect of this in response to Mr Byrne's question about tanks, when you mentioned that there are three particular tanks that we are looking at. Why aren't we doing the same thing for what is going to be the most significant acquisition we make in the next decade, which is our F111 and F18 replacements? There was a program to review a number of alternative options. As I understand it, it does not exist any more at least, it is not an ongoing activity. Companies are not in town doing their bidding. It is the most important acquisition we will make and the most expensive acquisition we will make in defence procurement in the next 10 years, yet we do not have the same review mechanism and same evaluation mechanism in place that you just outlined for our tank replacement.

Gen. Cosgrove The tank technology is extant. The tanks that are being considered are either operationally proved or their technology is so contemporary that you can compare them: you are comparing apples with apples. It is somewhat different in the area of combat aircraft, which are, in virtually all respects, a drawing board issue.

This is partly an error of fact. Of the candidate combat aircraft for F/A-18A and possibly F-111 replacement, all but the Joint Strike Fighter are currently in full scale production or Low Rate Initial Production (LRIP). Even if we narrow the field to fighters with genuine stealth capability (F/A-22A and Joint Strike Fighter), of the two contenders one is in LRIP (F/A-22A) and the other (Joint Strike Fighter) in early development (SDD), with all of the associated risks. The broad capabilities and design optimisations of both aircraft have been on the public record since their conception around a decade ago - the F/A-22A designed for air superiority and strike against high value targets, the Joint Strike Fighter/F-35 designed for battlefield strike with a supplementary air defence capability. Therefore it is possible to make reasonably detailed comparisons of fighter capabilities at this time.

Mr BEVIS Isn't that more of a reason to have a comprehensive fully-fledged analysis of what is available and to what extent it might meet our needs? The fact is we do not know the range of capabilities of the aircraft that were being considered was it 18 months ago but are no longer being considered.

Gen. Cosgrove - This is very much an area where the long lead times involved and the need to make important decisions early are very necessary if you are to obtain cutting edge technology as it becomes available. Simply to replace the F/A-18 at a time when that platform is obsolete and increasingly hard to maintain requires decisions in principle around now or in fact a couple of years ago to put emphasis on a particular platform, but remembering that a decision on the F-35 is not due until 2006.

This response is an error of fact, insofar as only the Joint Strike Fighter involves a long lead time due to its developmental status at this time. For instance the F/A-22A is in LRIP and will be in full scale production later this decade, permitting acquisition with a lead time under 4-5 years, for a buy which enters production concurrently with the last aircraft in the initial US Air Force acquisition block of ≈300 F/A-22As. Other current production types can also be sourced with a 2-4 year lead time as evidenced by the recent South Korean purchase of the advanced Boeing F-15K.

Notes[2]

Mr BEVIS - I can understand that, with a critical acquisition like this and the way in which the aerospace industry works, we may well take a decision that we want to be in on the ground to some extent, as we have done with the Joint Strike Fighter. I can understand that being a prudent thing to do. What I am questioning, though, is at the same time deciding that we as a government, as a parliament, Defence acting on behalf of the government, should cease to be involved in a process of evaluation of the range of options available to us, particularly given the exact set of circumstances you describe, which is that we do not know what the final capability of any one of those craft will be because they are still largely on the drawing board.

Gen. Cosgrove - We have a very good idea that the United States future combat aircraft, the F-35, will be exceptionally good. We also know that it is a very well resourced project. The number of like countries which have invested in it is quite high and it will be produced in its hundreds and hundreds. So in terms of the bet that we are making, it is a pretty sure bet.

This response understates the number of risk factors in the Joint Strike Fighter program and the severity of their impact, should they materialise. Key risk factors can be summarised thus:

1. The US armed services significantly reduce their planned numbers thus driving up the unit cost of the Joint Strike Fighter. This has partly materialised with the reduction in US Navy and Marine Corps Joint Strike Fighter numbers, and recent proposals to reduce US Air Force numbers to pay for more F/A-22As.
2. The basic development cost, and unit production cost of the aircraft rise as technical problems are solved in the design, thus driving up acquisition costs.
3. The US Congress refuses to approve export of full software capabilities to Australia.
4. The US Congress refuses to approve export of full stealth capabilities to Australia.
5. The production aircraft is not representative in aerodynamic performance and system capabilities against the paper aircraft envisaged in 2002. Reported difficulties with aircraft empty weight could contribute significantly to such risks.

6. Stability in a multinational development program - historically most such programs have collapsed (ASRAAM, Eurofighter/Rafale) pushing the cost burden on to the primary user and driving up costs.

7. Regional fighter capabilities may grow faster than currently expected, especially the radar / weapons capabilities and numbers of regional Sukhoi Su-30 aircraft. This would produce pressure for earlier replacement of F/A-18As but also compromise any capability advantages to be gained in operating the Joint Strike Fighter.

8. Software reliability has proved to be a major issue with the development of the F/A-22A, with significantly more software in the Joint Strike Fighter the prospects are that similar problems greater in magnitude will be seen in the Joint Strike Fighter.

9. Hardware reliability in the Commercial Off The Shelf (COTS) centric avionic system could prove to be a major problem, and may not be found until the aircraft has been in service for some time. Inadequate aircraft avionic cooling capacity would exacerbate this risk significantly.

10. In service durability of the 'supercooled' engine hot end technology newly adopted in the Joint Strike Fighter may fall below expectations, forcing engine derating and this thus further reducing aircraft performance.

11. Alterations in the production and delivery schedules of the aircraft could see deliveries delayed beyond the planned withdrawal dates of the existing F/A-18A, and now F-111, exacerbating the existing capability gap. Where withdrawal dates are bounded by airframe fatigue life (F/A-18A) this would force an expensive lease of interim aircraft.

12. The supportability of the aircraft may not meet the ambitious aims of the program, increasing the total number of aircraft required to achieve a target capability level.

13. Difficulties could arise with the integration and clearance of munitions carried by the aircraft. Historically munitions carried in internal weapon bays have presented difficulties with clearances for most aircraft types.

Notes[3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15]

Mr BYRNE - In terms of the F-35, what about it specifically makes it suited to Australia s needs in the future?

Gen. Cosgrove - There is a whole raft of things, I consider: its stealth technology; its sensor suite; its capacity to carry a wide range of ordnance; its ability to network with other aircraft, particularly our AWACS Wedgetail aircraft; its ability to virtually be a broadcaster of sensor information to many other platforms; and its aerodynamic characteristics it is going to be a very flyable aeroplane. All of these mean that it is very superior to its competitors.

This response contains several errors of fact - at first glance this description appears to relate to the F/A-22A rather than the less capable Joint Strike Fighter.

1. The Joint Strike Fighter sensor suite is intended to be basic to minimise unit aircraft cost - early proposals were devoid of a radar and intended to rely wholly on targeting data provided by other platforms. The radar was later added to satisfy more demanding users.

2. The Joint Strike Fighter radar is only 9% larger than the APG-79 radar now being introduced on the US Navy F/A-18E/F fighter and is optimised for strike rather than air intercept roles. It is not designed like the F/A-22A's APG-77 radar for long range airborne target detection.

3. The Joint Strike Fighter EOTS thermal imager is a derivative of the LM Sniper XR pod design, with around 80% of the aperture area of the Pave Tack now carried by the F-111C. It is not designed for long range target imaging.

4. All modern western fighters including the Joint Strike Fighter are equipped with the Mil-Std-1760 digital weapons interface. The issue for the Joint Strike Fighter is that of what weapons can fit into its internal weapons bays to preserve the aircraft's stealth. At this time only the JDAM, Small Diameter Bomb, Mk.80 series dumb bombs, WCMD cluster weapon and air-air missiles have been cited. Many weapons which may be carried by the F-111 will not fit into the internal weapon bays of the Joint Strike Fighter.

5. The 'ability to network with other aircraft' is not unique to the Joint Strike Fighter. Current US fighters like the F-15E and F-16C have this capability already, using Link-16 and IDM radio datalinks. This capability can be added to any fighter by installing Link-16 and IDM terminal equipment and supporting software.

6. The 'ability to virtually be a broadcaster of sensor information' is a role envisaged for the US Air Force F/A-22A which has long range sensor capabilities absent in the Joint Strike Fighter. While a suitable datalink terminal would permit the Joint Strike Fighter to relay sensor information to other aircraft, the limited sensor footprint of the Joint Strike Fighter means it would do so no better than an existing fighter if retrofitted with suitable datalink terminals.

7. The Joint Strike Fighter's 'aerodynamic characteristics' are similar to the RAAF's existing F/A-18A Hornets and inferior to the F-111, F-15E and F/A-22A. In terms of agility and speed performance it will not represent a significant improvement over the F/A-18A.

8. The statement 'All of these mean that it is very superior to its competitors' is a non-sequitur - the F/A-22A outperforms the Joint Strike Fighter on all cardinal parameters, including stealthiness. All of the capabilities attributed to the Joint Strike Fighter are not unique to the Joint Strike Fighter, and with the exception of full stealth could be retrofitted to types like the F-111.

Notes[16] [17] [18]

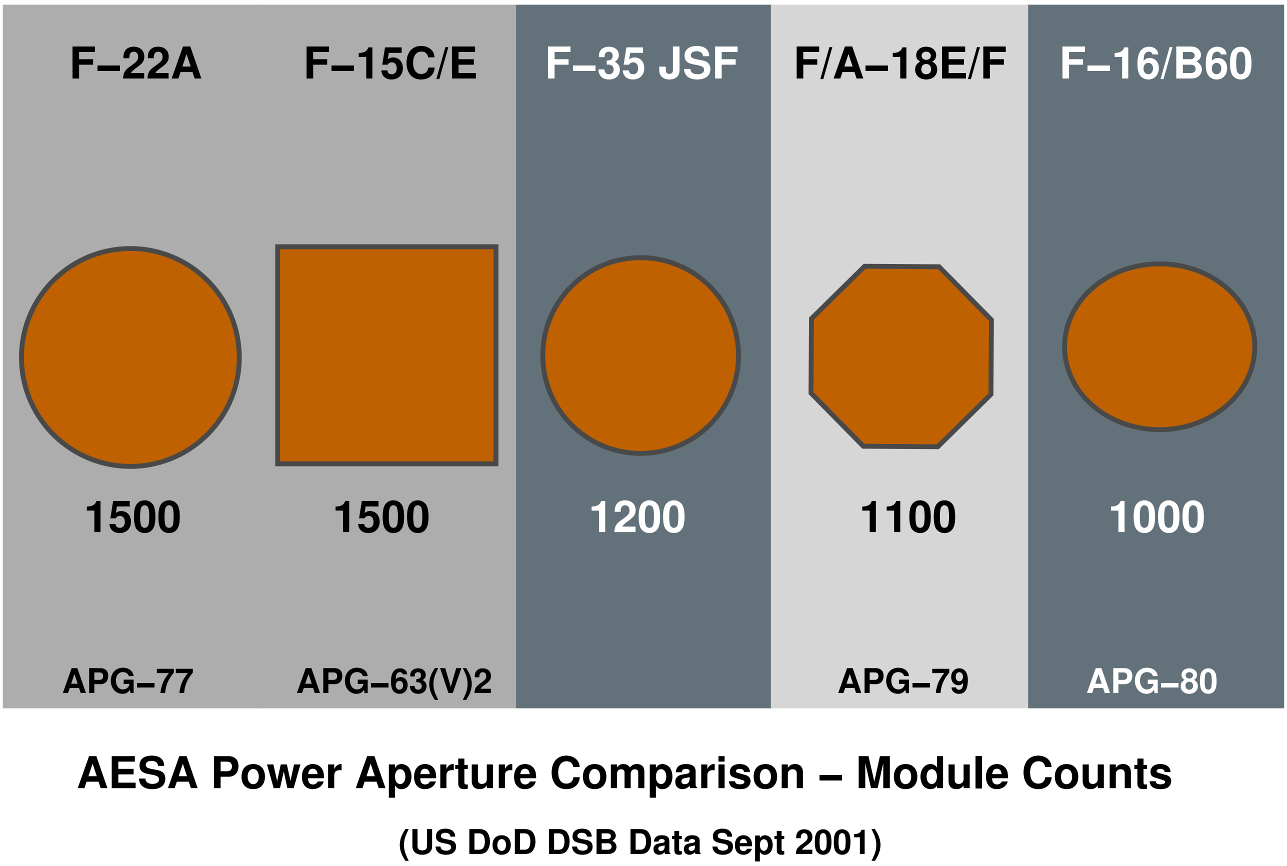


Figure 1: *Advanced radar size comparison. This diagram demonstrates that the Joint Strike Fighter radar is closer in size and basic performance to the existing lightweight radars in the F-16E/F and F/A-18E/F, rather than the top tier radars fitted to the larger F/A-22A and F-15C fighters.*
Notes[19]

Mr BYRNE - I understand that in America they have an accompaniment to that, which is the F/A-22. Given that the Americans are saying that they need a craft for their future operations, is that something that we have looked at or are we just going to stick with the Joint Strike Fighter and have no accompanying craft to maximise our performance in this area?

Gen. Cosgrove - The Americans of course have a huge budget, a global responsibility and can afford to have aircraft that are optimised for particular roles. We will look, as we looked with F/A-18, for a multirole aircraft. We know that if we have the F-35 in the time frame that we expect to have it we will have, regionally, a very superior aeroplane.

1. This statement implies that the F/A-22 is 'optimised for particular roles' whereas the Joint Strike Fighter is 'multirole'. This misrepresents the design aims of these aircraft. The F/A-22 is a multirole fighter which evolved from a high performance air superiority fighter. The Joint Strike Fighter is a battlefield strike fighter with a secondary air defence capability, mostly intended for self defence.

2. The assertion that the 'F-35 in the time frame that we expect to have it we will have, regionally, a very superior aeroplane' is not supportable by fact. The current variants of the Su-30 being purchased in this region outperform the Joint Strike Fighter (F-35) in many key performance parameters, by 2015 we will see improved variants of the Su-30 in service and follow-on radar, infrared sensor and weapons upgrades applied to regional Sukhoi fleets now being acquired.

3. A recent Russian paper detailed trials of stealth coatings and antenna improvements performed on a Sukhoi Su-35 (similar to Su-30) fighter. The authors claimed stealth performance which would effectively drive radar detection range of the Sukhoi fighters down by 40% or better. This would significantly degrade the advantage afforded to the Joint Strike Fighter by its stealth capability. especially if the US do not agree to provide full stealth capability to Australia.

4. A more appropriate comparison is that the F/A-22A is a 'high performance multirole fighter' and the Joint Strike Fighter a 'low performance multirole fighter'. On publicly available data the Joint Strike Fighter is aerodynamically inferior to the Russian Su-30 series, being purchased by Malaysia, Indonesia, China and India.

Notes[20] [21] [22] [23] [24] [25]

Mr BYRNE - Therefore, you are saying that we do not have the budgetary capability to supplement that with additional-

Gen. Cosgrove - We never have had. We will seek to invest in a multirole aeroplane where one those very obviously will suit our regional needs.

This is an unsupportable statement. The unit flyaway cost of both the F/A-22A and Joint Strike Fighter in the post 2012 timeframe cannot be accurately estimated at this time, as the production numbers of both types are yet to be determined. The US Air Force intends to increase its numbers of F/A-22A aircraft and this will most likely be at the expense of Joint Strike Fighter numbers. On available data we estimate that the F/A-22A flyaway cost will be circa 30% larger than the Joint Strike Fighter, yet the F/A-22A is twice as productive due to its unique supersonic cruise capability, permitting a smaller number of F/A-22As to perform as much work as a larger number of Joint Strike Fighters.

Notes[26]

Mr BYRNE - There was a scenario in terms of the F-111 being phased out and cruise missiles being put on F/A-18s and Orions. There has been some criticism of that, particularly in terms of the Orion, in terms of it being fairly vulnerable to attack. There are some of the Soviet fighters that are being utilised by countries such as Indonesia et cetera. Do you have any particular comment on that?

Gen. Cosgrove - We would not be putting an aircraft that may carry some form of weapon into a situation where, of itself, it was vulnerable immediately to an aggressor combat aircraft or missile. It comes down to a question of tactics. If the missile itself is capable enough then the Orion or any other non-combat aircraft or aircraft of lower capability, if I could put it that way is used in a way to reduce its vulnerability. It is certainly not used in a way where it, of itself, is vulnerable. It is a great thing that the Orion can be fitted with stand-off weapons. It presently can carry Harpoon, as you know. So it is a question of how you use the aeroplane. Again, criticism of mentioning Orion as carrying a stand-off weapon, and therefore making it more vulnerable, is a bit self-serving in a way because it forgets the fact that we simply would not, in a tactical sense, use the aeroplane in a way that heightens its vulnerability.

> This is a non-sequitur. The AGM-84 Harpoon is carried for anti-shipping strikes, in a region where hostile warships are not defended by jet fighters. The use of this aircraft for land strike or littoral strike operations would involve flying it into airspace which is under the footprint of regional Su-30 fighters. If the AP-3C Orion is not to be flown into such airspace, then it has no significant utility as a land or littoral strike asset.

Notes[27] [28]

Mr BYRNE - What sort of scenario would you and I know this is hypothesising a bit use an Orion in? What is a potential scenario?

Gen. Cosgrove - An Orion has huge endurance and can reach out an enormous distance. It has reasonable sensors itself. It might be used in an anti-shipping role. Really that is only one particular target set, but that is the way, classically, that a P-3 with a Harpoon presently operates.

Mr BEVIS - This is an issue I intend to raise later in the debate but I might take the opportunity to seek your comments, gentlemen. With the proposed early retirement of the F-111s, with or without an upgrade to the F/A-18s, there has been comment that there will be a time gap before the replacement presumably but not yet determined Joint Strike Fighter arrives in service. At the same time, we will see within our region the deployment of a number of sophisticated aircraft new generation Su-30s and aircraft of that kind which will present for a window of a couple of years an environment in which for the first time ever we will not be able to claim air superiority in the region. Is that scenario plausible and, if not, what parts of the process that I have just mentioned are out of kilter? If it is plausible, how is it tolerable?

Gen. Cosgrove - It is a bit of sloganeering, if I can say that to you, Mr Bevis. As in all of these sorts of arguments, you need to go to another level of detail. We will not be retiring the F-111s unless we have successfully got through a number of other steps, which entail optimising what we might call the air combat package F/A-18s with upgraded weaponry, upgraded sensors and any fundamental maintenance-for-life extension which incorporates air-to-air refuelling and uses all the sensors that we have for aerial combat; for example, the AWACS and the Jindalee. We would see that as a total package. If any of those programs for any reason are slowed down or do not work, which would be very unexpected to us, we still have options with the F-111. But at this stage the intent is that, having done all these things acquired modern air-to-air refuellers and the Wedgetails, and having them in service we would be in a totally different position. So, from our point of view, we will maintain the same or superior air combat capability and strike capability by the end of all these improvements.

This is a non-sequitur. Provision of 'F/A-18s with upgraded weaponry, upgraded sensors' and the intended 4-5 twin engine 'modern air-to-air refuellers' cannot offset the loss of the existing precision strike capability in the F-111 fleet (*refer Figure 2*). Moreover the Wedgetail AEW&C aircraft cannot usefully increase the weapon carrying capability of the F/A-18 fleet as its contribution lies in improving situational awareness, with the aim of improving survivability where hostile fighters are present. The statement that 'we still have options with the F-111' only holds true if the F-111 fleet is fully maintained and upgrades proposed to be cancelled to facilitate early retirement are implemented between now and 2010. If the previously planned F-111 upgrades are cancelled this will see the loss of expensive software development and system integration capabilities at Amberley, preventing a rapid resumption of upgrade work to maintain F-111 competitiveness should the aircraft be retained in service as suggested.

Notes[29] [30]

One of the issues which people do not take into account is that the F-111, which is a mighty platform and has done marvellous service for us, is getting very old, very hard to maintain and very expensive and would need considerable assistance to conduct its strike role. Ten years ago its strike role was superior, but as other capabilities come into the region the F-111 itself needs further assistance than would have been necessary 10 years ago. So the refuelled F/A-18, with a precision stand-off weapon, is a very comparable strike platform to the F-111. The F-111 will carry more bombs, but we are moving rapidly from quantity to the precision and the discrimination of the weapon.

These are multiple errors of fact.

1. Considerations of age, cost and maintainability will be addressed later in this analysis.

2. The statement 'Ten years ago its strike role was superior, but as other capabilities come into the region the F-111 itself needs further assistance than would have been necessary 10 years ago' disregards the operational reality since 1986 whereby all non-stealthy strike fighters are provided with defensive fighter escorts.

3. The high speed of the F-111 results in a lesser demand in numbers of escort fighters since the F-111 can penetrate and egress hostile airspace much faster than an F/A-18A tasked with strike.

4. The assertion that 'The F-111 will carry more bombs, but we are moving rapidly from quantity to the precision and the discrimination of the weapon' omits the fact that the F-111 was equipped to carry the precision Harpoon antishipping missile, precision laser guided GBU-10/12 and precision television guided GBU-15 bombs since the mid 1980s.

5. If upgrades planned for prior to November, 2003, are implemented, the F-111 could carry twice as many of the weapons the F/A-18A could carry, to twice the distance.

6. The ability of the F-111 to deliver the same number of precision weapons as two refuelled F/A-18s halves the number of RAAF aircraft which need to be exposed to hostile defences.

7. The intended purchase of new tankers under AIR 5402 was never intended to provide a full scale operational capability, and it is unclear how a 'replacement' and 'enhancement' of a 'training and limited operational capability' can transform itself into a full scale operational capability without changes in the size and number of tanker aircraft sought. Cite DMO website: 'Since the early 1990s, the Royal Australian Air Force (RAAF) has operated four Boeing 707s as tanker aircraft to provide a training and limited operational capability,' 'The aircraft were modified for air to air refuelling under Project Air 5080 by fitting two wing-tip mounted refuelling pods to refuel probe equipped aircraft such as the F/A-18. Due to issues associated with continuing to support the ageing B707 fleet, AIR 5402 seeks to replace and enhance the air to air refuelling capabilities of the Australian Defence Force (ADF).'

Notes[31] [32]

Mr BEVIS - Earlier today Mr Price asked some questions of the Chief of the Defence Force, and it was suggested that it might be worth while raising them with you. Firstly, I want to talk about an issue I raised this morning of our F-111 and F/A-18 replacements and the question of process. As I understand it, we no longer have a process of evaluation of various options by a participant at some level in the Joint Strike Fighter program. What is the benefit that we derive from declining to operate the normal processes that Defence would otherwise undertake for the evaluation of a new platform? What is the value to us in not going through that evaluation phase?

Air Marshal Houston - I suppose I should kick off on that question. We have joined the SDD phase of the joint strike fighter project as a level 3 partner. That gives us considerable advantages which I think we have briefed you on before. Essentially, we have committed to the joint strike fighter. I think that is a good decision because, of all the candidates that might have been on that list indeed, were on that list as part of Air 6000, there were only two fifth-generation aircraft. I think a fifth-generation aircraft is bound to be more capable than a previous generation aircraft, and the only two aircraft are the F/A-22 and the F-35. They are both manufactured by Lockheed Martin, and I think the really big difference is in cost. Simply put, I do not think Australia can afford to go out and buy the F/A-22. We are much better off going for a multi-role capability, which the F-35 joint strike fighter provides. I think going in at this stage is a sensible move. It eliminates a lot of unnecessary staff work there were a lot of candidates on that original Air 6000 list that I do not think would have made it much further anyway, for a variety of factors. I think we have made a commitment and we are headed in that general direction.

This is a non-sequitur.

1. While it is true that the F/A-22A and Joint Strike Fighter are the only two fighters in the current market worth investing in, there is an immense difference in capability between the 'top tier' multirole F/A-22A and the 'second tier' strike optimised Joint Strike Fighter.

2. The F/A-22A was designed with 'all aspect' stealth capability to impair hostile radar detection from any direction, across a wide range of radar wavelengths. The Joint Strike Fighter uses 'economy stealth' which is optimised to reduce aircraft cost by compromising stealth performance of the rear sector of this aircraft.

3. The larger F/A-22A is more agile, much faster, stealthier, and has the unique capability to perform supersonic cruise - it can transit to targets at roughly twice the speed of the Joint Strike Fighter. Therefore the F/A-22A is a much more 'productive' asset in that it can fly twice as many long range strike sorties as the Joint Strike Fighter could fly, over a given number of days.

4. A smaller number of F/A-22As could replace a larger number of Joint Strike Fighters, and provide significantly better capability to destroy opposing fighters and to penetrate heavily defended airspace.

5. The assertion that 'I think going in at this stage is a sensible move. It eliminates a lot of unnecessary staff work' is opinion not supportable by fact. The decision to pursue the Joint Strike Fighter exclusively was made prior to any substantial briefing materials on the F/A-22A becoming available to the AIR 6000 project office.

6. The F/A-22A was evidently excluded from contention without any substantial analysis of its cost in the 2012 timeframe, its capability vs the Joint Strike Fighter, and the benefit/cost ratio against the Joint Strike Fighter (*refer Annex C.*).

7. Australia is regarded by the United States as one of its very few allies trustworthy enough to be sold the otherwise unique F/A-22A capability.

Notes[33] [34]

Mr BEVIS - That is not quite the question I was asking. I have no difficulty with us participating in the Joint Strike Fighter program. That is not necessarily in conflict with us conducting an evaluation of various platforms that we might want to use to meet our requirements as distinct from whatever may come out of the end of the tunnel of the Joint Strike Fighter program. The question that seems to me to be still standing is not what benefits we get out of participating in Joint Strike Fighter one of the development partners but what is the benefit for us in not conducting an evaluation? Or did we just get it wrong when we set up Air 6000 to start with? Did we make a mistake there? Should we have just not set up Air 6000? There is nothing new that transpired between when we set it up and when we decided to dispose of it. Was that when the error was made? Should we never have looked in the first place?

Air Marshal Houston - We did an enormous amount of staff work as part of Air 6000 and, as we worked through that, it became quite clear that the F-35 was by far and away the best of the options available for Australia. If you remember, aircraft like the Sukhoi 30 were on the list, as was the Gripen, the Eurofighter, the current generation F-16 and F-15 and the Rafale. Of those aircraft, only two were fifth generation. One of the important things that both those aircraft have over all the others is a stealth capability. Stealth gives you an enormous advantage in the air combat environment. We are looking at all the candidates and, by virtue of the combination of the fifth generation technology that was going to be available stealth, better situational awareness for the pilots, improved sensors when we did the staff work initially it was quite clear that the Joint Strike Fighter stood out as the aircraft for us.

This statement includes errors of fact.

1. The decision to pursue the Joint Strike Fighter was made prior to the completion of the RFI phase of the AIR 6000 project. Therefore the only analysis which could have been performed would be a superficial reading of initial submissions.

2. The assertion that 'when we did the staff work initially it was quite clear that the Joint Strike Fighter stood out as the aircraft for us' is opinion which cannot have been supported by detailed analysis.

3. The F/A-22A and Joint Strike Fighter differ markedly not only in performance, but also in the stated areas of 'stealth, better situational awareness for the pilots, improved sensors'. The F/A-22A has superior stealth capability to the Joint Strike Fighter, especially in its aft fuselage and engine nozzle design. The F/A-22A has a superior radar detection range and passive emission detection range to the Joint Strike Fighter, by virtue of more capable avionics and larger sensor apertures.

Notes[35]

Mr BEVIS - As much as I respect your advice, I have to say I would feel more comfortable receiving that advice at the end of a normal evaluation program, which it seems to me we undertake for just about every other platform and have in the past for these sorts of major platforms. There is one downside to the fifth generation option, and that is time. When the government decided it would no longer look at any other alternatives and would close down that evaluation process, when was it intended to keep the F-111s flying until?

Air Marshal Houston - If we go back to the white paper 2000, the plan for the F-111s was withdrawal between 2015 and 2020.

Mr BEVIS - If I move from the question of process to the question of capability, that seems to me to raise another set of dilemmas. We seem to be entering an environment in which we will retire the F-111 earlier than was originally anticipated and presumably upgrade the F/A-18s by some measures, but we will not then have a replacement aircraft for potentially four, six, seven or eight years that is, between the retirement of the F-111 and the date on which we would expect our F-35s to be in service.

Air Marshal Houston - I do not think that is actually the case.

Mr BEVIS - Please correct me.

Air Marshal Houston - Essentially, we are looking to introduce the F-35 joint strike fighter from 2012 onwards. The project is going quite well at the moment and we are pleased with the way it is progressing. You seem to be suggesting that there might be a capability gap.

The originally stated Initial Operational Capability (IOC) for the Joint Strike Fighter was 2010 for the US Marine Corps, 2011 for the US Air Force, and 2012 for the US Navy and RAF/RN. These dates were intended *goals* for the first operational units in the US and UK.

As a result of the recent JSF Program Budget Decision No 737, the SDD (development) budget was increased to US$33B, while a 12 month extension was added to the SDD schedule deferring the production schedule by 12 months, and the number of aircraft to be purchased was reduced. Historically IOC dates for modern fighters usually lag behind targets by several years, this aside from the issue of whether it is wise to opt for early production aircraft which often experience teething problems. These recent developments in the Joint Strike Fighter are tangible evidence that the risk factors in this program are genuine, and many are likely to further impact the program. Schedule delays are of particular concern for the RAAF as they extend the duration of developing capability gaps, while resulting cost increases present difficulties with funding the intended complete block replacement of both the F/A-18A and F-111 fleets within the short timeframe planned for.

Notes[36] [37]

Mr BEVIS - Certainly plenty of people have.

Air Marshal Houston - Let me give a perspective from the Chief of Air Force. There will not be a loss of strike capability. What we intend to do is basically give the strike capability to the F/A-18 and the AP-3C. Before we can do that a number of things have to happen, and they are on the public record. We need to have the full introduction of the AEW&C, the full introduction of the air-to-air refuelling tankers, the full upgrade of the Hornet with an improved EW soft protection suite, an improved targeting pod, the integration of a follow-on stand-off weapon and the completion of the bomb improvement program so that we can drop either JDAMs, satellite guided munitions or laser guided munitions. We would also put the follow-on stand-off weapon on the AP-3. Once we have done all of that, we will have a good strike capability.

This assertion is not supportable by fact. Applying two different Measures of Effectiveness (MoE) for strike capability (Normalised Throw Weight and Normalised Firepower) indicates that a reduction in strike capability of the order of 50% or more will result from the retirement of the F-111 without replacement (*refer Figures 2, 3*), prior to Joint Strike Fighter deployment. If the planned for 100 Joint Strike Fighter aircraft are acquired, there will still remain a significant capability gap against the existing RAAF force structure of F/A-18As and F-111s. Delays to Joint Strike Fighter deployment and any possible reductions in buy numbers would extend the duration and size of the developing capability gap.

There has been a lot in the papers about this concept of throw weight. The concept of throw weight is something that goes back to the Cold War, where you were comparing nuclear force against nuclear force. If you have a look at what happened in recent conflicts around the world, carpet bombing indiscriminate dropping of dumb bombs is very much in the past. In the Gulf War, eight per cent of what was dropped was precision munitions and everything else was dumb. This time around it was 75 per cent. We are moving into an era where precision is what it is all about.

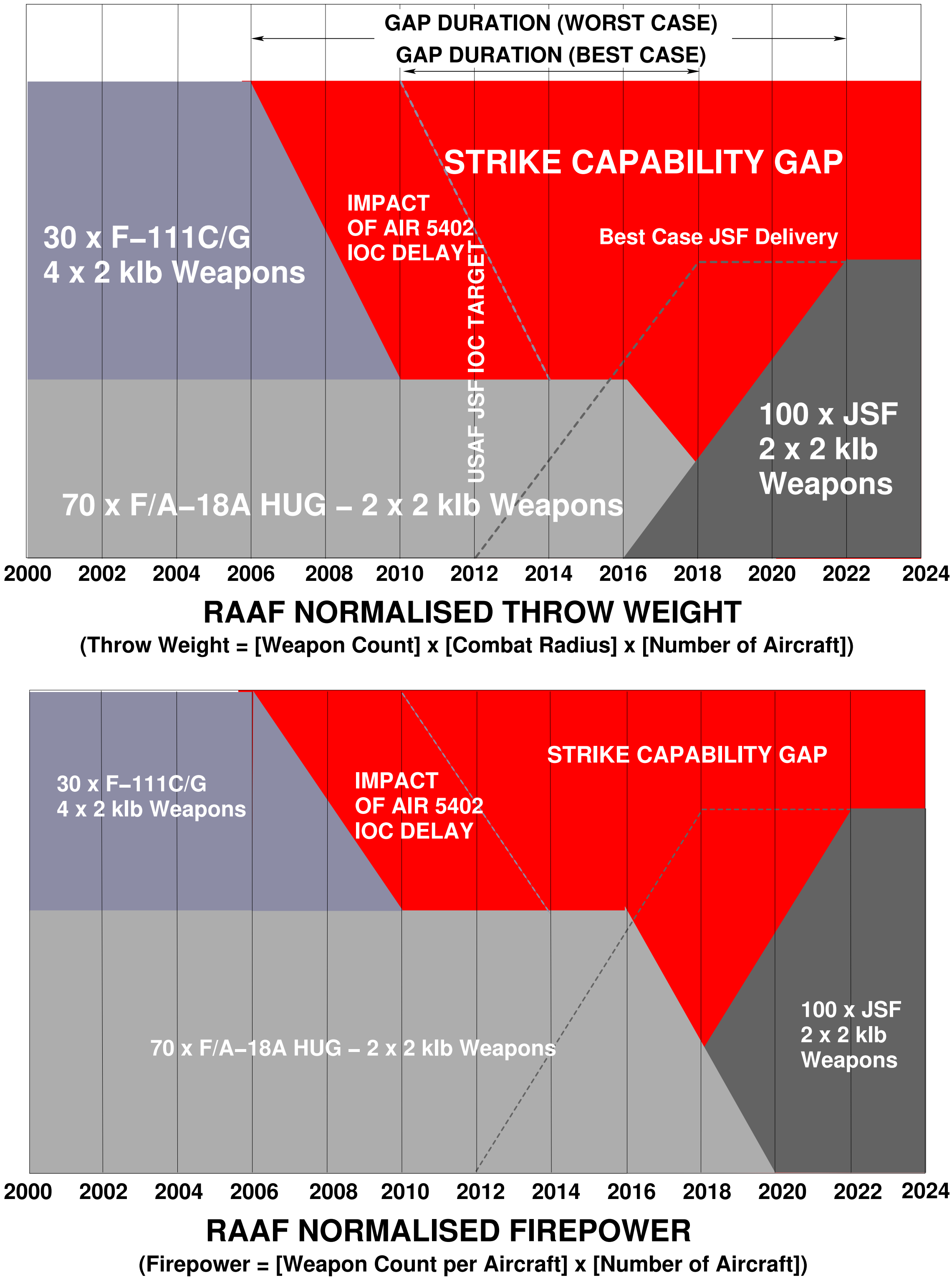


Figure 2: *RAAF strike capability MoEs - normalised firepower and throw weight. These measures are normalised and calculated for the carriage of 900 kg precision guided munitions. The diagrams illustrate that the loss of the F-111 will reduce RAAF strike capability by about 50% and that the total strike capability using the Joint Strike Fighter will remain well below that of the current RAAF fleet (C. Kopp).*

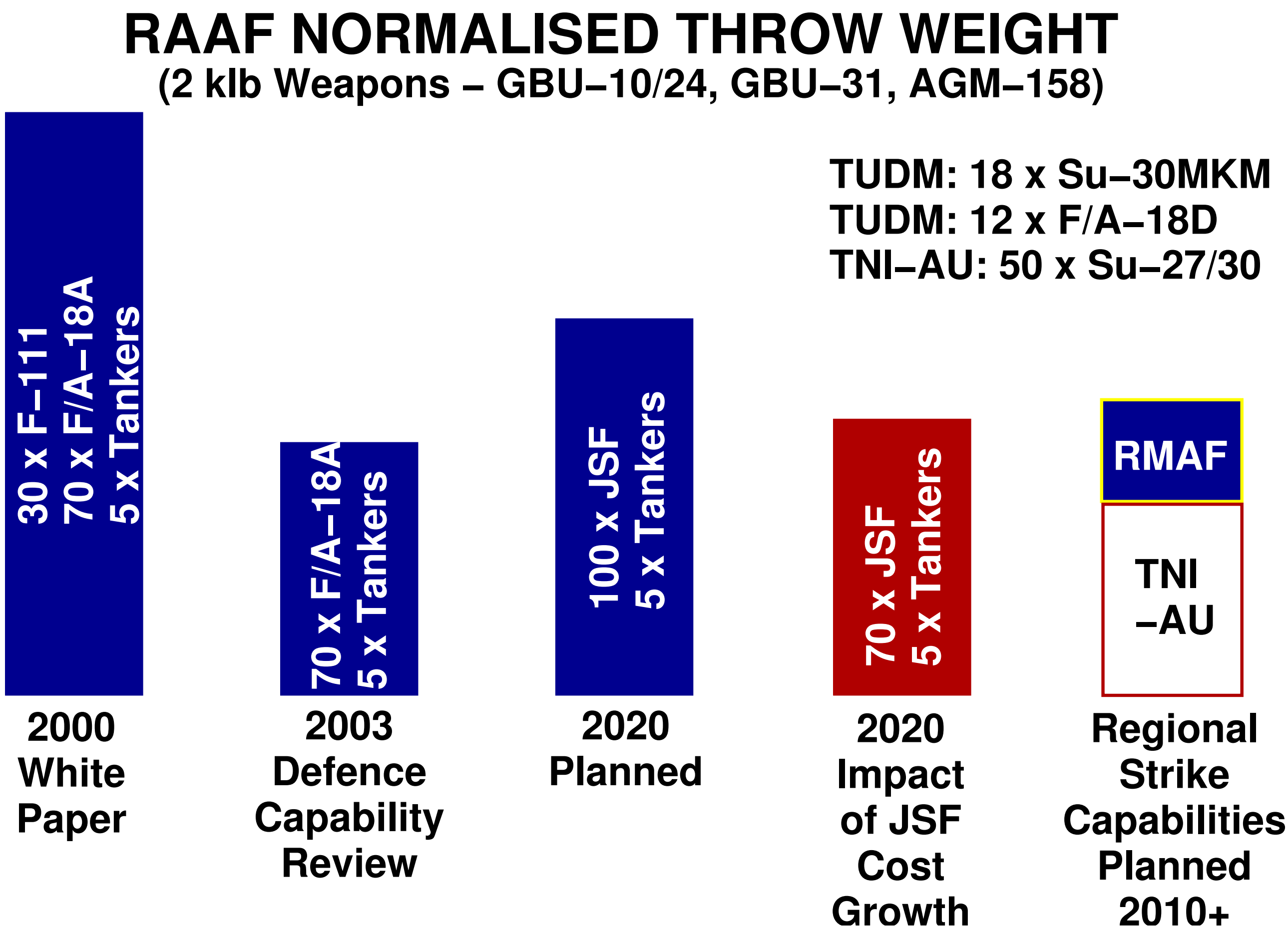


Figure 3: *RAAF strike capability vs the region. These measures are normalised and calculated for the carriage of 900 kg precision guided munitions. The diagram illustrates how concurrent RAAF downsizing and regional buys of Russian fighters will likely drive Australia down to parity in strike capability with the region (C. Kopp).*

This is an error of fact, insofar as 'throw weight' based Measures of Effectiveness are equally applicable to any class of munition. Throw weight is a measure of how many weapons of a given weight can be delivered to a given distance by a given number of aircraft, and is independent of the type of weapon, providing the weapon types used in comparison are similar in effect. It is a variant of the commonly used 'payload-radius' measure, but adjusted to account for the number of aircraft in a fleet and similar or identical weapon types. The reason why 'throw weight' was used so widely during the Cold War was because it was a measure which both the Soviets and United States were prepared to accept, again with the important caveat of agreed weapons effect. That 'throw weight' as a metric of striking force effect remains in use after several decades is testimony to its robustness, yet simplicity. If the weapon types used in the 'throw weight' calculation are identical then 'throw weight' provides a very exact measure of relative strength between two different strike forces. As the F/A-18A, F-111 and Joint Strike Fighter would all carry the same types of precision munitions, such as the GBU-31/38 JDAM, GBU-10/24 Paveway, Small Diameter Bomb and AGM-158 JASSM, there is no difficulty in applying 'throw weight' as a measure of capability.

Carpet bombing has no relevance in this context, even though this technique proved very effective for recent battlefield strikes in Iraq, Kosovo and Afghanistan.

Notes[38]

All of the bombs that we, the Royal Australian Air Force, dropped in Iraq were precision guided bombs. I would go so far as to say that we, as a nation that worries about collateral damage, would always endeavour to drop precision munitions. When you drop precision munitions, you do not need as much high explosive in the weapon that you are dropping. So when we eventually field the Joint Strike Fighter with eight small diameter munitions in the bomb bay and each of them will be precision guided by probably either laser or satellite guidance we will have a very capable aircraft that will basically match what we can do now with an F-111. By the way, if we want to use it as a bomb truck, it actually has more weapon stations on the wing than an F-111 does.

This statement contains multiple errors of fact:

1. When a precision munition is employed, the size of the munition and its explosive payload is determined by the type of target. For instance a 250 kg GBU-12 laser guided bomb is adequate to destroy a tank or machine gun emplacement, but much too small to destroy a large bunker or house. Many targets require especially heavy munitions as multiple metres of concrete must be penetrated, which is the reason why 900 kg GBU-10/24/31 and GBU-28 2,300 kg precision bombs exist.

2. The 125 kg class Small Diameter Bomb is optimised for battlefield and urban targets, and cannot be expected to produce the same effect as 900 kg bomb for all target types. When a US Air Force B-1B bomber attempted to kill Saddam in March this year, no less than four 900 kg bombs were used to destroy a single large house.

3. Equipped with a suitable smart bomb rack the F-111 could carry about twice the number of 125 kg class Small Diameter Bombs carried by the Joint Strike Fighter, or 24 of the 250 kg class GBU-38 satellite guided bomb. Moreover, it could carry these weapons to a much greater distance than the Joint Strike Fighter.

4. The statement that the Joint Strike Fighter 'has more weapon stations on the wing than an F-111 does' disregards the importance of the load carried on the weapon station, and how far the aircraft can carry that load. A small fighter like a Joint Strike Fighter cannot lift the total bombload of the much larger F-111, and with its maximum external bomb payload suffers a significant range reduction due to payload induced aerodynamic drag effects.

5. All of the munitions to be carried by the Joint Strike Fighter could be integrated on the F-111, but the opposite is not true due to the limitations in Joint Strike Fighter internal weapons bay size, and its wing weapon station carrying capacity.

6. The F-111 has an internal bomb bay similar in capacity to the internal bomb bays of the Joint Strike Fighter. It is currently used by F-111Cs to carry the Pave Tack targeting system, but could be used to carry satellite aided bombs.

7. The survivability of the Joint Strike Fighter depends critically on its stealth performance. Carriage of external weapons effectively nullifies the stealth capability of the Joint Strike Fighter.

Notes [39] [40] [41] [42]

There has been a lot of loose talk in the media about the capability of the Joint Strike Fighter. There has also been a fair bit of talking up of the F-111. I think the F-111 is a very capable platform right now. It is going great guns at the moment. But about 18 months ago I was seriously concerned about its future. We had had a wing breakage, a fuel tank implosion and major fuel leaks. We are having all the symptoms of an ageing aircraft and, as a sole operator, there are some considerable challenges for Australia to maintain that capability in service. So we have had a very good look at all the factors that are at play here, and we assess that the risk of loss of capability goes up from what it is now medium to high at the end of the decade.

This statement disregards several important factors:

1. The wing breakage was a test article in a jig at DSTO Melbourne laboratory. The F-111 Cold Proof Load Test facility at Amberley is used to guarantee the integrity of the primary structure in operational F-111s - the F-111 is the only ADF aircraft where such a guarantee exists.

2. The wing breakage happened during a test intended to verify how many wing hours could be flown by a wing on an operational aircraft. At that time the RAAF were flying aircraft with wings which had accrued more fatigue hours than US testing had verified to be safe. As a result of the test article breakage, all RAAF F-111s were retrofitted with low time wings recovered from mothballed US F-111s.

3. The pool of around 200 mothballed US F-111s provides a large collection of structural spares permitting significant structural life extension.

4. The fuel tank overpressure/explosion (not implosion) resulted from insulation breakdown in an original fuel tank wiring harness. Given that most of the wiring in the F-111s has been replaced over the last decade, it is unclear why wiring of such age was left in the aircraft since this problem is known to have been the cause of several airliner crashes in recent years.

5. The problems experienced with fuel tank leaks were a result of the suspension of fuel tank overhauls resulting from serious OH&S concerns arising from inappropriate work practices. This problem has since been rectified and is no longer an issue. The F-111 has had a history of fuel tank leaks since the 1970s, as an unsuitable sealant was used during aircraft production - F-111 fuel tank leaks are not an age related problem.

6. All three examples cited by AM Houston as 'symptoms of an ageing aircraft' were problems arising from improper support or maintenance planning / practices and all three items have been since rectified (*refer Annex A*). With proper fleet management none of these problems should have ever occurred. This is an example of attributing underperformance by Defence in planning and management to the age of a platform.

7. The statement that 'we assess that the risk of loss of capability goes up from what it is now - medium to high at the end of the decade' is not supportable by fact. Defence have not published their risk assessment and therefore it is unknown how this conclusion was arrived at. A 'loss of capability' situation arises only as a result of a critical problem which is prohibitively expensive to fix - examples being catastrophic structural fatigue or corrosion in difficult to repair areas of an airframe. Given that all key structural components e.g. wings, Carry Through Boxes, undercarriages can be recovered at very low cost from the mothballed US F-111 fleet, it is unclear how a 'high risk' could exist.

8. Evidence provided to the Parliament on Wednesday 08 May 2002 by the then VCDF: **Lt Gen. Mueller:** *In the most recent discussions I have had with the Defence Science and Technology Organisation - and I might make the observation that the Aeronautical and Maritime Research Laboratory at Maribyrnong are world leaders in the management of fatigue in airframes - they are of the opinion that at this point the airframe could be managed through to the period 2015-20. The issue with the F111s between now and the planned withdrawal date is more likely to be a question of avionics, sensors and weapons systems. That is not to say, however - as is often the case with ageing aircraft - that there will not be surprises.*

9. Asserting that 'It [F-111] is going great guns at the moment.' reflects the observable reality that the support and planning problems seen two years ago have been rectified. To assert then that future problems of greater magnitude are highly likely to arise as implied by stating that a high risk of 'loss of capability' exists is a non-sequitur, as it essentially assumes that the 'ageing aircraft engineering program' active at Amberley and DSTO will fail to continue producing effect in isolating and replacing or repairing aged components.

Refer Annex D for publicly available materials recently cited by the media.

Notes[43] [44] [45]

The other factor that is really important here is that, if we look back over the last few years, the F-111 has cost us an extra six per cent per year over the last few years. We project into the future that it will continue to cost us more as each year passes. We are working on five per cent compounded, which is probably a fairly conservative estimate. So, for reasons of capability and cost, we think the decision we have made is a reasonable one and gives the Australian government and the Australian people a good strike capability well into the future. The interim capability is different from that provided by the F-111 but, with wide bodied tankers, an upgraded F/A-18, follow-on stand-off weapons and the ability to drop either laser guided munitions or satellite guided munitions, we think we have a reasonable capability.

This statement is remarkable insofar as it is a defacto admission that Defence used an inappropriate model for future F-111 operating costs, and used that model improperly. This effectively invalidates the case put to Cabinet for early retirement of the F-111.

1. The 'compounding cost' method for projecting the operating costs of ageing aircraft is mostly used for estimating the costs of commercial airliner aircraft, which typically are not subjected to systems and propulsion upgrades, and 'ageing aircraft program' structural and system repairs. It is unsuitable because the F-111 has been subjected to extensive and ongoing upgrades, and an ongoing 'ageing aircraft program' on the F-111 fleet is replacing worn out components.

2. A precondition for the use of the 'compounding cost' method is a period of several years in which no major modifications are performed on the aircraft - this is used to establish the costing baseline for this model.

3. The last three years cannot be used as a baseline for F-111 costs as this period encompasses the replacement of wings across most of the F-111 fleet, the introduction of the 'ageing aircraft program' at Boeing, the clearing of a large backlog of deferred deep maintenance tasks accrued prior to the commercialisation of the Amberley depot, the commissioning of the Cold Proof Load Test facility and Block Upgrade Program items C-2, C-3 and C-3A.

4. The use of a 'compounding cost' model is thus unsuitable, and it was employed using an inappropriate baseline cost. Therefore any results it would produce would overstate of actual future operating costs.

5. **Annex A contains a more detailed analysis of the future operating costs issue.**

Mr BEVIS - There are a couple of points there that I would like to go to. We could probably all discuss with our crystal balls when the Joint Strike Fighter is going to be in service here and how well the program is going, and I guess it depends on which bit of information we are reading. I do not particularly want to get into that. I am happy for the purposes of today to accept your advice on that. But, assuming we get the upgrades to the F/A-18 and the other assets that you described, how would you rate the survivability of that aircraft in a hostile environment with the sorts of aircraft that you earlier referred to, such as the Sukhoi 30?

Air Marshal Houston - The Sukhoi 30 is a very capable aircraft, but obviously the weapons it carries are the crucial thing. The other thing that is important is how well they are employed, how well they are supported and how well the pilots are trained. I think our pilots are world's best standard in terms of training, and I think they will continue to be a good match for anybody. You mention survivability. I point out that we also assess that, with those sorts of capabilities being deployed in the region, the F-111 would have to be escorted by F/A-18s anyway.

This statement omits several key points:

1. While it is true that the RAAF's pilots remain the most competent within the broader region, pilot ability alone cannot offset very large differences in aircraft capability. The Su-30MK series fighters being acquired by Indonesia, Malaysia, China and India aerodynamically outperform the F/A-18A across the board - they are closest in capability to the top tier US Air Force F-15E series (refer Figure 5).

2. The Su-30MKs are equipped with a much larger radar than the F/A-18 HUG APG-73 - it can outrange the F/A-18A in the crucial Beyond Visual Range combat regime. A number of long range air-to-air missiles are now being marketed on the Su-30, weapons which significantly outrange the AIM-120 AMRAAM carried by the F/A-18A HUG (refer Figure 4).

3. There is no guarantee that regional operators of the Sukhoi fighters would not make operational use in combat of Eastern European contract instructor pilots in a crisis. These pilots are often highly skilled with thousands of hours of fighter time in their logbooks.

4. Any fighter tasked with strike, even an F/A-18A or Joint Strike Fighter, would need to be protected by escort fighters if flown against the Su-30. As the F-111 is much faster than the F/A-18A, and can sustain high speeds much longer, the F-111's odds of evading a pursuing Sukhoi fighter are significantly better.

5. Assessments of regional capabilities in which the technical assessment of opposing aircraft is devalued and the superiority of Australian aircrew emphasised were characteristic of the early 1940s, with disastrous consequences following.

Notes[46]

Mr BEVIS - Do not misunderstand me. I am not arguing the F-111 case.

Air Marshal Houston - No. I am just saying that. The reason we planned those upgrades to the F/A-18 was to cater for the exactly the sorts of developments that we are now seeing in the region. I guess my predecessors anticipated that we would face a stiffer challenge in maintaining the qualitative edge within our region towards the end of this decade. That is why we have all of those upgrades to the F/A-18 in place. Once we have those upgrades I think we will be more than a match for the opposition, particularly when supported by AEW&C, air-to-air refuelling tankers and so on. Also, the quicker we become a network-centric force rather than a platform based force the better off we are going to be.

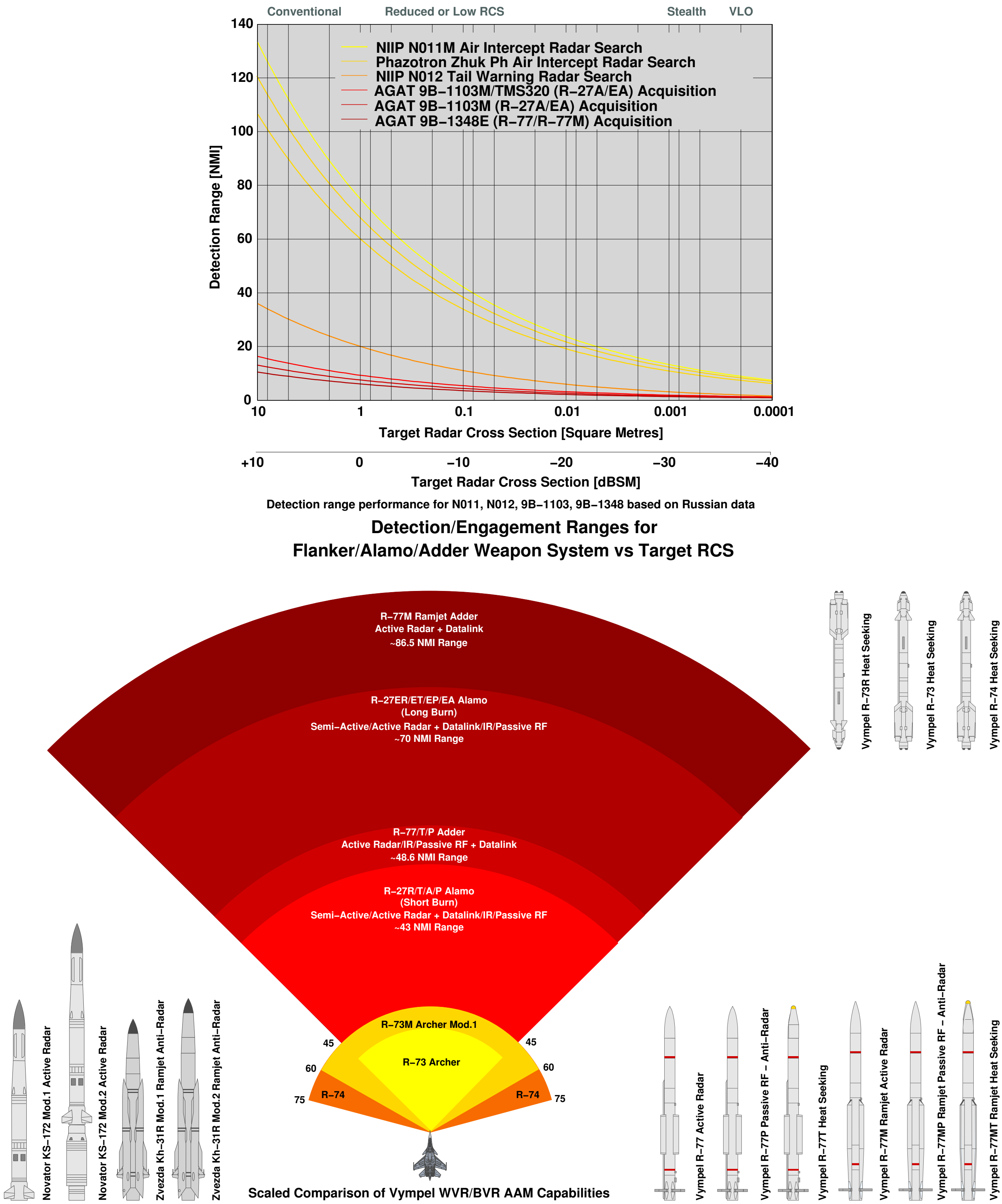


Figure 4: *Sukhoi Su-30MK Radar/Missile Performance. This diagram illustrates the range of Russian weapons which could be deployed in the region by the end of the decade. The Sukhoi's radar and missiles outperform Australia's F/A-18A HUG (C. Kopp).*

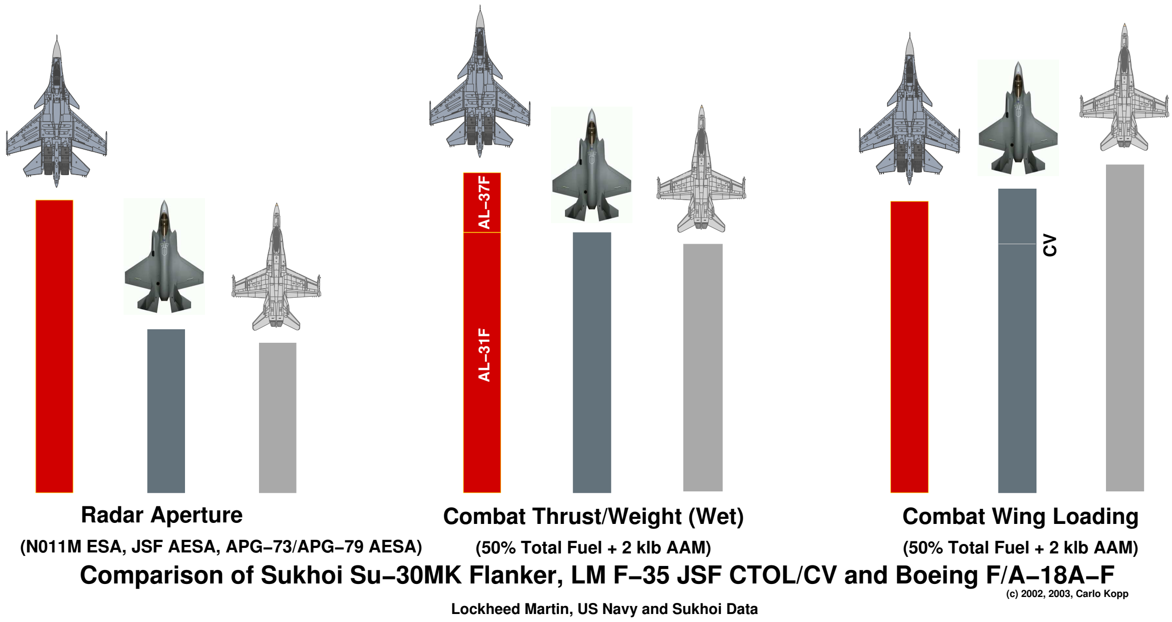


Figure 5: *Sukhoi Su-30MK vs RAAF F/A-18A HUG and Joint Strike Fighter CTOL. This diagram shows the superiority of the Russian Sukhoi in radar aperture size and agility against the F/A-18A and Joint Strike Fighter (C. Kopp).*

This statement omits several important regional developments:

1. India has ordered the Israeli A-50I/Phalcon AEW&C aircraft, China has ordered the Russian A-50E AEW&C aircraft, while Malaysia is evaluating several AEW&C types for a purchase later this decade.
2. India is taking delivery of its first batch of Ilyushin Il-78 Midas tankers - most of the Sukhois being acquired regionally are equipped for aerial refuelling (refer Figure 6. The Russian UPAZ pod can be carried by Su-30 variants to refuel other Su-30 fighters.
3. It is a reasonable prospect that AEW&C and tanker aircraft will be widely used across the region by the end of this decade, while the Su-30 will become the defacto 'standard' fighter across the region.
4. Asserting that 'we will be more than a match for the opposition' makes the implicit assumption that RAAF pilot skills and platform networking can offset superiority in fighter and missile capabilities, and parity in AEW&C and tanker capabilities.
5. *There is no historical precedent to support the case that superior pilot skills and platform networking can nullify the impact of superiority in fighter and missile capabilities, and parity in AEW&C and tanker capabilities.*

Notes[47] [48].

Figure 6: *India is taking delivery of its first Il-78MKI tankers, a type being widely marketed across the region. This example is refuelling a pair of advanced Su-30MKI fighters. With aerial refuelling the Sukhoi fighters can significantly extend their prodigious combat radius, which without refuelling is around 60% greater than that of the RAAF's F/A-18As (Indian Air Force).*

Mr BEVIS - Unfortunately, this takes me back to where I started, because I know that, in the early stages of considering what our replacements might be, some of the competitors that is, people bidding for proposals other than the Joint Strike Fighter had models of survivability that did not make me feel all that relaxed looking at the sort of configuration you have described. But I will never really know the answer to that through the normal processes, because we no longer have the normal processes to evaluate them. There is one other issue on that that I want to raise, and that is the question of tankers because of the inherent limitations of the F/A-18. Some advice the committee received on that following the experience in Operation Iraqi Freedom was that, if we wanted to have air tankers to refuel a fleet of, say, 70 to 100 aircraft or thereabouts, you would want 20 to 25 tankers. I think we are getting four or five?

Air Marshal Houston - We are getting up to five. In terms of the number required, I would like to take away the figures you just gave and come back to you to give you some better advice on what we can and cannot do.

Mr BEVIS - I would appreciate that. It will mean more to you than to me, but the advice we received came from a conference on 30 April a CENTAF review of Operation Iraqi Freedom. I cannot attest to its accuracy, but I would certainly appreciate your advice on it.

Air Marshal Houston - Certainly the more tankers you have, the better off you are. During Operation Iraqi Freedom the US Air Force would have liked to have had a few more tankers, but they will always want more tankers. If I could come back to you on that, I would appreciate it.

CHAIR - For my benefit and I hope the committee's as well, could you give us an understanding of the different capabilities of an F-35 and an F-111? As is proposed in the plan for the F-35, we are part of the project, and I know the project may vary on the way through. But in terms of capability, do they have similar ranges and payloads or are they different? Is one faster than the other? I do not know.

Air Marshal Houston - You are really comparing apples with oranges. The joint strike fighter F-35 is a true multirole air combat aircraft. It can excel in the control of the air environment and in any form of strike operation. The F-111 is really a one-mission platform. It is a strike aircraft: it can do land strike and maritime strike, and it can do close air support as well, but it cannot do anything in terms of control of the air. It has a rudimentary capability but it is very deficient in that role, whereas the Joint Strike Fighter will cover the whole spectrum of air combat and will cover it very well.

This statement contains multiple errors of fact.

1. The F-111 was designed from the outset as a multirole fighter, intended to perform both strike and air defence interceptor roles, but not the close-in visual range air combat role.

2. Cite 'The F-111B is a two place high performance, all weather, long endurance supersonic fighter aircraft. As a weapon system the primary mission is fleet defense and distant air superiority...''A secondary mission capability provides ground support attack with either air-to-surface missile, conventional armament or special weapons.' (*refer NAVAIR 01-10FAB-1, NATOPS Flight Manual, Navy Model F-111B Aircraft.*)

3. Cite 'Mission capabilities include: long range high altitude intercepts utilizing air-to-air missiles and/or guns, long range attack missions utilizing conventional or nuclear weapons as primary armament and close support missions utilizing a choice of missiles, guns, bombs and rockets.'(*refer T.O.1F-111E-1 Flight Manual F-111E, 1973, also T.O.1F-111D-1 Flight Manual F-111D, 1972.*)

4. *The RAAF choose to operate the F-111 as a dedicated strike aircraft and to that effect the F-111 has not been fitted with air-air missiles other than the defensive short range AIM-9M, and it carries a radar optimised for strike operations, but with a basic air intercept capability.*

5. With the exception of close combat against agile fighter aircraft, the F-111 aerodynamically outperforms the F/A-18A as a long range / long endurance interceptor, part of the F-111's original multirole design. The interception of hijacked airliners, long range maritime patrol aircraft and reconnaissance aircraft are all air defence roles which the F-111 would aerodynamically perform better than the F/A-18A.

6. The large Russian MiG-31 Foxhound air defence interceptor, designed specifically to hunt and kill long range bombers and reconnaissance aircraft, is very close in size, weight and performance to the F-111.

7. Industry proposed the retrofit of the new F-16E/F (formerly F-16C/B60) APG-80 radar as a cost saving and reliability improvement measure two years ago. This radar outperforms the F/A-18A HUG APG-73 radar in all air combat and strike regimes of operation. Defence did not respond to this upgrade proposal. The unit cost of this category of radar falls between US$2M and 3M.

8. Industry proposed the retrofit of a new multispectral imager package to the F-111's Pave Tack targeting system as a cost saving and reliability improvement measure two years ago, providing fleetwide reconnaissance capabilities at minimal incremental costs. This imager outperforms all established targeting pods in air combat and strike regimes of operation, including the EOTS in the Joint Strike Fighter. Defence did not respond to this upgrade proposal.

9. The Joint Strike Fighter has its primary design optimisation in the strike role, which is reflected especially in its wing design and thrust to weight ratio parameters. While such a wing can perform well in subsonic close combat, it is not well suited to supersonic air combat. The weight of the Joint Strike Fighter relative to its engine performance will limit its acceleration, climb and sustained turn performance (*refer Figure 5*).

10. *The assertion that 'the Joint Strike Fighter will cover the whole spectrum of air combat and will cover it very well' overstates the Joint Strike Fighter's supersonic performance, its manoeuvring agility and its radar detection range performance. In air combat the Joint Strike Fighter's best capability lies in its stealth which provides a good advantage in Beyond Visual Range combat - if that stealth capability is compromised the Joint Strike Fighter is likely to be marginally better than an F/A-18A in air combat. The Joint Strike Fighter is not an F/A-22A.*

Notes[49] [50] [51] [52] [53] [54] [55] [56]

CHAIR - In terms of the planned range of the F-35, how does it compare to the F-111?

Air Marshal Houston - We intend to go for the conventional take-off and landing aircraft. The F-35 has much longer legs than an F/A-18 but not quite the legs of an F-111. However, with air-to-air refuelling, it will give more than adequate range for anything that we might want to do.

> This answer overstates the relative range performance of the Joint Strike Fighter. The original design target of the F-111 was a combat radius of 1,000 nautical miles. Subject to payload and profile, F-111s typically achieve radii between 900 and 1100 nautical miles, with payloads of up to 5,400 kg of weapons. The original design target of the Joint Strike Fighter was 400 to 600 nautical miles, with an internal payload of around 2,200 kg of weapons. If an F-111 is configured to carry two internal 900 kg smart bombs, the same design payload as the Joint Strike Fighter, then it achieves almost twice the combat radius of the Joint Strike Fighter (*refer Figure 7*). Aerial refuelling can only offset the range limitations of the Joint Strike Fighter if significant numbers of aerial tankers are available. Currently planned tankers would be enough for only a fraction of the planned force.

CHAIR - Does the F-35, compared to the F/A-18, have a similar sort of payload?

Air Marshal Houston - If we are just talking about tonnes of bombs, the F-111 can carry more, but, as I said, what is important to compare in the future is the number of precision munitions that the aircraft can carry. Whilst the F-111 can carry a little bit more precision weapons than the F-35, the comparison is not as great as you might imagine.

> This answer overstates the range-payload performance of the Joint Strike Fighter relative to the F-111.
>
> 1. In practical terms the F-111 can carry about twice the weapon payload of a Joint Strike Fighter to almost twice the distance (*refer Figure 7*).
> 2. *In terms of 'payload-radius' based Measures of Effectiveness, the F-111 provides at least three times the 'payload-radius' of a Joint Strike Fighter.*
> 3. The standard precision weapons payload for the F-111 is four 900 kg smart bombs. The standard precision weapons payload for the Joint Strike Fighter is two 900 kg smart bombs, half that of the F-111. This twofold ratio is repeated for smaller smart bombs and is determined mostly by the size of the aircraft.
> 4. A twofold difference in capability cannot be described as 'a little bit more'.
> 5. Since 2001 bombing technique has shifted to the engagement of highly mobile targets, using 'persistent strike' (killbox interdiction) techniques. To perform this role successfully a strike aircraft must carry a large payload of precision munitions so it can loiter over the battlefield for hours without exhausting its weapons supply. While aerial refuelling can extend the persistence of a smaller fighter like the Joint Strike Fighter, it cannot replenish expended munitions.
> 6. The large fuel capacity and much larger precision weapons capacity of the F-111 make it a much better suited aircraft than the Joint Strike Fighter in performing modern battlefield strike technique against mobile ground targets.

Notes[57]

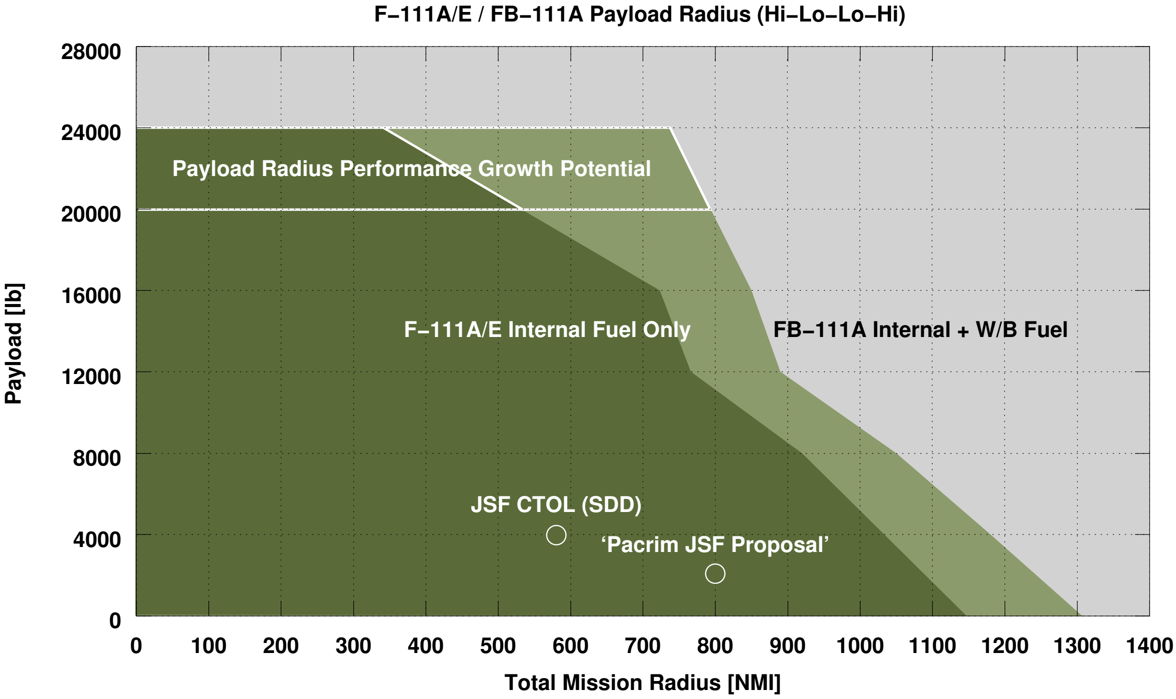


Figure 7: *This plot is based on General Dynamics performance charts for the F/FB-111 series, and published Lockheed Martin data for the Joint Strike Fighter. The F-111 provides nearly twice the combat radius of the Joint Strike Fighter with a similar precision munitions payload, or up to four times the payload of the Joint Strike Fighter to the same distance.*

CHAIR - Why would we be going for just the conventional take-off and landing aircraft? There are three versions, I understand, and conventional aircraft can carry in a kind of adjunct sort of way.

Air Marshal Houston - The conventional take-off and landing aircraft is considerably cheaper than the other two variants. The carrier based version will be a much heavier aircraft because it has to operate off aircraft carriers. It has all of the landing gear and the heavy equipment that is required to operate off a carrier deck. The vertical landing and short take-off aircraft obviously has a much shorter range and is much more expensive. Whilst it is very reasonable over short ranges, it is quite limited over longer distances. It will also operate to lower G limits than the conventional take-off and landing aircraft.

Mr BEVIS - That has run into some weight problems. I was not planning on getting into this discussion but the chairman's question sort of prompts me to. Given our involvement in the Joint Strike Fighter program, are we concerned about the difficulties that have been encountered with the weight to power ratio problems, which have impacted most substantially on the vertical take-off variant?

Air Marshal Houston - I do not think there is a problem with the power to weight ratio; I think there has been a problem with weight, and those problems are greatest on the V-style model. I am not concerned about the weight problem as it applies to the conventional take-off and landing aircraft. I think those problems are manageable.

> This answer understates the importance of the aircraft's thrust to weight ratio as applicable to Australia's intended use of the Joint Strike Fighter for air combat roles.
>
> 1. The problems of weight and available engine thrust are inseparable in a combat aircraft. The aircraft cannot have a 'problem with weight' without having a problem with 'power to weight ratio'.
> 2. A weight problem will impair the aircraft's climb rate, important for air combat and intercept roles; its manoeuvring performance, important for air combat roles; and its range performance, as finite fuel is burned to carry the extra weight.

Mr BEVIS - Manageable in the sense that you reduce the range or you reduce the payload or is there a solution to the weight?

Air Marshal Houston - The project is working on the issues at the moment. I would hope that we get further weight reduction, but the weight issues are not major issues. They do not give me major concern put it that way and, indeed, nor do they give any concern to some of the people I have spoken to in the United States.

> 1. Typical measures to reduce weight include reducing the fuel payload, reducing the capability of the avionics, reducing structural strength and manoeuvre limits.
> 2. The primary role of the Joint Strike Fighter in US service will be battlefield strike, the role of the US aircraft the JSF is to replace (F-16C, A-10A, F/A-18A, AV-8B). In the battlefield strike role weight is not a critical performance factor.
> 3. Therefore weight reduction measures which impair air combat performance indeed may not be of major concern to US customers for the Joint Strike Fighter, even if they compromise the aircraft's capability to perform air combat in Australian service.
> 4. The roles intended for the Joint Strike Fighter in Australian service are much broader than the roles planned for by its US customers, including air combat and long range strike.

Mr PRICE - In terms of the F/A-18 improvements, could you run through what improvements need to be made and in what timeline they will be made?

Air Marshal Houston - What I can do, if you like, is run through the Hornet upgrade program. In the first phase we upgraded the communications, navigation and identification system. In HUG 2.1 we upgraded the radar; we have now got an APG 73 radar. That was the aircraft that we sent to the Gulf, and it performed very well. The combined interrogator transponder made it very useful in the air-to-air environment and, with the new radar, it went very well. With HUG 2.2 we have the Joint Helmet Mounted Cueing System, colour displays and Link-16. Link-16 is vital to give us that network enabled capability we need in the defence force of the future. It will enable us to link up with the AEW&C and, if necessary, remain passive. It gives us a lot more tactical options than otherwise would be the case. We will also have the software upgrade, and that will enable a lot of other things to be done to the jet further downstream. HUG 2.3 is the EW self-protection upgrade. HUG 2.4 is the replacement of the target identification and designation pod, and HUG 3.1 and 3.2 are structural refurbishment phases that will enable the aircraft to continue operation into the future.

Mr PRICE - What about time lines?

Air Marshal Houston - HUG 2.1 was completed earlier this year; HUG 2.2 should be delivered by about 2006. I have not got information in front of me for the EW Self Protection. The new pod will be in by about 2006 and we will be embarking on HUG 3.1, the minor structural refurbishment, in the near future. I have not got a completion date for you. EW Self Protection will be complete no later than 2009.

Mr PRICE - With the AEW&Cs, isn't there an option for an additional 10 per cent and you can get two more in terms of the price?

Air Marshal Houston - The government has an option available to it to purchase two more AEW&C if they decide to go that way.

Mr PRICE - When does that option run out?

Air Marshal Houston - I believe the option is open to us until the middle of next year.

Mr PRICE - Has the government sought recent advice on that option?

Air Marshal Houston - I think the government, as part of the defence capability review, confirmed the decision it made as part of the white paper 2000 that it would still

Mr PRICE - So it is four, is that what you are saying?

Air Marshal Houston - Yes.

Public statements at the time of the AEW&C decision indicated that the purchase would include four complete aircraft, plus two 'mission systems' comprising the complete radar and avionic hardware required to convert two Boeing 737 airframes in to complete AEW&C aircraft. Therefore the package is for six mission systems, but only four aircraft to carry them. The incremental cost of the additional two airframes required to produce six complete AEW&C aircraft is thus quite low and not taking up this option results in the taxpayer covering the cost of the additional mission systems but not receiving any benefit from their use as they would be put into storage.

Mr PRICE - When do you anticipate the five tankers will be in service?

Air Marshal Houston - It should be 2007.

CHAIR - Has the decision been made on the tanker?

Air Marshal Houston - It is out for tender at the moment. The tenders are being assessed.

Mr PRICE - Are you able to indicate how many Global Hawks you are looking at and what time they might be in service?

Air Marshal Houston - We anticipate around five, with a view to introduction to service around 2009.

CHAIR - In relation to the airborne early warning and control aircraft system, we have got four on order with the possibility of ordering another three is that correct?

Air Marshal Houston - Four are being worked at the moment as part of the project, and there is an option for a further two but only two.

CHAIR - I see three, but it must have been two.

Air Marshal Houston - The confusion probably goes way back. The original project had an option of three but it was reworked, if you remember, in 1999-2000.

CHAIR - How critical are the additional two for our capability that is, having six rather than four? Will four do the job? All of these things are related to money, I know, but four obviously gives us a degree of capability. How much more would another two give us?

Air Marshal Houston - You would obviously get more capability the more aircraft, the more capability. But four gives us a very, very good capability.

This response does not explain how much capability is provided by a package of four aircraft, relative to strategic needs:

1. 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.

2. To provide on-demand coverage of single immediate area of operations requires one AEW&C aircraft, plus an additional spare should this aircraft experience technical difficulties.

3. A single aircraft can continuously surveil a circle of about 450 nautical miles diameter for low altitude airborne targets.

4. 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.

5. 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.

6. 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.

7. 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.

8. With four aircraft the RAAF could not provide continuous 24/7 air defence coverage between the North West Shelf and Darwin areas. At least seven aircraft would be required.

9. With four aircraft the RAAF could not provide 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 would be required.

10. Should Australia need to provide 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 permit coverage for only three capitals.

Mr BEVIS - When we signed the contract for the AGM-142 air-to-ground missile, did ADF know at the time that it would not fit on to any existing platforms?

Air Marshal Houston - It would fit on an F-111.

Mr BEVIS - There is modification work required for the F-111 to use that AGM-142.

Air Marshal Houston - Yes, any weapon that you buy

Mr BEVIS - How many years has that modification program been going for?

Air Marshal Houston - I would have to get back to you on the precise number of years.

Mr BEVIS - How long will it be, after we sign the contract and have got the AGM-142s, before we can use them?

Air Marshal Houston - We anticipate being able to use them operationally in 2006.

Mr BEVIS - Which is 10 years after we signed the contract, I think.

Air Marshal Houston - I would have to get back to you on that, Mr Bevis.

Mr BEVIS - Which takes me back to my original point: did we know when we signed the contract which I think was in 1996 that we did not have a platform that we could put them on? Maybe that was not the right way of phrasing it. Did we anticipate that it was going to be 10 years before we could fit it to a platform that, theoretically, could take it with modifications?

Air Marshal Houston - I think that, with any weapon you buy, it has to be integrated into the platform. It would not matter what we went out and bought, we would have to integrate it into a platform. I think it is probably true to say that the scope of the integration task was underestimated when we started the project. I can get back to you on those other details.

This assertion omits important facts:

1. The integration task for the AGM-142 missile on the F-111C comprises two main tasks, one of which is specific to the AGM-142 missile, and one of which permits the F-111C to easily accept a wide range of other modern smart munitions.

2. The tasks specific to the AGM-142 include aerodynamic clearance testing for the weapon, integration of the guidance pod, and weapon specific software.

3. The tasks not specific to the AGM-142 include the addition of a high performance VME mission computer, additional software and a enhancement to the store management system permitting the use of munitions equipped with the Mil-Std-1760 interface. The latter includes some airframe rewiring.

4. The 'AGM-142 upgrade' therefore equips the F-111C with the hardware and software provisions permitting rapid and cheap addition of further smart munitions, including the GBU-31/38 JDAM satellite aided bomb, the AGM-158 JASSM cruise missile and the ASRAAM hypersonic air combat missile. The latter munitions are either carried by the F/A-18A or now planned for it at additional cost.

5. The 'AGM-142 upgrade' also provides the F-111C with a migration path for the existing weapon systems software, when the currently used IBM AP-102 mission computers eventually become obsolete. With minimal modification this upgrade could be applied to the F-111Gs to permit delivery of precision munitions - the collapse of the planned 'weaponisation' of the F-111G under AIR 5404 leaves these aircraft incapable of targeting smart munitions.

6. Most engineering activity on this project by contractors occurred over the last two years. Defence have not disclosed why funding was not provided earlier for full rate engineering work on this project by contractors. There is no evidence available to indicate that delays with this program resulted from causes other than restrictions in funding applied by Defence.

7. Similar circumstances apply to the retrofit of a new internal Electronic Warfare Self Protection (EWSP) system to the F-111. Planning during the 1990s, endorsed during the last White Paper process, envisaged that a new Radar Warning Receiver and internal Self Protection jammer would be fitted to the F-111. During the 1990s Defence funded the ALR-2002 program (AIR 5416), in which DSTO designed a new warning receiver for the F-111 and trials were successfully completed under the Block C-2A program. To date Defence have only funded interim EWSP capabilities, with an incremental upgrade to the existing ALR-62 receiver, and the Block C-3A retrofit of external Elta 8222 jamming pods (AIR 5391 Phase 6). As far as can be determined, the only cause for this delay are restrictions in funding applied by Defence post 2000.

Notes[58] [59] [60]

Mr BEVIS - The other question that follows from that is: are we continuing with that, so that it will be able to be fitted to an F-111 in 2006 now that we are planning on getting rid of the F-111s around 2010?

Air Marshal Houston - It has actually been fully tested on the ground, so we have a high degree of confidence that it will work as advertised once the integration task is complete.

Mr BEVIS - I guess I am just looking at the return on the dollar of a decision in 2006 for an aircraft which, at the time, we thought we would probably keep until 2020, then found that it will not be able to be fitted to the aircraft until about 2006; and in the interim we decided that we will not keep that aircraft until 2020 anyway but that we will probably only keep it until 2010. I am just not sure of the utility of the use of the money, for all of us, to do that.

Air Marshal Houston - Government have made a decision and they decided, as part of the defence capability review, to persist with the AGM-142. It is, at the end of the day, the only stand-off capability for land strike that we would have.

Mr BEVIS - If I heard you correctly earlier, you were suggesting I think that the P-3 Orions could be used as a platform for guided precision munitions.

Air Marshal Houston - Yes. It already is used as a platform for precision guided strike in the maritime strike role. We fire Harpoons from it on a fairly regular basis.

Mr BEVIS - But in the context of filling a need in that period when an F-111 decommissioning occurs and the Joint Strike Fighter comes on-line, I assume that your reference there was to some greater role for the Orions. If it was not, then please correct me. I am just trying to get the context correct.

Air Marshal Houston - Certainly we anticipate that we will integrate a follow-on stand-off weapon into the AP-3. As it happens, the role of the P-3, with the new system the AP-3 is expanding. Right now we do, over land, ISR tasks over Iraq. In terms of this, we already do precision strike, using the Harpoon missile, in the maritime environment. Integration of the follow-on stand-off weapon will broaden the options and will enable us to use the aircraft in other strike roles other than just the pure maritime environment. They will be able to be used in the littoral environment and in the land strike environment.

This statement is a non-sequitur.

1. The AP-3C Orion is not survivable in any environment where it would be challenged by Sukhoi Su-30 fighters, unless escort fighters are provided generously.

2. The demand for aerial refuelling tankers for these escorts exceeds planned tanker fleet capacity, and would divert F/A-18A fighters from strike tasks.

3. The AP-3C is much less productive than an F-111 as a launch platform for 'follow-on stand-off weapon[s]', as it is much slower and requires more escort fighters.

4. The AP-3C cannot operate in airspace defended by modern surface to air missile systems. The Russian S-300 series systems are being marketed within the near region, and China has operated them for about a decade at this time.

CHAIR - On the proposed retirement of the F-111: has there been any study or evaluation done as to how this may affect our industrial base, specifically on Queensland since it is based at Amberley in Queensland? There are a couple of Queenslanders here.

Vice Admiral Ritchie - We will declare our pecuniary interests.

CHAIR - We will declare pecuniary interest on behalf of Queensland first. But in terms of our natural industrial base that has been with us for nearly 40 years now, there obviously must have been some build-up of the natural industrial base, and employment as well. Has there been any evaluation done of what the retirement of the F-111 will mean to that industrial base in Queensland and to the jobs?

Air Marshal Houston - If you are talking in terms of a formal study, no.

1. The Amberley based Weapon System Business Unit (WSBU) operated under contract by Boeing is the largest systems integration facility in Australia, and employs several hundred highly skilled personnel including software engineers, hardware engineers, technicians and maintainers.

2. The WSBU develops and maintains software for the F-111 weapon system, integrates weapons on the F-111, performs 'ageing aircraft' engineering modifications to extend the life of the F-111 and other aircraft types (e.g. Boeing 707 tanker), electromagnetic compatibility testing and Block Upgrades on the fleet to install designed modifications.

3. The capabilities in the WSBU are unique to nations with advanced technological capabilities, like the US, UK, France, Germany, Japan and Russia. India and China are investing heavily to develop such a capability. Australia has invested over the last decade cca $1B to build up the WSBU.

4. The WSBU provides expertise applicable to modification of other ADF platforms, including vital life extending 'ageing aircraft' engineering modification design.

5. Without the F-111 the WSBU could not sustain its existing skills base and would experience a rapid collapse in capabilities. As a result Australia would lose a unique and very expensive to develop capability.

6. The proposed industry collaboration in the Joint Strike Fighter program does not include the system level software development and integration activities performed by the WSBU. Component and subsystem manufacture requires quite different skills sets and capabilities to system level software development and integration work.

7. The loss of the F-111 would thus cause the collapse of the WSBU and in turn the loss of Australia's capability to perform such avionic integration tasks. The recent announcement of plans for early F-111 retirement will produce an ongoing loss of highly skilled personnel seeking stable careers elsewhere, given that the future of their current positions is now in doubt.

8. As the loss of highly skilled personnel at Amberley is an inevitable result of the announcement of the early retirement of the F-111, the 'options' referred to earlier by CDF for addressing the risks inherent in the JSF program become extremely expensive as such personnel would need to be hired at short notice to restore lost engineering capabilities.

9. Failing to consider let alone address the impact of the decision to retire the F-111 early on Australia's Strategic Industrial Base is not in keeping with Australia's Defence Industry Policy.

Notes[61] [62]

CHAIR - Will there be F/A-18s located at Amberley in the interim until the joint strike fighter is available?

Air Marshal Houston - There is an ongoing study being conducted that is relevant to these circumstances the force disposition study. That is yet to be considered by government, so that is all I can say at this stage.

CHAIR - So the F/A-18s may not necessarily go to Amberley when the F-111s are retired, or the joint strike fighter may not go there? Is it all still in the consideration basket?

Air Marshal Houston - All I can say is that the future of Amberley is, I think, pretty good. It is certainly a strong preference of mine to keep it going, but clearly the force disposition study has to go to government, and government will consider it and make the decisions when the time comes.

CHAIR - Would that include perhaps the impact of the decision to retire the F-111 say, the potential loss of jobs or the redeployment of those jobs into other areas?

Air Marshal Houston - I would hope so, but I am sure the government will make the decisions on the basis of everything that is put before it.

2 Annex A

1. This annex contains two detailed analyses demonstrating that Defence did not employ appropriate models for estimating the future operating costs of the F-111, as a result of which unusually inflated cost estimates were produced.

2. These unusually high estimates of future cost would have been provided to Cabinet to support the case for early retirement of the F-111 aircraft.

3. Consequently the case put to Government by the Defence Senior Leadership Group is not supportable by hard data.

2.1 Financial Estimation Model

In his last year in the appointment, the former Vice Chief of the Defence Force, Lt Gen Des Mueller, provided first hand insights into the workings of the senior levels of Defence. His message was communicated through various forums, presentations and writings including his speech to the SIMTECH Conference that year and his retirement legacy paper entitled "Farewell to Arms".

The message was delivered in such an erudite and literally eloquent way that it led one senior defence staffer to say and several others to echo that it was "typically classic Des Mueller". However, stripping out the niceties of diplomacy, the message was clear. Decision making in the Defence senior leadership group is heavily influenced by perceptions, rumours, hearsay and innuendo with realities and facts, such as derived from the laws of physics and other areas requiring specialists with expert knowledge, playing little part in the process.

The following is but one example of this message.

In evidence to the Standing Committee for FADT on 15 December last, AM Houston states:

"The other factor that is really important here is that, if we look back over the last few years, the F-111 has cost us an extra six per cent per year over the last few years. We project into the future that it will continue to cost us more as each year passes. We are working on five per cent compounded, which is probably a fairly conservative estimate. So, for reasons of capability and cost, we think the decision we have made is a reasonable one and gives the Australian government and the Australian people a good strike capability well into the future."

The principal inferences one is encouraged to draw, given the Office of the Chief of Air Force's recommendation to Government to retire the F-111 early (circa 2010), are, firstly, that the F-111 is expensive relative to other RAAF Capabilities. Secondly, the F-111 will place an intolerable burden on the Defence Budget in the out years.

Other pronouncements, both public and internal to Defence, indicate the general perception within the organisation, particularly at the Defence Senior Leadership Group level, is that the F-111 is expensive to operate and maintain and a costly burden to the rest of the RAAF and Defence at large.

However, as history reminds us all with monotonous regularity, knowledge of the facts plus perceptions equals reality - not the half baked version of this equation.

The term "the last few years" referred to in the above statement presumably embraces the fiscal periods of 1999 to 2003.

This being the case, the financial statements in the Defence Annual Reports (DARs) for these periods do not support the promotion of such inferences nor the assertion that the decision to retire the F-111 is reasonable "for reasons of capability and cost".

An analysis of the costs of RAAF outputs has been done using data from the financial accounts in the Defence Annual Reports, at the following three levels -

1. Total Direct Expenses (made up of the total costs for defence employees and suppliers - both inventory and non inventory),
2. Total Operating Expenses (being the Total Direct Expenses plus other expenses including depreciation, amortisation, interest, grants, expenses of asset sales, and write down expenses)[63], and
3. Price to Government (being the Total Operating Expenses plus considerations for the Capability Usage Charge and Own Source Revenues).

Looking at the 'Price to Government' for Air Force capabilities as tabled in DAR 99/00 results in the following findings:

a. The total price for the F-111 capability was $787.1m in FY99/00 dollars and made up 17.3% of the total 'Price to Government' for the Air Force capabilities ($4,551.4m).

b. In relation to the 'Price to Government' and, therefore, to the Australian tax payer, the capability represented by the F-111 cost less than all the other airborne platform based capabilities operated by the RAAF.

These findings are summarised below in the following table (Table 1).

Air Force Capabilities	Price (AUD $'m)	% of Total Price
Output 13: Capability for Air Strike/Reconnaissance	787.1	17.3%
Output 14: Capability for Tactical Fighter Operations	1,398.1	30.7%
Output 16: Capability for Strategic Surveillance	445.1	9.8%
Output 17: Capability for Maritime Patrol Aircraft Operations	788.4	17.3%
Output 18: Capability for Airlift	892.6	19.6%
Output 19: Capability for Combat Support of Air Operations	240.1	5.3%
Total Price to Government of Air Force Capabilities	4,551.4	100.0%

Table 1: Price to Government of RAAF Outputs in 1999/00 (Extract from DAR 99/00, Page 158 of Section 3 - Outputs).

The 'Price to Government' level of Defence accounts incorporates 'own source revenues' and the 'capability usage charge' which, because of their fluctuation from year to year between capability groups within Defence outputs, have the potential to skew the observer's appreciation of the real costs at the output and capability levels.

Therefore, looking more deeply into the expenses (costs) aspects of the financial statements of the RAAF shows the following.

a. In DAR 99/00, the total (business) operating expenses attributed to the then Air Strike / Reconnaissance Capability AKA F-111 (Output 13) was $527.0m, being nominally 18.5% of the Total Operating Expenses of the RAAF which was reported as $2,852.1m.

b. For the same period, Output 14 - Tactical Fighter Operations Capability cost $782.2m or 27.4% of the Total Operating Expenses of the RAAF.

c. For information, the Maritime Patrol Capability (Output 17) total operating expenses attribution was $460.8m (16.2%) and that for the Air Lift Capability (Output 18) was $632.3m (22.2%).

d. At the operating expenses level, the F-111 ranked number three out of four in 'the most costly airborne platform capability' stakes, with Output 14 - Tactical Fighter Operations coming in as the most costly of the four.

Unfortunately, these and similar cost figures for other capabilities have not been available from the Defence Annual Reports since DAR 1999/00. The level of fidelity in the statements on financials as well as performance has been significantly coarsened in the subsequent annual reports[64]. This lessening of fidelity was reported to Defence by the one of the authors following the tabling of DAR 2000/01. However, if the Defence budget estimates can be taken as an indication, the level of fidelity, at least in the financials, to the Force Element Group level (as per DAR 1999/00) may be returning.

Fortunately, the above statement by the Chief of Air Force to the FADT Committee from a (presumed) analysis undertaken by the RAAF enables these figures on F-111 costs over the period to be derived with a level of confidence.

Now, applying the reported 6% to the total operating expenses for the F-111 capability in DAR 99/00 and compounding the cost at this rate on a per annum basis results in a total operating expense for the F-111 capability in FY 02/03 of $627.7m.

Over the same period (1999 - 2003), the operating expenses of the whole of the RAAF rose by some 63.7% to $4,669.7m, making the cost of capability of the F-111 now 13.4% of the total operating expenses of the RAAF - a reduction in relative cost of some 5.1% against other RAAF capabilities and the F-111's proportion of the RAAF budget in the year 2000 to 2003.

The increase in the total operating cost of the RAAF of 63.7% (or $1,817.6m) equates to an average rate of increase for the whole of the RAAF of more than 18% per annum. Therefore, the stated 6% rate of increase attributed to the F-111 Capability is less than one third the average annual rate of increase in operating expenses of the rest of the RAAF[65].

A graphical summary of key aspects of the above analysis is presented in Figure 8.

The actual data points (ie. numbers reported in the DAR's and projected for the F-111 on the basis of the reported 6% annual rate of increase) are shown with data markers. These data points are connected by distinguishing lines to provide a relative picture over time between data points of the same parameter and those of other parameters and trends. Projections and trends over time derived from the analysis are shown by lines without data markers.

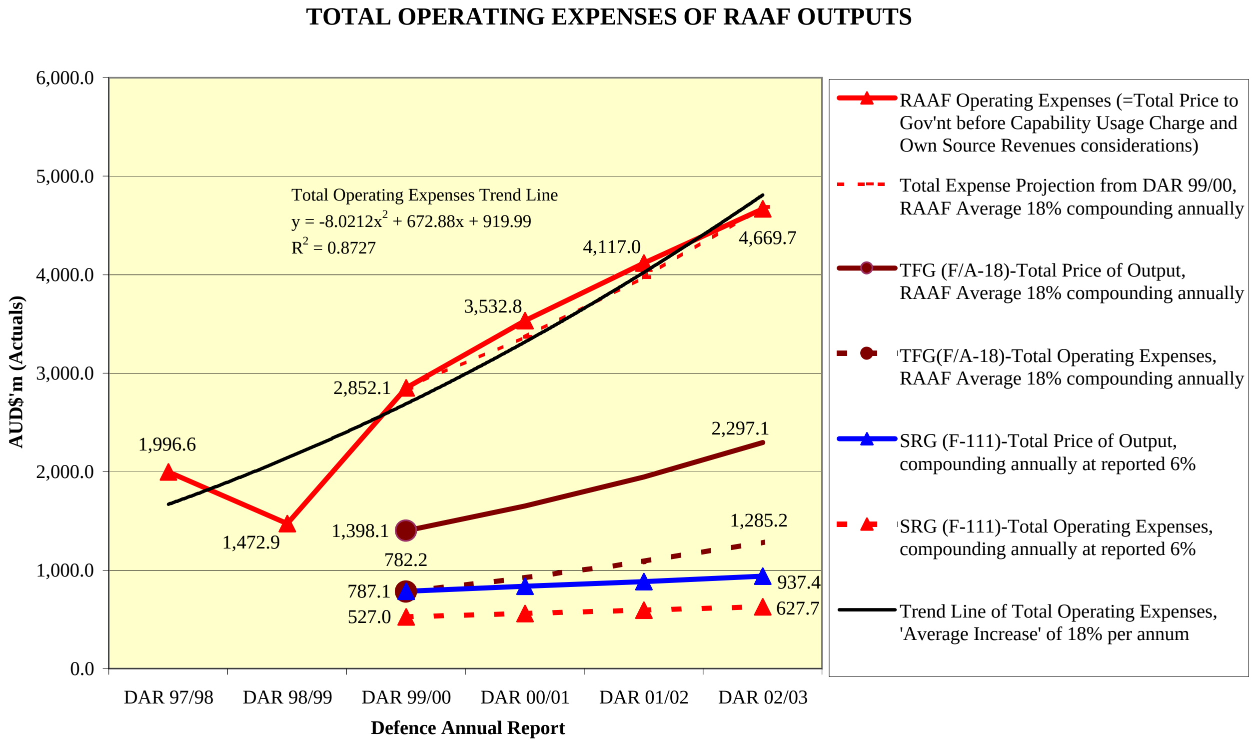


Figure 8: *Total Operating Expenses of RAAF Outputs (P.A. Goon).*

Additionally, the actual price to Government for the F-111 as reported in DAR 99/00 is shown projected out to 2002/03 using the 6% per annum compounding figure.

For completeness, the DAR 99/00 figures for total operating expenses and price to Government for the other elements of the RAAF Air Combat Capability (formerly known as Tactical Fighter Group - TFG) are shown and projected to 2002/03. The rate of projection used is the average nominal annual increase for the whole of the RAAF, namely 18% per annum.

However, the average rate of increase over the period for the other capabilities (including those of TFG) would have to be greater than the nominal 18% derived from this analysis to compensate for this 'under-performance' of the F-111 in these cost increase stakes.

An analysis at the Direct Costs level shows similar trends, with the reported rate of increase in costs for the F-111 (6% per annum compounding) being about half the rate of increase in Direct Costs over the period for the whole of the RAAF. What is not included at the Direct Costs levels are any of the expenses for depreciation/amortisation or other expenses associated with capital items and related expenditures.

In regard to capabilities, the F-111 represents, using two different Measures of Effectiveness, over 50% of the RAAF's Air Strike Capability. The F-111 is the corner stone of Australia's deterrence strategy, and the resulting air power supremacy that has underpinned Australia's strategic position in the region for over 30 years.

Therefore, to claim the Office of the Chief of Air Force recommendation to Government to retire the F-111 early is reasonable for "reasons of cost and capability" is, at best, non sequitur.

2.2 Reliability Engineering Estimation Model

The admission by Defence that a '5% compounding cost model' was employed as a predictor of future operating costs for the F-111 fleet effectively invalidates the case that the cost of operating the aircraft will significantly increase over time[66]

The '5% compounding cost model' overstates the future operating costs of the F-111, and directly conflicts with engineering analysis available to Defence in the latter part of 2003.

The compounding cost model has historically been used as an approximation to the wearout phase section of the reliability engineering 'bathtub curve'. The 'bathtub curve' describes the effect of cumulative old age wearout in a large population of parts and reflects the statistical behaviour of component age related failures[67].

For this model to be mathematically valid and accurately predict the behaviour of an aircraft fleet, several critical conditions must be satisfied:

1. A period of high stability must exist in the aircraft's configuration to permit a 'baseline' operating cost to be determined accurately. Significant upgrades of systems and structural alterations incur additional costs and change the statistical spread of component ages in the fleet, and, therefore, would result in an excessive but unrealistic apparent baseline cost[68].
2. A period of high stability must exist in the aircraft's maintenance regime. Changes in servicing policies, maintenance procedures and personnel skill levels will compromise the baseline costs and predicted costs.
3. Throughout the time period over which the aircraft's behaviour is being modelled, it must be maintained using an 'on condition' policy in which parts are replaced only when they fail, or just prior to failure as a result of inspection.

If these conditions are met, then the 'bathtub curve' model will provide a reasonable prediction for estimating operating costs. A 'compounding cost' model will then be feasible as a short term approximation to the 'bathtub curve' model - the fit of the 'compounding cost' model will diverge for any long term prediction, and should never be used as a long term predictor.

The basic 'bathtub curve' model has been used most frequently for estimating the costs of airliner fleets, and similar aircraft such as aerial refuelling tankers converted from airliners. Such aircraft do not usually receive mid-life airframe upgrades, and are retired once the profit margin on the operation of the aircraft becomes uncompetitive. Large scale rewiring, re-engining and replacement of avionics is uncommon in the airline industry - most midlife upgrades involve passenger seating and entertainment systems.

The basic 'bathtub curve' model is not a suitable predictor for military combat aircraft. Military combat aircraft are usually subjected to a series of upgrades through their service lives, and often large block upgrades. As a result, military aircraft fleets usually have component populations of highly mixed ages. A good example is the US B-52H bomber, which is planned to be flown until 2040. This aircraft has an airframe and engines which are around 40 years of age, but the complex avionics carried span a range of ages between 30 and 1 year. It is likely that new engines will be soon fitted and this will further spread the age distribution of parts in the B-52 fleet[69]. [70]

For the RAAF F-111 fleet, the compounding cost and basic 'bathtub curve' models are completely inappropriate and cannot produce cost predictions with any validity.

This is because the last four years cannot be used to accurately fix a baseline operating cost for the F-111 fleet, and because the maintenance policies employed at Amberley have significantly changed over this period. In detail:

1. Boeing Australia took over depot level maintenance of the F-111 fleet, resulting in major changes to personnel skill levels applied.
2. A large backlog of deeper maintenance tasks accrued due to funding shortages during the late 1990s had to be cleared.
3. The whole F-111 fleet was subjected to replacement of its wings, a major effort involving overhaul of mothballed wings, rewiring and retrofit.
4. The fuel tank repair technique was changed significantly, and new technology introduced.
5. A backlog of airframe Cold Proof Load Testing tasks had to be cleared once the new Cold Proof Load Test facility was completed.
6. The fleet was subjected to ongoing Block Upgrade Program modifications to introduce new hardware, specifically Blocks C-2, C-3 and C-3A.
7. The maintenance regime was drastically altered with the introduction of an 'ageing aircraft engineering program' which identifies age related problems in components and effects block replacements or repairs.

The result of these factors is that any attempt to use operating costs derived from recent years as a 'baseline' will overstate the operating costs by some margin.

Of much greater concern is that the 'compounding cost' model was used despite the fact that an 'ageing aircraft engineering program' was introduced during this period. Such programs significantly and effectively alter the statistical behaviour of aircraft fleets, as they result in block replacement or block repairs of the most aged components in the fleet. In effect they depopulate the fleet of components with specific ageing problems, invalidating the basic mathematical premises underpinning the use of the basic 'bathtub curve' model, and its 'compounding cost' model approximation[71].

Figure 9 graphically illustrates a comparison between the three models used for prediction of aircraft fleet failure rates. The 'sawtooth' curve produced by the block replacement policy now used on the F-111 departs drastically from the basic 'bathtub curve' and 'compounding cost' models[72].

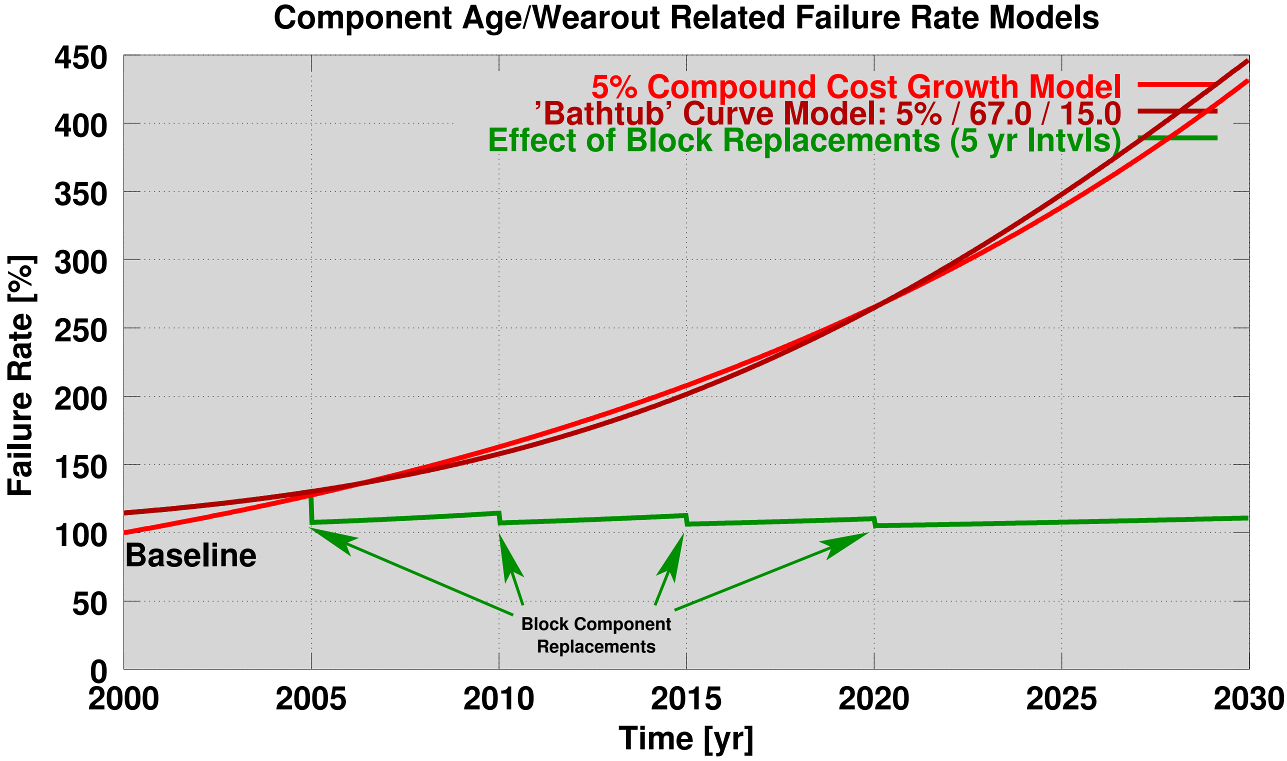


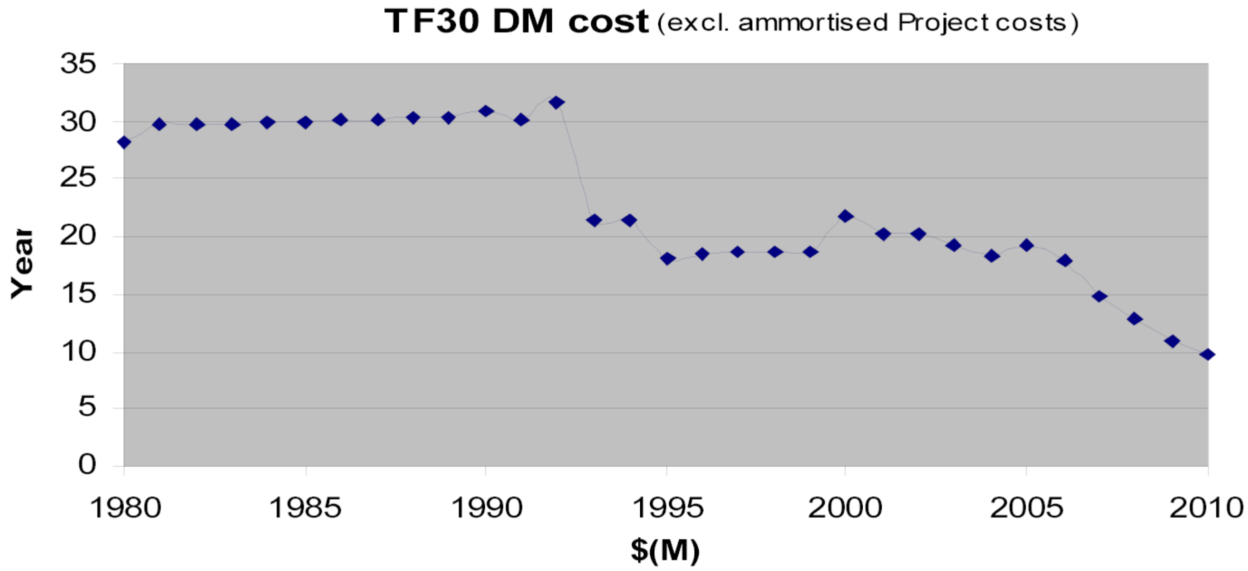
Figure 9: *This plot compares the failure rate predictions for the 5% compounding cost model (red), the 'bathtub curve' model (dark red), and a 'bathtub curve' model adjusted to account for the block replacement of worn out components (green). In situations where the aircraft is maintained using a block replacement policy, e.g. the F-111, the depicted 'sawtooth' curve is a much more accurate predictor of future operating costs (C. Kopp).*

The plots display predicted failure rates, the block replacement policy in the model assumes that the majority of components exhibiting old age wearout are systematically removed at five year intervals, a period which fits well with the current Block Upgrade Program cycle used at Amberley.

An analytical prediction of costs would reflect the shape of this curve, with small spikes reflecting block replacements aligned with each step in the 'sawtooth' curve. What is important is that there is little long term cost growth when this model is applied.

Of no less concern is that the Amberley SPO and Boeing have followed a policy in recent years of replacing problematic components with replacements of much better reliability and durability. This has been done not only with engines, but also many avionic and structural components. Therefore, over the longer term the failure rate behaviour will display a trend to further reduction, and thus further decreases in annual operating costs. This is also not reflected in the use of a 'compounding cost' model[73][74].

The outstanding success achieved by the joint effort of DSTO, the F-111 SPO and RAAF operated Amberley Engines Business Unit (EBU) is depicted in Figure 10. The cost of maintaining jet engines is the single biggest cost contributor to the operation of military aircraft, especially older aircraft. Statistical studies of US Air Force fleet operations conclude that in FY 2002 around 48.9% of costs



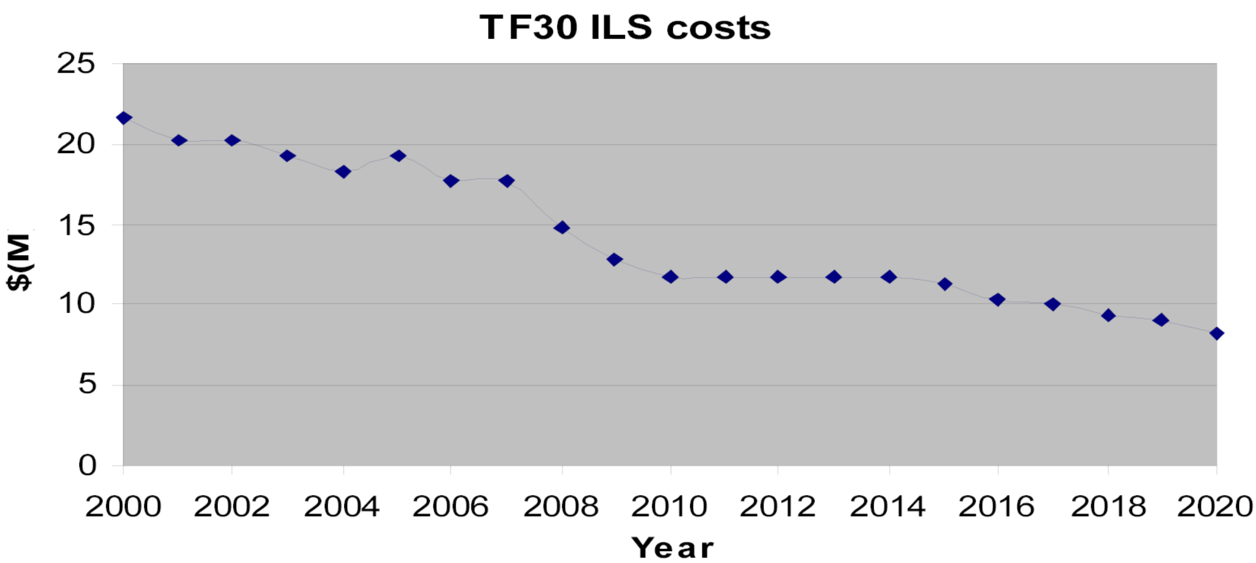


Figure 10: *Plots illustrate the ongoing support costs incurred by the Amberley engine support facility, which overhauls the aircraft's TF30 engines. The upper plot shows the depot maintenance cost from 1980, projected to 2010. The lower plot shows the integrated logistic support total cost projected to 2010. The data clearly illustrates a sustained trend of reducing F-111 support costs.*

were incurred in supporting engine 'hot ends' across the US Air Force fighter, bomber and transport fleets, with similar findings for the US Navy and Marine Corp fleets[75]

As the annual cost of maintaining the F-111 fleet is dominated by the $\approx$ A$50M cost of the Boeing WSBU and $\approx$ A$20M cost of the RAAF EBU, significant reductions resulting from DSTO's research will result in major long term reductions in the fleet's currently modest operating costs.

Another issue of significant concern is the failure by Defence to account for additional repair costs incurred over the last years in rectifying problems produced by improper maintenance planning / maintenance techniques, and quality inspections of incoming parts during the 1990s - these costs effectively inflate the 'baseline' cost used in a 'compounding cost' prediction. Around 50% of these problems appear to have been attributed to aircraft age, while they were actually caused by poor training of maintenance personnel, the loss of capability and expertise due to the downsizing of the RAAF in the early 1990's, the subsequent deskilling of the RAAF in many areas of aircraft maintenance and engineering, and errors in technical documentation. As a result unnecessary recurring maintenance costs were introduced, and not removed until recent interventions. Good examples are thus[76]:

1. Wing pivot shear rings.
2. Wing pivot bearings.
3. Wing pivot pins.
4. Environmental Control System water tanks.
5. Hydraulic swivels.
6. Landing Gear uplock roller shimming.
7. Fuselage panel 4310.
8. Weapons bay panel damage.
9. FS 770 frame panel damage.
10. F2 fuel tank floor panel damage.
11. Nose undercarriage landing light elevation bolt.

The attribution of many of these problems to age related wearout rather than improper maintenance planning / maintenance techniques creates a false perception that age related problems are occurring at a higher frequency than the engineering data will support.

2.2.1 Summary

The findings of the analysis performed on the long term cost prediction model used by Defence to assess future F-111 operating costs are thus:

1. The Defence Senior Leadership Group accepted an inappropriate cost prediction model for the F-111, one which inherently inflates long term costs.
2. This cost prediction model was used inappropriately, further contributing to an inflated long term cost estimate.
3. Then available data from the F-111 engineering community was not exploited to build an accurate long term cost prediction model, which fits with engineering data indicating longer term cost reductions. Establishing the competencies and skill sets of the personnel who developed this model will show why the appropriate engineering data was not used.
4. The Defence Senior Leadership Group made public statements and provided advice to Cabinet based on a defective and inflated estimate of long term operating costs.
5. Any decisions about F-111 (Life of Type) withdrawal dates based on the inflated estimate of long term operating costs are defective and should be reversed.
6. The Planned Withdrawal Date of 2020 for the F-111 could be exceeded without prohibitive costs being incurred.

3 Annex B - Endnotes and References

[1]Statements by a customer organisation's leadership which shift responsibility for risks from the vendor to the customer create an environment which is not conducive to proper risk management and, in fact, is counter to the responsibilities of executives in the promotion of risk management in accord with AS/NZS-4360 and other internationally recognised best practices in risk management. If the organisation's leadership is perceived to be protecting a program, subordinate personnel will be reluctant to raise problem issues for consideration as this could place them in conflict with their own leadership. Moreover, where an organisation fosters a culture of 'Group Think', subordinate personnel can be subjected to intense peer level pressure to conform to the perceived views of their leadership.

[2]Fulghum D.A., 'Boeing's ROK Star', Aviation Week & Space Technology, August 11, 2003.

[3]'JSF expected to cost more than budgeted - Lockheed program will now build fewer planes, records show', Dallas Morning News, 06/01/04.

[4] Capaccio T., 'Joint Strike Fighter delayed a year as costs soar by 17%', Seattle Post-Intelligencer , 06/01/04.

[5] Butler A., 'Overall JSF Buy Unaffected By Near-Term Cut, DoD Says', Defense Daily, 08/01/04.

[6]Capaccio T., 'Cost to develop F-35 rises $5 billion', Fort Worth Star Telegram, 06/01/04.

[7]Weinberger S., 'Congressional Panel To Explore JSF Software Issues', Defense Daily 08/01/04.

[8]Kopp C., 'Hedging the Bet - Joint Strike Fighter for the RAAF?', Australian Aviation, August 2002.

[9]Selinger Marc, Review: Joint Strike Fighter Still Grapples With Extra Weight, Dec 23, 2003, AviationNow.com.

[10]Kopp C., 'Hedging the Bet - Joint Strike Fighter for the RAAF?', Australian Aviation, August 2002.

[11]Kopp C. 'Asia's Advanced Flankers', Australian Aviation, August 2003.

[12]Barrie D., Taverna M.A., 'Long Range Effort - Russia's Novator advances air-to-air missile project, with a possible eye to exports', Aviation Week & Space Technology, December 22, 2003.

[13]Wall R., 'Tweaks to the F/A-22', Aviation Week & Space Technology, July 28, 2003.

[14]Ibid.

[15]Kandebo S.W., 'Joint Strike Fighter Power Play', Aviation Week & Space Technology, June 30,

2003.

[16]Fulghum D.A., 'F-22, JSF designed for distinct roles', Aviation Week & Space Technology, Volume 152, Issue 6, 7 Feb 2000.

[17]Joint Strike Fighter Electro-Optical Targeting System, Lockheed Martin Corporation, Technical Brochure.

[18]Kopp, C., 'Network Centric Warfare', Defence Today, Vol 2 No 3, Page 28 - 34, Strike Publications, Pty Ltd, Amberley, August, 2003.

[19] Report of the Defense Science Board Task Force, 'Future DoD Airborne High Frequency Radar Needs/Resources', Office of the Undersecretary of Defense for Acquisition and Technology, April, 2001.

[20]Fulghum D.A., 'F-22, JSF designed for distinct roles', Aviation Week & Space Technology, Volume 152, Issue 6, 7 Feb 2000.

[21]Kopp C. 'Asia's Advanced Flankers', Australian Aviation, August 2003.

[22]Barrie D., Taverna M.A., 'Long Range Effort - Russia's Novator advances air-to-air missile project, with a possible eye to exports', Aviation Week & Space Technology, December 22, 2003.

[23]Kopp C., 'Sukhois present new strategic risk for Australia', Defence Today, December, 2003.

[24]Sweetman W., 'Russian Stealth Research Revealed', Journal of Electronic Defense, p26, January, 2004. The assertions of the ITAE researchers cited in the paper are credible, and the large power output of the NIIP N011 series radars in the Sukhois vs the modest power rating of the MIRFS/MFA radar in the Joint Strike Fighter present interesting questions about how great a BVR combat advantage the Joint Strike Fighter might have in the post 2010 period.

[25]Sweetman W., 'Hostile radar range cut on Su-35s', International Defense Digest report, Jane's International Defense Review, No.37, January, 2004.

[26] It is important to distinguish what costing models apply, as much of the public debate in the US employs 'program costs' rather than Foreign Military Sales (FMS) costs. Program costs are more expensive because they include the total development cost of the aircraft, excluded from the FMS unit cost of the aircraft. This is detailed in US legislation 22 USC 2762 cited:

(d) Competitive pricing

Procurement contracts made in implementation of sales under this section for defense articles and defense services wholly paid for from funds made available on a nonrepayable basis shall be priced on the same costing basis with regard to profit, overhead, independent research and development, bid and proposal, and other costing elements, as is applicable to procurements of like items purchased by the Department of Defense for its own use.

The Joint Strike Fighter is significant since it departs from the established model of indirectly subsidising exports by selling at the FMS price - participants contribute to the development costs of the program. An F/A-22A purchase would occur at the FMS price, significantly lower than a price derived from program costs with their development cost overhead, borne by the US taxpayer.

[27]Kopp C., 'Taking the Force out of Air Force?', Australian Aviation, Jan/Feb, 2004.

[28]Kopp C., 'The changing world of maritime patrol', Defence Today, December, 2003.

[29]Kopp C., 'Taking the Force out of Air Force?', Australian Aviation, Jan/Feb, 2004.

[30]Kopp C., 'Towards a 'boutique Air Force' - downsizing the RAAF', Defence Today, December, 2003.

[31]Ibid.

[32]Kopp C., 'How expensive is the F-111?', Defence Today, September, 2003.

[33]Molloy, M.H., Lt Col, USAF, 'U.S. MILITARY AIRCRAFT FOR SALE: CRAFTING AN F-22 EXPORT POLICY', Masters Thesis, School of Advanced Airpower Studies, Air University, Maxwell Air Force Base, Alabama, June 2000.

[34]Grant R., 'The F-22 Raptor - Air Dominance for Tomorrow's Threat', Briefing, Iris Independent Research, Washington DC, 2002.

[35] Ibid, also Fulghum D.A., 'F-22, JSF designed for distinct roles', Aviation Week & Space Technology, Volume 152, Issue 6, 7 Feb 2000.

[36]'JOINT STRIKE FIGHTER', Briefing Slides, Joint Strike Fighter Project Office, US DoD, 2002.

[37] Capaccio T., 'Joint Strike Fighter delayed a year as costs soar by 17%', Seattle Post-Intelligencer, 06/01/04.

[38]Prior to the recommendation for early retirement of the F-111, the aircraft was to receive the AGM-158 JASSM cruise missile (AIR 5418), and GBU-31/32/35 JDAM GPS aided bomb (AIR 5409 Bomb Improvement Program) under the Block C-5 upgrade. It appears that both upgrades will now not survive. Refer Kopp C., 'Amberley Weapon System Business Unit', Australian Aviation, October 2001.

[39] The design rating of the existing wing stations on the F-111/FB-111 is in excess of 2,000 kg each. Full performance is achievable with four pivoting wing stations, however an additional four outboard fixed stations can be installed. Refer T.O.1F-111E-1 Flight Manual F-111E, 1973, T.O.1F-111D-1 Flight Manual F-111D, 1972, T.O.1F-111-B-A-1 Flight Manual FB-111A, 1973, and T.O.1F-111F-1 Flight Manual F-111F, 18 May, 1979.

[40] 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.

[41] The F-111 internal weapon bay is detailed in General Dynamics manual FZM-12-6282, 'F-111/FB-111 Structural Breakdowns', 1 Sept, 1969, Forth Worth. This includes a flight tested trapeze launcher for guided missiles. The F-111G was recently used by RAAF ARDU as a test

platform, under contract to the US Air Force, for trial drops of the 125 kg class Small Diameter Bomb demonstrators, refer Figure 11.

Figure 11: *An RAAF F-111G was used as a trials platform for validating the Small Diameter Bomb demonstrator. Refer Eglin Eagle, Vol. 59, No. 31, Aug. 4, 2000, Eglin AFB, Fla.*

[42] External pylons, fuel tanks and weapons significantly degrade stealth performance as their shape results in often large radar reflectivity. A detailed discussion of the radar signature of such items can be found in Knott E.F. et al, 'Radar Cross Section', Second Edition, Artech House, 1993.

[43]Walker K., 'Recovery of structural integrity assurance for the Australian F-111 fleet following an unexpected wing fatigue test failure', DSTO Briefing, F-111 Ageing Aircraft Forum, 24-26 September 2003.

[44] Houston, A. AM in Hansard, Senate Estimates, MONDAY, 3 JUNE 2002, cite:

When we did the fatigue testing it was not an F-111 that we were testing; it was just a wing. The wing failed during routine testing that we have been doing for a number of years. It was unexpected. As a consequence of that our technical airworthiness people had a look at it and determined that the safe flying limit for the long wings that we were operating meant that 15 aircraft would have to *have new wings to operate again. Those 15 aircraft are eight -C models and seven -G models. In other words, all the G models were affected by this.*

The fix for the problem was to have a look at what was available in the United States at Davis-Monthan at AMARC. We were able to find some really good wings in the United States. We already had four sets of wings in the store, and we have since received another seven sets. We expect to get a delivery of every other set, one every fortnight, until we get 26 wing sets. Those wing sets have cost us next to nothing. In fact, most of the cost involved with getting them is to do with transportation and putting the wings through wing bay servicing at Boeing Australia at Amberley.

The prognosis is that we will be able to remediate the wing problem very easily and relatively cheaply.

[45]'F-111 Fuel Tank Repair', Briefing, F-111 Ageing Aircraft Forum, 26 September 2003.

[46]Perhaps the best case study is the undervaluing of the Japanese Mitsubishi A6M2 Zero fighter in 1941 by British and Australian intelligence in the Far East. Then Commander-in-Chief, Far East, Air Vice-Marshal Sir Robert Brooke-Popham, overstated the relative capabilities of the underperforming Brewster Buffalo fighter then flown by RAAF pilots in Malaya: 'we can get on all right with Buffaloes out here, but they haven't got the speed for England. Let England have the Super-Spitfires and the Hyper-Hurricanes. Buffaloes are good enough for Malaya', cited in Pelvin R., 'JAPANESE AIR POWER 1919-1945: A CASE STUDY IN MILITARY DYSFUNCTION', Aerospace Centre Paper Number 31, Royal Australian Air Force, http://www.defence.gov.au/raaf/Aerospace/. The sometimes heard view that the 'F/A-22A is too capable for Australia' directly mirrors attitudes during the early 1940s.

[47]Kopp, C., 'Network Centric Warfare', Defence Today, Vol 2 No 3, Page 28 - 34, Strike Publications, Pty Ltd, Amberley, August, 2003.

[48]Department of Defense, 'Network Centric Warfare, Department of Defense Report to Congress', Office of the Secretary of Defense, 27 July 2001.

[49]NAVAIR 01-10FAB-1, NATOPS Flight Manual, Navy Model F-111B Aircraft. Introduction detailing aircraft design roles.

[50]T.O.1F-111E-1 Flight Manual F-111E, 1973. Introduction detailing aircraft design roles.

[51]T.O.1F-111D-1 Flight Manual F-111D, 1972. Introduction detailing aircraft design roles.

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

[53]Equipping the F-111 with the new hypersonic ASRAAM air combat missile now being introduced on the F/A-18A is a low cost proposition, as the missile has the same umbilical interfaces as the older AIM-9M, and the new block C-4 system about to be fitted to the F-111. As very little cost is involved it is unclear why Defence have not opted to fit the ASRAAM, especially given its potential benefits in expanding F-111 capabilities and further enhancing the F-111's survivability.

[54]Kopp C., 'AN/AVQ-26 Pave Tack: Technology and Capability Growth Options', Unsolicited

Innovative Proposal to the Department of Defence, 2002.

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

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

[57] Lockheed-Martin data published in 2002 indicates that with full fuel the maximum payload of internal and external weapons for the Joint Strike Fighter is around 7,000 kg. Under the same conditions the F-111 has a maximum weapons payload of around 14,000 kg, almost exactly twice that of the Joint Strike Fighter. Refer T.O.1F-111-B-A-1 Flight Manual FB-111A, 1973.

[58]The Israeli AGM-142 missile was selected over its US competitor, the AGM-130, as the Israeli missile delivered slightly better range and was faster. However, the Israeli missile required extensive aerodynamic clearance effort, unlike the US missile which was already being flown on the F-15E and US F-111Fs. While the systems upgrades required to support either missile would be similar, the choice of the Israeli missile incurred a significant project overhead in clearances and flight testing. It is not entirely clear whether Defence acquisition appreciated the implications of their choice at that time. Refer Kopp C., 'AGM-142E Raptor - The RAAF's New Standoff Weapon', Australian Aviation, December, 1996.

[59]The Interim EW upgrade arose as a result of delays in the planned AIR 5391 upgrade, and was originally intended to provide a near term capability. At that time the two principal contenders were the US ALQ-131 series pod, then carried by US F-111Fs, and the more capable and newer Israeli Elta EL/T-8222 pod, which incorporates a Digital RF Memory. While the Israeli pod was more capable, it also required a more extensive integration effort and aircraft rewiring, unlike the US pod which was a defacto 'bolt on' addition. Additional costs and delays in this program arose as Defence insisted on different pod placement on the F-111 compared to the US fleet. US F-111s were fitted to carry pods either on the aft centreline station, or a hardpoint on the Pave Tack cradle. As a result, the Australian program required several times greater effort in radiation pattern and electromagnetic compatibility testing. It is not clear that Defence acquisition appreciated the cost implications of their choices at that time. Refer Kopp C., 'Amberley Weapon System Business Unit', Australian Aviation, October 2001 and Figure 12.

[60]The ALR-2002 project was a resounding success, with DSTO successfully designing and prototyping a modular warning receiver, custom built to fit into the unique antenna architecture of the F-111, and to be built by Australian industry. Feedback from the Block C-2A trials of the system was very favourable, but the project did not progress past this point. The ALR-2002 was originally placed under the umbrella of the DMO/DAO AIR 5391 with planned operational capability by the end of the 1990s. A key aim was to provide an warning receiver which was wholly supported in Australia, including the software source code. Refer Kopp C., 'New Defensive Avionics for the F-111', Australian Aviation, December 1995, and Kopp C., 'Amberley Weapon System Business Unit', Australian Aviation, October 2001.

[61]Refer http://www.boeing.com.au/DIVAerospaceSupport/ASf111.htm, F/RF-111C Modification and Support.

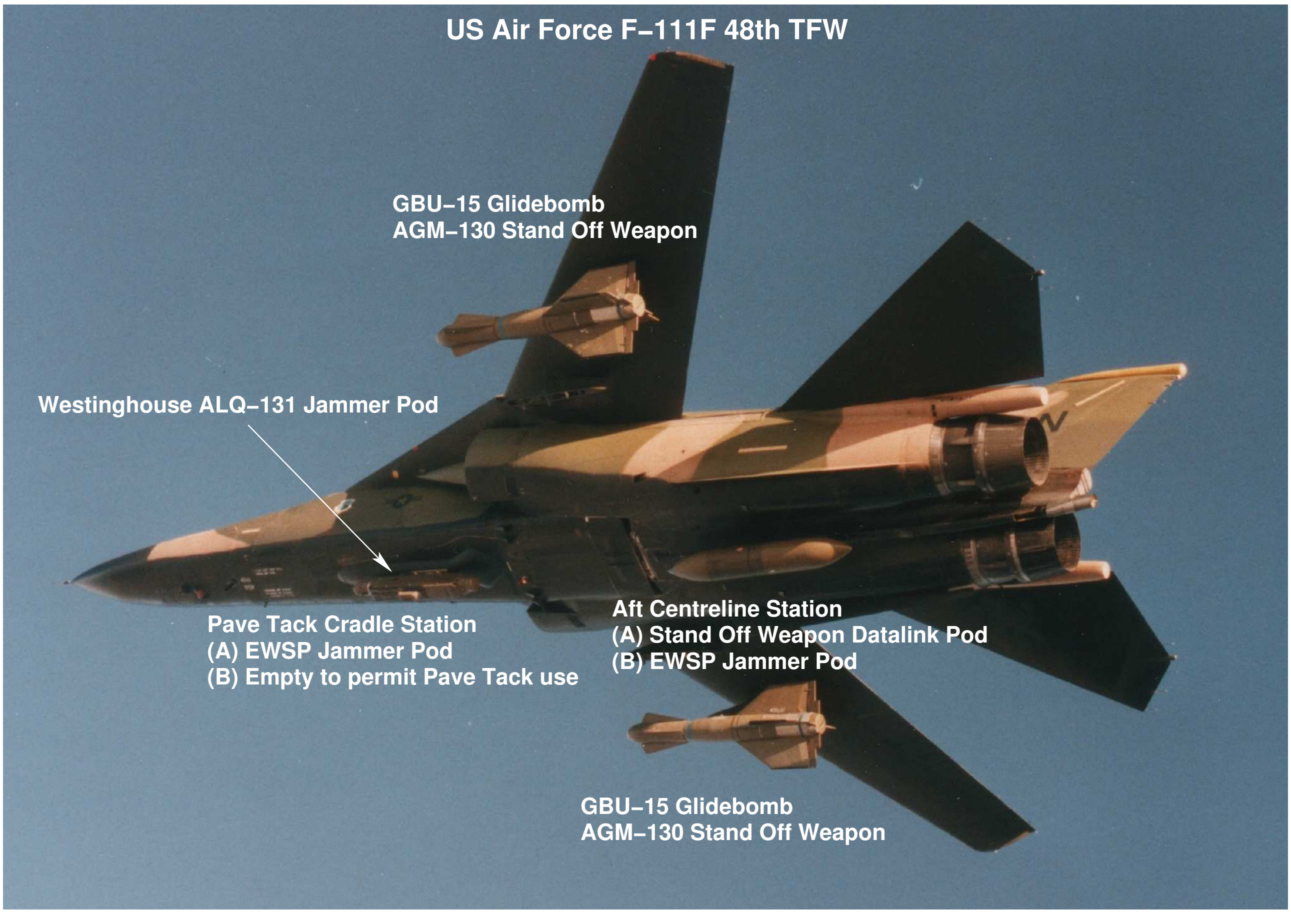


Figure 12: *A significant cost overhead and delay was incurred in the interim EW upgrade by opting to employ different jammer pod locations on the F-111 to those then used by the US Air Force. As the US pod placements deliver better radiation pattern coverage and lower costs, it is unclear why Defence acquisition specified a different arrangement (J. Rotramel, USAF).*

[62]Refer TEAM Australia: Strategic Policy for Defence and Industry - June 1998, DEF2000 - Defence White Paper, December 2000.

[63]The entry "Expenses Assets Under Construction" was only reported in two of the six reports (DAR99/00 and DAR00/01) over the period of interest. The entries against this 'expensed item' represented less than 1% of the total operating expenses of interest in the baseline year (FY99/00) of the analysis. Therefore, to enable direct comparisons to be made, this entry has not been included in analysis totals. This approach is considered conservative.

[64]The review of the Defence Annual Reports for the past six years enables several other interesting findings to be made. Included in these is the fact that DAR 99_00 is the most comprehensive and informative of all the Defence Annual Reports over the period by some degree, with a level of fidelity and objectivity not seen before or since. that enables analysis down to the FEG level for not only financial but also operational performance, with some clear metrics which, if determined in subsequent years could form the basis for determining Measures of Performance (MoPs) and Measures of Effectiveness (MOEs). One indicator of this finding is a simple page count comparison.

The RAAF Section of DAR 99/00 is made up of 32 pages. The highest page count seen for the RAAF section in Defence Annual Reports prior to 99/00 is 16 pages (98/99) with previous years averaging about 12 pages, including the ubiquitous organisational diagram. The RAAF sections in Defence Annual Reports since DAR 99/00 average 7 pages (or less than 22% of the information space tabled in DAR 99/00).

[65] This discrepancy may reflect the reality that the F-111 is wholly supported in Australia, and thus engineering costs incurred in maintaining the F-111 will be centred in Australia, rather than overseas. In general, engineering costs in Australia are significantly lower, compared to the United States, especially due to much lower salary levels for mid and senior level engineering personnel.

[66]Both authors practiced reliability engineering during their respective industry engineering careers. Moreover, Dr Kopp taught software and systems reliability theory at Melbourne University over a recent three year period, while Mr Goon has extensive Engineering and Test and Evaluation/Flight Test experience on the F-111 as a result of RAAF service at Amberley, Headquarters Support Command, and ARDU as well as his Industry activities.

[67] as per Ch.6, 7, Bazovsky I., ‘Reliability Theory and Practice’, Prentice Hall, NJ, 1961.

[68] The baseline in this model is often labelled the ‘active life’ or ‘honeymoon’ period. It is characterised by random failures statistically outnumbering wearout related failures.

[69]Carns, Gen M (USAF, Ret),‘Defense Science Board Task Force on B-52H Re-Engining’, Office of the Under Secretary of Defense For Acquisition, Technology and Logistics, December 2002.

[70]Axelso P.D., Maj (USAF), ‘THE B-52 CAN IT FLY UNTIL 2050?’, Masters Thesis, School of Advanced Airpower Studies, Air University, Maxwell Air Force Base, ALABAMA, JUNE 2000. Refer Figure 13.

[71]It is precisely the intention of ‘ageing aircraft engineering programs’ to change the failure rate statistics of a fleet to reduce operating costs. The practice of ‘ageing aircraft engineering programs’ is intimately bound to the mathematics of basic reliability theory, established during the 1940s and 1950s.

[72] Ibid.

[73]F-111 ENGINES BUSINESS UNIT, Technical Issues, F111 Ageing Aircraft Forum, 26 September 2003, Presentation.

[74]F-111 ENGINES BUSINESS UNIT, F111 Ageing Aircraft Forum, 26 September 2003, Presentation.

[75]Stoll L., ‘Analysis of Component Repair Costs for Navy and Air Force Aircraft Impact of Age and Other Cost Drivers on Increasing Flying Hour Program Costs’, Presentation for Aging Aircraft Conference, NAVAIR Cost Department, Aging Aircraft IPT ALB Study Group, 10 September 2003.

[76]F-111 Ageing Aircraft Forum, Proceedings, September, 2003.

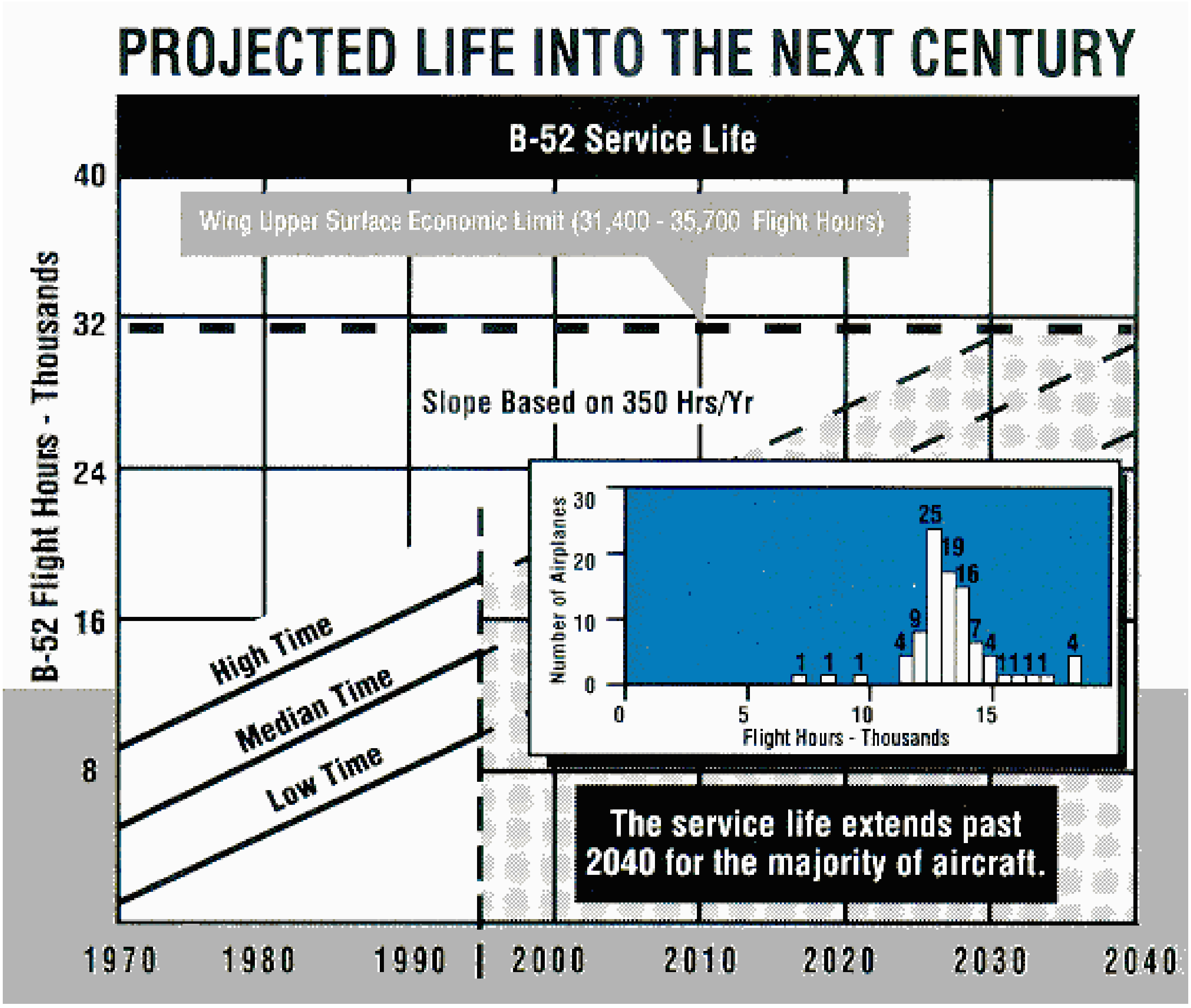


Figure 13: *The US Air Force B-52 fleet, a decade older than Australia's F-111s, will be operated past 2030 (US Air Force).*

4 Annex C

1. This annex contains copies of electronic mail correspondence from the period of the announcement of the Joint Strike Fighter as the preferred choice for the replacement of the F/A-18A and F-111.

2. These documents demonstrate that the F/A-22A was not evaluated in any detail beyond the reading of publicly available materials.

3. These documents therefore demonstrate that Defence were not equipped to form any accurate judgements on the production unit cost, operating costs and operational capabilities of the F/A-22A.

Peter Goon

From: Peter Goon
Sent: Tuesday, 2 July 2002 11:58 AM
To: ACDRE John Harvey, DGCS_Aero<john.harvey1@cbr.defence.gov.au>; GPCAPT Peter Layton (E-mail)
Cc: Dr Carlo Kopp <Carlo.Kopp@aus.net>; Paul Arthur, DarT; DTC Office; donna.warcaba@cbr.defence.gov.au; mark.green@cbr.defence.gov.au
Subject: ADVICE FROM THE STATES

***Our Reference**:* **837/24 Pt2 ( )**

John and Pete,

Confirming the information passed on in my call last week to the AIR6000 office, I got a heads up from a buddy in the USA to say the following:

1. People in the Pentagon, particularly in SAF(IA), are of the opinion that AIR6000 has been shut down. It appears the News Brief they saw in the States on Australia's decision to join the SDD Phase of the JSF Program led to them drawing this conclusion (perception, or whatever one wants to call it).

2. As a result, they are of the belief that Australia (particularly you folks) don't want to see the briefing material on the F-22 that had been prepared by the LM and the F-22 Program Office and approved for release in response to the AIR6000 RFI. Therefore, there is no intention, at this stage, to send it.

I gathered from my discussion with Mark last week that this is not the case, so I figured you needed to know what we are being told by our friends across the pond.

However, if this does become the situation (in this changing environment we call Defence), could you please let us know as soon as possible since our group and its members will need to re-jig their business planning in this regard.

Also, Pete, have received a response from our friends in P&W on propulsion system modelling, so when you get a moment, give me a call to discuss.

Best regards,

Peter Goon
Managing Director
Australian Flight Test Services Pty Ltd

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Telephone: National (08) 8262 6998 Intern'l +61 8 8262 6998
Facsimile: National (08) 8343 8888 Intern'l +61 8 8343 8888
Address: Australian Flight Test Services Pty Ltd
Innovation House West, First Avenue, Technology Park
MAWSON LAKES SA 5095, AUSTRALIA

The.Firm

From: Peter Goon
Sent: Tuesday, 8 October 2002 11:10
To: ACDRE John Harvey (E-mail 2)
Subject: FW: Military Aviation Week's AviationNow.com

Hi John,

My auto addressing went hay wire and inadvertently sent this to your last post (c/o Kev Paule) – Ooops. Anyway, here it is directed specifically to you good self.

Regards,

Peter G

-----Original Message-----
From: Peter Goon
Sent: Tuesday, October 08, 2002 9:29 AM
To: GPCAPT Kevin Paule (Acting) (E-mail); GPCAPT Peter Layton (E-mail)
Subject: FW: Military Aviation Week's AviationNow.com

Pete and John,

The obvious error (USD$100b as opposed to USD$100m) was picked up during filing of this. Such a large number of zeros can be soooo confusing.

I also went back to our logs and am able to confirm that –

a. The average Total Unit Procurement Cost for IOC of the F/A-22A, based upon the build number of 333 (not including the 6 PRTV birds which are funded separately), was advised back in May 02 as USD$115.2m (2001 dollars) and this price included training, GSE, spares, contractor and US Govt charges).

b. The Average Unit Fly-away Cost (UFC-2001 dollars) over 333 units = USD$97.8m with No 333 planned to go out the door at a UFC of USD$82m.

I have sought an update on these costing figures from the folks we know within the land of the GAAPAA.

John, what are your thoughts on our proposal for using the Evolved F-111 Option as a Risk Mitigation Strategy and true IV&V Model for the New Air Combat Capability Project? A number of us in the DTC AIR6000 Technology Group have some interesting ideas on this and would welcome the opportunity to share and discuss them with you and your team. We see this as fitting quite neatly into the emerging Defence paradigm of introducing a systemic approach to risk assessment and mitigation and improving the capability decision process, including a defined role for Industry in the process, which are two of the Goals under the Initiatives for Implementing the White Paper.

Would appreciate the opportunity to discuss this with you further.

Cheers,

Pete G.

-----Original Message-----
From: Peter Goon
Sent: Thursday, October 03, 2002 7:51 AM

To: GPCAPT Peter Layton (E-mail); ACDRE John Harvey (E-mail)
Subject: Military Aviation Week's AviationNow.com

Pete and John,

Take a look at this! 'tis a bit worrisome.

The reported price for 150 F-35Bravos is 10 billion pound sterling of USD15b which, assuming this is for IOC, would make the Initial Operational Capability Cost (average) some USD$100b per aircraft which is only some USD15m shy of the current average IOC cost for the F/A-22A, based on the currently planned build numbers of 339.

The other concern, given the level of investment the Brits are making into SDD, is why are they committing now, at this price? What do they know that we don't? (My commercial nose is starting to twitch again.)

Regards,

Peter Goon
Managing Director
Australian Flight Test Services Pty Ltd

Phone : +61 8 8262 6998
FAX: +61 8 8343 8888
Email: pag@afts.com.au

Military Aviation Week's Aviat...

http://www.aviationnow.com/avnow/news/channel_military.jsp?view=story&id=news/muks1001.xml

5 Annex D

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

1. Kopp, C., 'Hedging the Bet - JSF for the RAAF?', Australian Aviation, August, 2002.

2. Kopp, C., 'Asia's Advanced Flankers', Australian Aviation, August, 2003.

3. Kopp, C., 'Su-30 vs RAAF Alternatives', Australian Aviation, September, 2003.

4. Kopp, C., 'Next Generation SAMS for Asia a Wake up Call for Australia', Australian Aviation, October, 2003.

5. Kopp, C., 'Asia's New SAMs', Australian Aviation, November, 2003.

6. Kopp, C., 'Network Centric Warfare', Defence Today, Vol 2 No 3, Page 28 - 34, Strike Publications, Pty Ltd, Amberley, August, 2003.

7. Kopp, C., 'Taking the Force out of Air Force?', Australian Aviation, Jan/Feb, 2004.

8. Kopp, C., 'RAAF Aerial Refuelling - Where To Next??', Australian Aviation, March, 2004.

by Carlo Kopp

Hedging the Bet – JSF for the RAAF?

On June 26 the Defence Minister, Sen Robert Hill, in a joint press conference with Industry Minister Ian Macfarlane and Chief of Air Force AM Angus Houston, announced that Australia would buy into the Lockheed Martin F-35 Joint Strike Fighter development program with the intent to purchase the aircraft as a replacement for the F/A-18A and F-111 fleets, should the aircraft meet expected needs in 2006, the planned AIR 6000 decision time.

For all practical purposes, the government decided to pre-empt the planned AIR 6000 competition and opt immediately for the JSF, with qualifying escape caveats which may or may not be observed at a future date.

To those closely observing the Canberra defence debate, the move to buy into the JSF program was not unexpected, however the decision to effectively shortlist the JSF into the position of preferred contender was a surprise to most observers and has elicited considerable criticism in strategic and informed media circles.

In this analysis AA will explore a range of issues which fall out of the government's JSF decision, and some of the possible ramifications of these. (Refer also Recce).

The Basic Capabilities of the F-35 JSF

The F-35 family of strike fighters was developed to cover a fairly diverse range of end user needs. In the land based regime the F-35 is to serve primarily as a supplement to the USAF's F-22 top tier air superiority and strike fighter, to fulfil the roles performed by the F-16CJ/CG variants tasked with tactical strike in the 400 to 600nm (740 to 1110km) radius band, and also the A-10A Warthog close air support and battlefield interdictor. In the maritime environment, the US Navy F-35 (CV) variant is intended to provide a survivable strike aircraft for carrier operations, while the US Marine Corps intends to use the vertical takeoff variant of the JSF to replace the AV-8B and F/A-18C as a close air support and battlefield interdiction aircraft.

A central design feature of all JSF variants is the use of elements of the F-22's integrated avionic architecture, engine and low observable technology. The JSF will employ an Active Electronically Steered Antenna in its radar, and has respectable stealth performance in the forward hemisphere, but is not an 'all aspect' stealth aircraft like the F-117A or F-22. The aircraft was designed from the outset to carry its primary weapons load internally, with provisions for external stores on four pylons in environments where stealth performance is not deemed critical. Wingtip rails may be adopted for carriage of the AIM-9X or AIM-132 ASRAAM heatseeking missiles, with some stealth performance penalty incurred.

Key design optimisations of the JSF (refer May/June 2002 AA for details) are the use of a moderate wing leading edge sweep to achieve best possible subsonic cruise range performance (very close to the A-7D Corsair II), and a generous internal fuel capacity to obviate the need for external drop tanks in its nominal 400 to 600nm (740-1110km) unrefuelled radius region. While the F-35 is roughly the size of an F/A-18A/C, its empty weight is closer to an F-15A/C, with an internal fuel capacity greater than an F-15A or F/A-18E – the characteristic external fuel payload of a fighter in this size class is carried internally by the JSF.

A very good historical analogy to the JSF is the Republic F-105 Thunderchief of Vietnam fame. The JSF and 'Thud' share almost identical empty weights, similar maximum gross weights and are both single seat single engine multirole fighters with a strong bias to strike rather than air-air capabilities. The fundamental departure between the two types is the basic penetration regime they employ – the 'Thud' used high speed at low level to evade defences, the JSF uses forward hemispheric stealth capability for the same purpose – both reflecting the preferred penetration paradigms of their times.

pic A

The best historical equivalent to the F-35 JSF is the Republic F-105D Thud or Lead Sled, a single seat single engine strike fighter with similar gross and empty weights to the new JSF. Like the JSF it was optimised for strike warfare with a secondary air combat capability, but in line with the penetration paradigm of the day it used high speed at low altitude rather than stealth at high altitude to evade opposing defences. The Thud was the backbone of the USAF bombing campaign during the first half of the Vietnam conflict. (USAF)

In terms of afterburning static thrust/weight ratio at 50% fuel load and 910kg (2000lb) weapons load the F-35 family sits very close to 1:1, with the heaviest navalised variant the least agile. This puts the aircraft in the acceleration and climb rate category of a well loaded F/A-18A/C, F-16C or lower thrust Su-27/30 variant. The F135 powerplant employs a variant of the F-22's F119 core, with a new fan and hot end to deliver a higher thrust rating at lower altitudes – the engine is not optimised for the supercruise regime of the F-22.

The JSF's strength is in its primary design optimisation, and it outperforms both the F/A-18A/C and F-16C in strike payload radius performance, with a low drag internal payload. The aircraft's forward sector radar signature is very good and will contribute to good survivability against typical battlefield radar guided SAM threats. In terms of payload radius performance, a JSF delivers roughly two-thirds of the radius of an F-111 on a similar profile, assuming both aircraft carry only internal weapons.

In the air combat role the JSF will provide subsonic Combat Air Patrol endurance better than the F/A-18A/C and F-16C, but not significantly different than the Su-27/30 Flanker series, which is the yardstick of regional fighter capabilities. In dealing with the Su-27/30 the JSF will be largely reliant upon scoring the first shot in a BVR engagement, using the advantage of a low forward sector radar signature. In the 'post-merge' environment, the JSF will have roughly parity in thrust to weight/ratio against the lower thrust Su-27/30 family models (the Sukhoi is more aerodynamically refined for this regime of combat), and the outcome of the engagement will be primarily dictated by short range missile and supporting avionics capabilities, tactics and pilot abilities.

Therefore, with the exception of BVR combat, JSF air combat tactics are likely to resemble F/A-18 tactics – the modest wing sweep, modest thrust/weight ratio and higher aft sector radar signature will preclude easy post-merge disengagements.

The JSF design concept was originally centred on cost reduction via the use of minimal radar capability, and generous use of external targeting data provided by E-3 AWACS, E-8 JSTARS, satellites and UAVs. Pressure from the USN/USMC camp, who required more air-air and autonomous air-ground targeting capability, saw the JSF acquire a respectable mid range radar, with aperture size roughly 10% to 20% better than the AESA designs for the F-16C/B60 and F/A-18E.

The tactical CONOPS planned for JSF operations by the USAF is to escort the JSF with F-22s, while European users such as the RAF and Italy would employ the Eurofighter Typhoon as an escort.

Force Structure Implications of the JSF

The JSF will require a number of adjustments in the RAAF's force structure to accommodate its idiosyncrasies, and the demands of the Defence 2000 White Paper strategic model.

In long range and loitering battlefield strike operations, the JSF will require very generous tanker support to provide the capabilities currently inherent in the RAAF's F-111 fleet. A preliminary analysis using Boeing offload data for

An X-35 demonstrator flies in company with an F/A-18. While the F-35 is roughly the size of an F/A-18A/C, its empty weight is closer to an F-15A/C, with an internal fuel capacity greater than an F-15A or F/A-18E. (Lockheed Martin)

the 767-200 tanker suggests that a one-for-one replacement of the F-111's existing unrefuelled capability (25 x F-111 to cca 950nm [1760km] with four external 2000lb bombs) using 50 JSFs (each with two internal 2000lb bombs) yields a requirement for around four supporting tankers, three for force refuelling and one airborne spare.

Pushing the radius out to 1500nm (2780km) roughly doubles that tanking requirement, to around 7 tankers, or about 2-3 times the requirement for the F-111 to that radius (the model allows only for JSF cruise fuel burn with internal stores, and would need adjustment if generous afterburner use or external stores are planned). At greater radii than 1500nm (2780km) the basic measure is that the pair of JSFs replacing each F-111 together burn 50% more fuel hourly than the F-111 does, requiring 50% more tanker support.

In a loitering battlefield strike environment, the JSF would most likely fly with a mix of internal and external guided bombs, either small diameter bombs or 500lb JDAMs. With an internal weapons payload it offers around one hour of loiter time at 450nm (835km), or roughly a third of the F-111. In practical terms this means that without aerial refuelling roughly three JSFs would need to be sortied to do the job of one F-111, at a station radius of 450nm (835km). With external stores on the JSF, that number will be higher as the aircraft's good nominal cruise fuel burn results from zero external stores drag.

Loitering battlefield strike is analogous in fuel burn needs to air defence combat air patrols at a fixed CAP station radius. A CAP radius of around 450nm (835km) would be required for air defence patrols over the North West Shelf and Timor Sea regions, and again the characteristic on station endurance with minimal afterburner use would be close to one hour. To maintain a CAP of four JSFs at 450nm (835km) for about four hours with a fuel reserve for combat would commit one KC-767-200 tanker, with one spare on standby.

In terms of tanking needs an all JSF fleet is therefore similar to an all F/A-18A fleet, but with better diversion range performance due to the JSF's better combat radius. The current White Paper 'regional denial' strike model envisages strikes to radii in excess of 1000nm (1850km) using the F-111 supported by F/A-18A escorts and tankers. With the planned five KC-767-200 sized tankers, a force package with two operational tankers and one spare could support a force of four F-111 bombers and four F/A-18A escorts to a circa 1500nm (2780km) striking radius. To put equivalent firepower in eight JSF bombers with four JSF escorts to the same radius will require three to four operational tankers and one spare. In practical terms, this amounts to a ~50% increase in the required operational tanker sortie rate to deliver a given amount of bombload to this radius.

Provisioning a fleet of 100 JSFs with robust tanker support to allow full concurrency in air defence and strike operations will require of the order of 24 KC-767-200 sized tankers, or roughly a doubling of the minimal tanker fleet size to support the current mixed F/A-18A and F-111 fleet size (three DCA tanker orbits and one concurrent package). This number reflects the standard USAF 'rule of thumb' which is four fighters per tanker, proven repeatedly since the 1960s SEA campaigns. While the White Paper tanker commitment covered about 40% of minimal required operational capacity, replacing the F-111s with tanker dependent JSFs pushes this out by roughly a factor of 50% to 100% (refer previous estimates).

It follows that the first major force structure adjustment following from the JSF decision would be to add 4 (four) additional KC-767-200 tankers, or equivalent capacity in a different type, to the existing AIR 5402 buy (or suffer a consequent reduction in capability – Ed). The delivery of these tankers would need to be phased in concurrently with the phasing out of the F-111 fleet to preclude a loss in nett RAAF capability. In effect this doubles the AIR 5402 tanker buy without even addressing the projected 'White Paper tanker gap' in a JSF centric force structure.

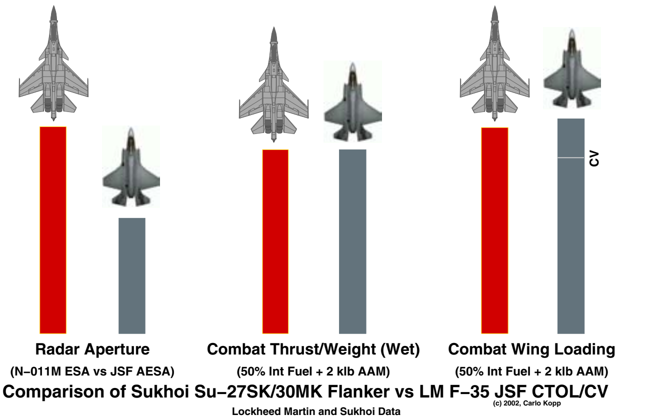
The second important force structure issue flowing from a JSF commitment is the number of Wedgetail AEW&C aircraft required to support the fighter fleet, and arguably the configuration of these aircraft. While the JSF radar is an improvement over the F/A-18A radar, it is much less capable in its detection footprint in comparison with larger fighter AESAs such as the F-22's AN/APG-77.

Therefore JSFs used in the air defence and air superiority roles will be more closely tied to the Wedgetail AEW&C aircraft to offset limitations in radar capability. This is especially true for air defence operations against low signature targets such as cruise missiles. Current USAF thinking for dealing with this threat is to use the JSTARS derived X-band AESA on the proposed E-767/MC2A AWACS replacement (mounted under the forward fuselage) to provide precise tracking of cruise missiles and vectoring of fighters to engage them.

With cruise missiles proliferating across the wider region a robust capability to defend against them will eventually be required. The radar power-aperture limitations of the JSF will necessitate an increase in the radar capabilities of the Wedgetail to do so. A case can also be made to commit to the full seven optioned for Wedgetails to provide for concurrency in strike and continental air defence operations.

Enhancement of the Wedgetail with an X-band capability to offset the limitations of the JSF radar is not an unusually expensive measure, insofar as the USAF is very likely to perform the required integration with the closely related Boeing mission package on the MC2A.

The third force structure issue arising from the JSF decision is that of supporting Combat Search and Rescue



Based on provisional JSF specs, the JSF has parity with the Su-27/30 series only if the latter is fitted with the lower thrust AL-31F engine variants. Thrust to weight ratio will be a critical parameter for the JSF if it is to be viable in air combat roles. (Author, LM)

(CSAR) capabilities. All long range overwater operations require supporting CSAR capabilities to account for aerial refuelling probe/receptacle failures – a fighter which can no longer refuel will need to divert to a safe runway or a naval vessel on station to prevent the loss of the pilot.

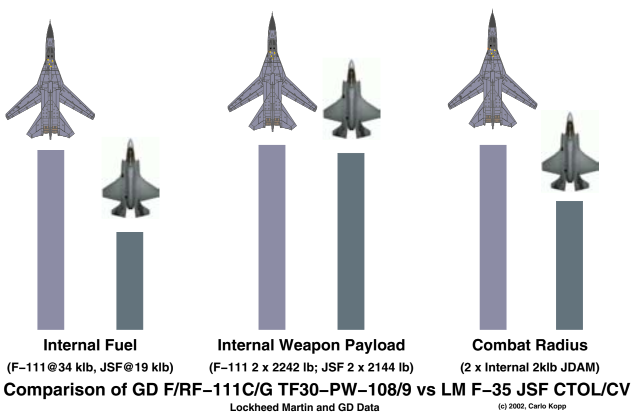
The JSF is a single engine fighter and thus an engine failure can put the pilot into the sea at any point along the flightpath between the operating base and target. In practical terms the result of this is that CSAR assets with the range and capability to penetrate contested airspace and waters will be needed to recover pilots. Training in long range overwater operations will also require appropriate SAR capabilities, not currently a priority with a twin engine fighter fleet.

The biggest force structure challenge for the RAAF arising from the JSF will be aerial refuelling – basically one tanker will be required to offset the loss of each six F-111s in the RAAF force structure. Even if the government opts to do no more than retain the existing force structure capability which falls well short of the stated White Paper capability goals, AIR 5402 will need to be nearly doubled in size.

Technological Issues in the JSF

The JSF is a high risk program with unusually ambitious goals, both in costs and in capability for an aircraft of its size. A number of key risk factors must be carefully considered in the JSF program:

The JSF is not an F-111 in terms of payload radius performance. The practical consequence of this is that the AIR 5402 tanker replacement buy will need to go up by four aircraft immediately that a final commitment is made to JSF, to offset the loss in RAAF force capability resulting from F-111 replacement by JSFs. (Author, LM)



• The JSF avionics system is to depart significantly from the established Milspec conventions and make use where possible of Commercial-Off-The-Shelf computer and bussing technology. This is a very fundamental shift in the basic technology used for fighter avionics construction. The last historical example of such a shift was the F-111D Mark II avionic package which provided astounding capabilities for its time but also overran its cost targets by large margins and proved to be very unreliable in service. A key concern is that COTS derived avionics reliability issues may not become apparent until the aircraft is established in a squadron operating environment and thus issues may persist beyond the development cycle period.

• The JSF is expected to be more software intensive than the benchmark in this area, the F-22. This is yet another aggressive and ambitious jump ahead of the established technology base and has much potential for problems arising downstream. Given the plethora of case studies in large and complex embedded software systems running late and overrunning costs by large margins, it is reasonable to conclude that mission package software could prove to be a major issue later in the program.

• The JSF uses a derivative of the F-22's P&W F119 engine, but employs a 'supercooled' hot end running with the highest turbine inlet temperatures used in any turbofan powered fighter. The designers of the engine pushed the temperature envelope out to achieve the required 1:1 combat thrust/weight ratio when installed in the JSF airframe. There is potential for durability issues arising in a very hot running engine which would be handled by engine derating, which could compromise performance in what is a sensitive area for the JSF design. Were the JSF in the 1.4:1 combat thrust/weight ratio class, a 10% loss would be tolerable, however at almost exactly unity (1:1) this is going to be a critical issue for the aircraft. The flipside of this argument is that total aircraft weight will be an ongoing issue throughout the life of the JSF.

These are three key areas of technological risk in the JSF and in magnitude they compare closely to the 1960s TFX/analog F-111A/B and digital F-111D programs all rolled into one – combining a new airframe, avionics/software technology and propulsion package. Even if we assume only a 20% probability of serious problems arising in each of these areas, the nett probability of the program getting into genuine development difficulties is very close to 50:50, using Lusser's product law.

Therefore we should not be surprised if JSF runs late and indeed if the cost does creep upward over time. The historical precedents suggest a typical cost growth between the demonstration/validation/prototype phase of a fighter program and full rate production of the order of 50% – numerous case studies exist. A JSF at $US60m to 75m flyaway cost apiece might not be the bargain many currently imagine – at around three quarters of the production cost of the much more capable and bigger F-22 Raptor.

Commercial/Political Issues in the JSF

There are a number of important political and commercial issues which arise from the JSF program. For the RAAF some will be of major importance:

• Releasability of the system source code. In a software intensive fighter such as the JSF, the software is the 'crown jewels' of the avionics system, which is largely built around general purpose computers rather than traditional custom hardware. Even if the manufacturer is happy to part with the code, the US Congress and State Department might not be.

• Releasability of 'USAF grade' stealth capability in the aircraft. It is likely that the JSF will end up being built with two levels of stealth capability, 'USAF grade' with absorbent structures and coatings of a high standard, and 'export grade' with lower quality materials. The stealth capability of the JSF is a 'do or die' combat survivability issue with the

JSF since it does not have the kinematic performance or BVR firepower of the F-22 or indeed the late model AESA equipped F-15 series. It is imperative that the RAAF gets the 'USAF grade' stealth capability.

• Releasability of 'USAF grade' EWSP capability in the aircraft. It is likely that the JSF will end up being built with two levels of EWSP capability, and the previous argument applies.

• Unit flyaway cost. The production cost of the JSF will be sensitive to technological parameters but also to total production numbers, and rate of production, all distinct from fiscal inflationary causes of cost growth. Significant cost increases could arise from large changes in build numbers, an effect most recently seen when the F-22 build got chopped from 750 down to 339.

The USAF is again pushing hard to have the F-22 program restored to 750 aircraft to meet evolving force structure needs, and any funding for more F-22s is almost guaranteed to be at the expense of USAF F-35 numbers. (The full scale production Block 5 F-22 will carry the Small Diameter Bomb, JDAM, SAR ground attack radar modes, a JTIDS transmit capability and most likely an AESA built using cheaper JSF generation modules – the expectation is that many technologies developed for the JSF program will be rolled into the F-22 to reduce production costs and achieve commonality to reduce support costs.)

The US Navy is ramping up a major program to replace surface combatants and in the post Cold War environment, carrier air wings have been the most frequent casualty of funding squeezes. Only the USMC is irrevocably committed by force structure to the STOVL JSF as it has no alternatives to fall back on. Both the USN and USMC have already trimmed back their planned JSF buys.

• Stability in a multinational development program. The historical precedents for successful multinational military development programs are few and far between. The most recent major effort was the US/European NATO air-air missile agreement, under which Europe was to develop a common Sidewinder replacement in the ASRAAM, the US was to develop the common Sparrow replacement in the AMRAAM, and all would buy or licence each other's missiles. Today both sides of the Atlantic make their own unique radar guided missile, and the AIM-9X, ASRAAM, Mica and Iris-T demonstrate complete fragmentation in the Western heatseeking missile market.

The Eurofighter/Rafale split is another case study, as is the 1960s TFX program. With a large number of players on both sides of the Atlantic the JSF program will face a major challenge in keeping divergent interests from fragmenting the program by pushing service or nation specific agendas. The departure of major players, or major buy reductions by players would produce a self-reinforcing feedback effect – every player chopping a buy drives the cost up, in turn encouraging other players to chop their buys, and so on. Australia as a small player is at the mercy of forces it cannot control in this respect.

• Australia has developed a significant capability for weapons and systems integration in the Amberley WSBU, which maintains the F-111. The retirement of the F-111 and adoption of a 'turnkey' off the shelf imported fighter product could see this strategically important capability vanish – thus nullifying the benefits of two decades of investment by the RAAF and causing the loss of the cumulative and expensive to develop experience base. The RAAF needs to define a strategy for migrating this capability to the F-111 replacement, since the ability to integrate arbitrary weapons and modify software in country provides not only a rapid response capability in times of crisis, but also keeps the weapons vendors honest.

Conclusions

The decision to buy into the JSF program and provisionally commit to this aircraft as the primary solution for AIR

On a wing and a prayer? History suggests there are significant risks ahead for JSF development. (Lockheed Martin)

6000 has far reaching implications, especially in terms of the future RAAF force structure, and the nation's strategic position. A key issue for the RAAF will be the introduction of necessary aerial refuelling capabilities to offset the significant payload radius and endurance differences between the new JSF and established F-111.

An order of magnitude estimate is that two to five times the number of tankers budgeted for under AIR 5402 may be required, the latter if the RAAF is to bridge the existing 'tanker gap'. Enhancements in Combat Search and Rescue capabilities will be required, and it is likely that further investment into the Wedgetail program will be necessary to offset the inherent limitations of a small fighter radar in the JSF.

The JSF program is by far the highest risk combat aircraft development program since the 1960s TFX, F-111D and TSR.2 programs, the risk spanning the technological capability of the aircraft to do the intended job, the timelines for aircraft delivery, and the cost of the aircraft. Cost will be highly sensitive to total build numbers of the JSF, and the basic technology being used in the aircraft.

The ability of a bomb truck to be adapted to highly demanding air superiority and air defence roles will hinge critically on the aircraft's weight, achievable engine thrust ratings, and radar/avionics/stealth performance. Shortfalls in any of these key areas could compromise the JSF for all but its core battlefield bomb trucking roles. The cost/capability balance and residual program risks will need to be monitored very closely throughout the period between now and 2006.

It is important that Australia does not overinvest politically in the expectation of a highly successful JSF program outcome – JSF is a high risk – high payoff gamble for the US industry and its clients. Come 2006, an overweight, underperforming JSF with software and avionics reliability problems, delivered at 75% of the flyaway cost of an F-22, would be a very poor investment of taxpayer's dollars as an operational AIR 6000 solution. Therefore, as in any high risk investment play, the smart strategy for the DoD/RAAF to pursue is to hedge the bet with an alternative solution based upon the more capable but more expensive fourth or fifth generation F-22. Without a well developed fallback strategy the government of the day, and the RAAF, will be up the proverbial creek without a paddle if the JSF does not become the low cost panacea solution it was declared to be on June 26 2002.

Australians are a betting nation, and the JSF decision is well in character with our national proclivities. The die has been cast, where it eventually falls remains to be seen.

by Carlo Kopp

ASIA'S ADVANCED FLANKERS

It is unfortunate that the media spectacle of Operation Iraqi Freedom diverted the public's focus in Australia away from happenings in the nearer region.

In recent months several important developments have taken place, with Malaysia and Indonesia signing delivery contracts for their first top-tier Sukhoi Su-30 fighters, and India taking delivery of its first fully configured Su-30MKI aircraft. While these developments have not been unexpected, they represent an ongoing shift in regional aerospace power and capabilities which Australia should not choose to ignore.

Some defence analysts in Canberra have argued vocally in the media that the War on Terrorism demands that Australia fundamentally restructure its basic strategic doctrine and indeed reshape its force structure. It is proposed that the needs of coalition warfighting in distant locations should take precedence over the 'Defence of Australia' in the nation's force structuring and funding priorities. Media comments attacking established doctrine and ridiculing it as 'Fortress Australia Policy' suggest that this perspective is more popular than one might imagine.

Such reasoning is dangerous and ill informed – reflecting on the part of most protagonists of this view a weak if not wholly absent understanding of modern airpower and its implicit strategic influence. To better understand how foolish this point of view actually is, we must explore more closely the capabilities of the latest Sukhoi fighters and their implicit longer term growth potential.

Sukhoi Su-30 derivatives

The early history of the Su-27 family of fighters has been widely documented, and some excellent references exist (Andrei Fomin's *Su-27 Flanker Story* published by RA Intervestnik is arguably the single best printed reference, while Easy Tartar's reference at www.sci.fi/~fta/Su-30.htm is the best website).

The original design aim of the Perspektivnyy Frontovoy Istrebitel (PFI – Future Tactical Fighter) was to kill the US Air Force's then new F-15A, and both the Sukhoi and Mikoyan bureaus submitted designs. The Sukhoi T-10 concept emerged in the early 1970s, and was conceptually closest to a fusion of the fixed wing Grumman VFX-404 configuration with the blended strake/wing/body configuration of the GD LWF demonstrator, later to become the F-16A. From the outset the design was to use various combinations of mechanical hydraulic and fly-by-wire (FBW) controls with some reduced static stability to achieve exceptional manoeuvrability.

The early T-10-1 demonstrator evolved into the current T-10-15/Su-27 configuration through an almost complete but necessary redesign during the early eighties. The result has been the most aerodynamically refined of all of the third generation fighters. Like the MDC F-15A, the basic design was devised from the outset to accommodate both single and dual seat configurations. The Su-27UBK tandem dual trainer airframe became the basis of the Su-30 series.

Introduction into PVO-S (Protivo-Vozdushnaya Oborona Strany – air defence force) and FA (Frontovaya Aviatsia – tactical air force) service was protracted, especially due to problems with manufacturing an airframe with a substantial amount of titanium alloy and honeycomb laminates, but also due to difficulties with the complex 'F-15-like' avionics package.

To demonstrate the aircraft's potency as an F-15 killer, the Sovs in 1986 stripped and modified the T10-15 prototype, redesignated it the P-42 and promptly took out no less than 22 FAI records, mostly in the 'time to height' categories previously held by the F-15A. Such impressive basic performance results from the exceptionally clean aerodynamic design and the pair of large Lyulka AL-31F series afterburning turbofans – the P-42 would have used early variants of the engine.

The baseline Su-27 airframe resulted in two nearly identical variants for the PVO and FA, the Su-27 and Su-27S, with a common dual trainer in the Su-27UB. The single seat Su-27/Su-27S was manufactured by the KNAAPO plant at Komsomolsk-on-Amur and the dual Su-27UB was manufactured by the IAPO plant at Irkutsk, with design authority remaining at the Sukhoi bureau. The principal distinction in the Frontal Aviation Su-27S was a capability to deliver dumb bombs and rockets – not unlike the F-15A/B/C/D models. Both types were to carry the large pulse doppler Myech air intercept radar, which was to use a mechanically steered planar array antenna with electronic vertical beam steering, but production aircraft with the NIIP N001 used a simple mechanically steered cassegrain antenna.

Several early derivatives of the Su-27 are of much interest since they paved the way for the production Su-30 subtypes now seen in the Asian export market.

The navalised Su-27K (for 'Korabl'ny') was developed for the Project 1143.5 55,000 tonne class aircraft carrier, of which four were to have been built. The Su-27K had beefed up undercarriage with twin nosewheels, upgraded hydraulics, a tailhook, enlarged flaperons, a modified ejection seat angle, folding outer wings and stabs, upgraded FBW, modified LERX (Leading Edge Root Extensions) with canards, enlarged leading edge slats, and a deployable aerial refuelling probe.

The refuelling probe modification included a pair of deployable floodlights in the nose, used to illuminate the tanker aircraft, here intended to be either an Il-78 Midas or another Su-27 buddy tanker carrying a centreline UPAZ hose-drogue pod. The probe permits a fuel transfer rate into the fighter of up to 1815kg (4000lb)/min.

Another notable Su-27K feature to migrate to later variants was the right offset IR Search and Track housing, this improving the pilot's downward view over the aircraft's nose. Production Su-27Ks operated by the Russian Navy are often designated the 'Su-33'.

Perhaps the most important feature of the Su-27K/Su-33 is the enlarged LERX/canards which increase the available body lift of the aircraft, and shift the centre of pressure forward, thus enhancing achievable pitch rates. The Su-27 series shares with the F-14 a large body lift capacity resulting from the wide fuselage tunnel – as a result the aircraft's effective wing loading is much lower than that of aircraft with different configurations. This is reflected in superb high alpha handling and sustained turn rates.

The side-by-side dual navalised trainer was so successful it evolved into the F-111 like Su-34 series bombers, intended to replace the Su-24 Fencer. As yet no production orders have been received for this series, although Chinese interest has been reported more than once.

While the navalised Sukhois spawned key aerodynamic design innovations in the series, the land based variants accounted for most of the avionics and propulsion improvements. The most important early derivative was the dual role single seat Su-27M strike fighter, frequently labelled as the Su-35. Initiated in 1982, the Su-35 best compares to the F-15C in basic capabilities. It was to be the initial platform for the then new Vympel R-77 'Amraam-ski' active radar guided AAM. The Su-35 was to carry a complete EWSP package, a cockpit wide angle Head Up Display (HUD), triple MFDs, an improved RSLU-27/N011 fire control radar package using a new slotted planar array antenna rather than the N001 design, an N012 tail warning radar, an improved OLS-27K Infra-Red Search/Track (IRST), the Schchel-3UM Helmet Mounted Sight (HMS), ShO-13A Doppler nav, an inertial nav package, air/air and air/ground GCI (Ground Control Intercept) datalinks, two additional inboard wing hardpoints to permit up to 12 external stores, and the aerial refuelling probe.

Structural changes were required to the forward fuselage to accommodate the larger radar aperture, relocated IRST, aerial refuelling probe and revised avionics. The additional 1360kg (3000lb) of empty weight required strengthened undercarriage, dual nosewheels, detail structural changes, and the Su-33's canards were later incorporated. To offset the loss of combat radius due to additional weight the wet portion of the wing was extended to the 13th rib, from the 9th, and a 360 litre tank was added to each vertical tail, thus providing a total internal capacity of 10,250kg (22,630lb). The dual combat trainer variant designed by KNAAPO is designated the Su-35UB. Twelve preproduction Su-35s were built, and tail number 711 became the Su-37 demonstrator.

The Su-37 was to incorporate two important advancements over the Su-27M/35. These were thrust vectoring nozzles and the new NIIP N011M passive shifter technology ESA (Electronically Steered Array – phased array). In addition, an electrical sidestick controller was mounted in the right side of the cockpit. The Lyulka bureau designed the first axisymmetric two dimensional thrust vectoring (2D TVC) nozzle ever deployed during this demonstration program – the nozzle Time Between Overhauls (TBO) is reported at 250 hours vs the 1000hr TBO for the AL-31FP core.

The all important Flight Control System (FCS) in the Su-27 family evolved incrementally, with the first generation hybrid analog system running in parallel with the conventional hydro-mechanical design. The Su-37 introduced a genuine redundant digital system, similar in concept to its contemporary western designs.

The Su-30 series is not directly evolved from the Su-27M line, but has incorporated many design features demonstrated in the Su-27M/35/37 line. The origins of the Su-30 lie in the last years of the Soviet era, when the PVO sought a combat capable derivative of the existing Su-27UB conversion trainer. The dual variant was to be equipped for aerial refuelling and used as a long range long endurance interceptor and combat 'command and control fighter' to lead long range CAPs. The aircraft was initially designated the Su-27PU (Perekhvatchik – Uchebnoy) and later relabelled the Su-30. The Su-30 was developed in part by the Irkutsk plant, responsible for manufacturing the Su-27UB. The export variant of the Su-30 was designated Su-30MK and unveiled in 1993 – as a multirole strike fighter rather than interceptor.

IAPO/Sukhoi Su-30MKI IAF

The hard sell by the Irkut plant (formerly IAPO) and Sukhoi paid off in late 1996 when the Indian Air Force signed for an advanced derivative of the baseline Su-30, the Su-30MKI (M-Improved, K-Export, I-India). In a complex deal which saw initial deliveries of basic Su-30K and progressive development and later delivery of full configured and licence build Su-30MKI, India negotiated a buy which will see around 180 of these aircraft deployed with IAF squadrons.

The Su-30MKI is a fusion of technology from the Su-37 demonstrator and Su-30 program, with additional Indian designed and built processor hardware in the Mission Computers, Radar Data Processor provided under the Vetrivale (Lance) industry program, and some items of Israeli and EU hardware. The aircraft has a Thales (Sextant Avionique) HUD and RLG (Ring Laser Gyro) INS/GPS, glass cockpits, NIIP N011M phased array, AL-31FP TVC engines, enlarged rudders, Su-33/35/37 canards and aerial refuelling probe, and an improved OLS-30 IRST package. The Indian developed Tarang RWR is used in the EWSP suite.

The TVC system in the Su-30MKI has evolved beyond the Su-37 system, which deflected only in the vertical plane. The Su-30MKI variant has a 32 degree canted TVC plane to introduce a lateral and vertical vectored force component, and is driven by the engine's fuel system rather than the main aircraft hydraulic loop.

The Indian Su-30MKI is to date the most advanced Su-27 derivative to enter production and with the exception of mission avionics and software is a credible equivalent to the F-15E/I/K/S family. It also underscores the 'no holds barred' international arms market, in which an export customer is supplied with a product which is half a generation ahead of the Russian air force – the IAF designates it as its 'Air Dominance Fighter'.

However, the greatest Sukhoi export success to date has been KNAAPO's deal to supply and licence build Su-27SKs and Su-27UBKs for the Chinese PLA-AF – also the very first export deal for the aircraft. The initial order was for 20 Su-27SKs and four Su-27UBKs, essentially the same configuration as Soviet Frontal Aviation units flew but claimed to be fitted with Phazotron Zhuk rather than the NIIP radars. A second batch of aircraft, consisting of a further 16 Su-27SKs and six Su-27UBKs, was supplied in 1996, bringing the fielded total to 46. That same year KNAAPO was awarded a contract to set up licence production of the Su-27SK at the Shenyang plant in China – these are designated as the J-11 and up to 250 may be built. An additional buy of 20 or more imported Su-27UBK dual trainers was reported in 2002.

India's buy of the Su-30MKI triggered a response in Beijing – the PLA-AF ordered around 50 Su-30MKK fighters from KNAAPO. The KNAAPO Su-30MKK is not the same as the Irkut Su-30MKI in configuration, despite the shared 'Su-30MK' designation. The baseline Su-30MKK has the Su-35/37 vertical tail design, no canards, no TVC capability, Russian avionics and a variant of the Phazotron Zhuk planar array radar. An improved OEPS-31E-MK IRST package is fitted. There are reports the aircraft has an increased maximum takeoff weight against the Su-30/Su-30MKI, requiring structural changes. Like the PLA-AF Su-27SK the Su-30MKK uses the original analog FCS.

KNAAPO/Sukhoi Su-30MKK PLA-AF

KNAAPO/Sukhoi Su-27SK PLA-AF

The Su-30MKK is a KNAAPO development which is closest in concept to a dual seat Su-35 without the canards added to the production Su-35. It is, like the Su-35, a dual role fighter, occupying the same niche as the F-15E but less accurate, and less capable in the air-air role than the Su-30MKI. A version for the Chinese navy is claimed to be under development, designated the Su-30MK2, to be armed with the Kh-31A ramjet anti-shipping missile.

Russian sources put the current Flanker total supplied to the PLA-AF as 76 Su-27SK/UBKs, 50 Su-30MKKs with outstanding orders for 19 more, and a commitment for licence production of around 200-250 aircraft. Russian estimates of the ultimate size of the Chinese air force Su-27/30 fleet fall between 350 and 500 aircraft. For comparison, the US Air Force fielded around 400 F-15Cs and 200 F-15Es, putting the PRC's orders into a similar force structure size bracket – and almost twice the size of the Indian Su-30MKI fleet.

IAPO/Sukhoi Su-30MKM TUDM (RMAF)

Malaysia has recently committed to purchase 18 Su-30MKMs beating the Boeing F/A-18F bid – evidently Malaysia's bilateral MiG-29 support relationship with India exposed the RMAF/TUDM to the Indian Su-30MKI program and they liked what they saw. The Su-30MKM is being supplied by Irkut and will therefore be of similar configuration to the Su-30MKI, although as yet no details are available on the specific fit of the MKM variant – it is known that some French avionics will be used. The aircraft will be delivered from 2006. It is likely that a large portion of the deal will be financed by barter of Malaysian industrial and consumer goods.

KNAAPO/Sukhoi Su-30MK TNI-AU

KNAAPO/Sukhoi Su-30KI TNI-AU

Indonesia's TNI-AU has had a long standing interest in the Sukhoi fighters and prior to the Asian economic crisis committed to purchase the Su-30KI. This aircraft was to be supplied by KNAAPO and was derived from the single seat Su-27SMK, a midlife upgrade design package for the baseline Su-27S. The Su-30KI is thus an improved single seat Su-27S, with the improved N001E radar and cassegrain antenna, aerial refuelling probe, centreline OLS-27 IRST, ILS-31 HUD, and provisions for the R-77 Adder missile. This variant is more the air superiority fighter than dual role strike fighter and is essentially a low cost upgrade of the basic production KNAAPO Su-27 line – the use of the early configuration centreline IRST installation suggests the Su-30KI may be built from refurbished low time PVO Su-27 airframes.

In late April this year Indonesian President Megawati signed an MoU with Russia for the supply of four Sukhoi fighters, two Su-27SKs and two Su-30MKs (some sources claim Su-35, others Su-30KI) to the Indonesian TNI-AU later this year. Media reports from Jakarta indicate that the TNI-AU intends to acquire between 48 and 54 of these aircraft over this decade, and often report the inclusion of an aerial refuelling capability – part of the Su-30KI configuration. Whether the TNI-AU aircraft are Su-27SKs, Su-35s, Su-30KIs or Su-30MKs is immaterial in the longer term, since the basic KNAAPO/Irkut T-10 family of designs permits incremental retrofits, and cash permitting any of these variants can over time morph into a more advanced model.

SU-30 GROWTH PATHS

The Su-27/30 series is by far the aerodynamically most refined of the third generation fighters in the market and is a direct equivalent to the late build F-15E/I/K/S variants. While it does not offer quite as good supersonic performance and handling to the F-15, it makes up for this with exceptionally good low speed high alpha handling and performance.

From an 'information age' warfighting perspective, the basic Su-30 series airframe has some very attractive features absent in competing western third generation fighters.

The first of these is its massive radar bay, capable of fitting a one metre phased array antenna. In the long range BVR combat game, radar range is a key factor and for any given radar technology, the larger the aperture the better. While the current N011M/ME uses passive array technology which delivers less peak power than competing active arrays (AESA), it is only a matter of time before NIIP and Phazotron adapt commercial GaAs MMIC technology (98%

of the total GaAs chip market) to build an AESA variant competitive against the AESAs in the latest western third generation fighters (some upgraded F-15Cs, F-16C Block 60, F/A-18E/F). With similar TR (Transmit-Receive) module performance, the fighter with the largest aperture size wins in this game – for instance the N011M has around twice the aperture size of the JSF AESA and F/A-18E/F's APG-79 and even with inferior TR module technology will be highly competitive. It is worth noting that India is only the fourth nation worldwide to field a phased array equipped third gen fighter, after France, the US and Russia.

While the existing N011M has limitations in its older technology back end processing, the future is the path India has followed, retrofitting third party hardware with better performance than the Russian processor hardware. With widely available commodity processor chips in the 1 to 2 GHz class, we can expect to see many other Sukhoi users emulate the Indians in coming years, be it in MLUs or new build aircraft.

The existing N011M series lacks a Low Probability of Intercept capability, in part due to antenna bandwidth limits and in part due to processor limitations. This is likely to change over the coming decade as customers demand an ability to defeat or degrade western ESM equipment and the technology to do this becomes more accessible.

The N012 tail warning radar has been reported to be part of the Su-30MKI suite and is offered as a retrofit to other models.

Another attractive design feature is the large IRST housing, which can fit an aperture larger than competing western IRST systems – the more photons the IRST can capture, the greater its detection range potential. The baseline OLS-27 IRST can scan a 120x75 degree field of regard, and cover a field of view as narrow as 3x3 degrees, but has poor sensitivity with a head-on detection range of about 8nm (15km). The integrated laser rangefinder is effective to about 1.5nm (2.8km). Specifications for the OLS-30 have not been disclosed – it is known that further development is underway on an IRST/FLIR design similar in concept to the Eurofighter's Pirate system.

As with radars, IRST and FLIR aperture size matters, and the Sukhoi is in a commanding position with the existing OLS-27/30 package. With commercial technologies such as Quantum Well longwave/multiband imagers of 800x600 pixel resolution in the EU market, it is only a matter of time before this technology finds its way into an OLS-30/31 derivative. Current US IRSTs using older MCT imaging arrays have detected fighters at distances of many tens of miles.

The cockpit of the existing Su-30 series provides plenty of opportunities for further growth, both in display technology and back end processing. With militarised commodity AMLCD display panels becoming increasingly available, the trend we have observed with the Thales (Sextant) displays in the MKI is likely to grow over time, driven by the need to compete against US and EU cockpit designs. We should not be surprised to see India and Israel become prominent in the Sukhoi MLU market. The same will be true of mission computer equipment.

Maturity in flight control software has seen aggressive improvements in types such as the F/A-18E/F, and it is reasonable to surmise that the adoption of digital FBW controls in recent Su-30 variants will see similar evolution in the Sukhoi types – especially given the Russian obsession with close in manoeuvre performance.

In terms of propulsion, we have seen incremental improvements in the AL-31F series, with the F-3 model cited at 28,250lb (125kN) (with the baseline F-1 at 27,600 lb/123kN). The Russians have been quite coy about the thrust ratings of later AL-31F subtypes, and we should not be surprised to see the AL-35F/FP (~31,000lb/138kN) and AL-37F/FP (~32,000lb/142kN) appear either in export models or MLUs, in basic and TVC variants. KNAAPO/Irkut are offering TVC kits as retrofit items to existing models, as they are offering seamless engine upgrades. It is unclear whether the 35,000 to 40,000lb (155 to 178kN) class AL-41F will find its way into the Su-30 series.

The engine configurations in current export models such as the Su-30MKI and Su-30MKK have not been disclosed – given the Sukhoi penchant for obscure nomenclature, we way well see AL-35/37 derivative engines marketed as AL-31F-X numbered variants. With uprated engines even the heaviest Su-30 models deliver impressive combat thrust weight ratios in the 1.2:1 class, competitive against the latest F-15C configurations.

In terms of avionics systems and propulsion we can expect to see ongoing incremental growth in the Su-30 series, as market pressures drive KNAAPO and Irkut to integrate newer technologies in the aircraft. As the Su-30 is the primary export revenue earner in Russia's defence industry, and a primary means of exporting Russian guided munitions, it is apt to continue to be the platform for the deployment of the latest domestic and imported technologies. The unknown factor is how much modern EU and Israeli technology will find its way into the Sukhois over the next decade. With Germany, France and Israel active in the MiG MLU market, the existence of Asian aggregate fleet numbers around 600 or more aircraft will present an irresistible attraction for the sale of avionics and systems upgrades, be they incremental or major block upgrades.

Air-to-air weapons is one area where the Russians have been very aggressively developing and marketing new products. The baseline Su-27S was armed with the R-27 (AA-10 Alamo) semiactive radar homing BVR missile and the R-73 (AA-11 Archer) WVR missile. The thrust vectoring R-73 (refer AA 4/97) was a trend setter and we have since seen an improved R-73M marketed, as well as a digitised seeker equipped R-74E variant credited with 75 degree off boresight capability and kinematics to kill 12G targets. Indian press reports suggest the Rafael Python 4 has been offered to India and it is not inconceivable that this missile will find its way on to Indian and other regional Sukhois –

A major asset of the original flanker design was the ability to accept a wide range of modifications and equipment upgrades including thrust vectoring and canards. The ability of these powerful aircraft to neutralise high value assets at long range should not be discounted. (Paul Merritt)

India is currently negotiating for the Phalcon AEW&C system fitted to the Ilyushin/Beriev A-50E airframe and has acquired ballistic missile defence radars from Israel.

The Vympel R-27 is the Russian equivalent to the late model US AIM-7 Sparrow series BVR missiles, but the similarity ends there since the R-27 is available in a plethora of variants. The basic airframe is supplied in long and short burn variants with differing range performance, and with heatseeking or datalink aided inertially midcourse guided semiactive radar seekers. The R-27R1 and R-27ER1 are the radar guided long and short burn versions, respectively, credited with F-pole (distance between shooter and target at missile impact) ranges of 43nm (80km) and 70nm (130km). The R-27T1 and R-27ET1 are the respective heat seeking equivalents, credited with slightly lower engagement ranges. The X-band anti-radiation seeker equipped R-27P/EP has been reported, designed to kill emitting fighters in the forward quarter by homing on their radar emissions. More recently Agat has offered new build or retrofit active radar seekers as the R-27A/EA, the 9B-1103M/9B-1348E, derived from the R-77 seeker.

The most recently exported missile in the region is the Vympel R-77 RVV-AE (AA-12 Adder), the ‘Amraam-ski’. This missile, with unique lattice controls, is a modern BVR weapon designed to kill 12G targets, and credited with an A-pole (distance between shooter and target when missile becomes autonomous) range of 54nm (100km), although some reports suggest early production rounds are not delivering the kinematic performance advertised, not unlike early AIM-120A Amraams. As the R-77 has Amraam-like capabilities, it permits an Su-30 to launch multiple rounds and guide these concurrently, engagement geometry permitting. As the R-77 matures, we can expect to see refinements in propellants, autopilot kinematics and seeker jam resistance.

We have yet to see reports of regional deliveries of the Vympel R-77M RVV-AE-PD (Povyshlenayya Dal’nost’) ramjet Adder, credited with an A-pole range around 80nm (150km). This missile is a direct derivative of the R-77.

Alternate seekers for the R-77 have been advertised – the heatseeking R-77T using an MK-80M seeker from the R-73M and R-27T, and the anti radiation R-77P. The deployment of the new F/A-22A later in the decade will see significant pressure on Vympel to supply heatseeking, anti radiation and electro optical imaging seekers on the R-77/R-77M in an attempt to counter the combined kinematics and all aspect stealth of the F/A-22A. While such seekers may do little to offset the overwhelming advantages of the supercruising F/A-22A, they are likely to prove quite effective against inferior types such as the F-35 JSF, F/A-18E/F, late model F-15E and F-16C/B50. If the Su-30 can close to a range where an advanced longwave IRST can track the target, an optical seeker equipped R-77 variant can be used to affect an engagement, defeating the RCS reduction measures on these aircraft. The anti-radiation R-77P could be used to engage at maximum missile range.

In the long range missile domain, the Vympel R-37 (AA-X-13) series of AIM-54 Phoenix look-alikes has been proposed – a developmental R-37 successfully engaged a target at 162nm (300km) of A-pole range in 1996. A more interesting proposal has been the use of the Novator KS-172 RVV-L (AAM-L) missile, a 215nm (398km) range 750kg (1650lb) launch weight long range AAM. The KS-172 uses datalink/inertial midcourse guidance and an active radar terminal seeker, and Russian sources claim a snap-up capability to 100,000ft and snap-down capability to 10ft AGL. KS-172 mock-ups have been photographed on Su-30 displays but its production status is unclear.

Of no less interest is the Kh-31R (AS-17 Krypton) family of ramjet anti-radiation missiles, offered as a standard store on the Su-30/35 subtypes. This missile, in basic anti-radiation and dual mode seeker variants (refer Part 2 next issue) is often dubbed the ‘AWACS killer’, and would be used to destroy opposing AEW&C aircraft, or surface based radars. Sukhoi advertises a load of up to six rounds, two on the inlet stations.

The dominance of US ISR capabilities (refer AA 7/03) is producing an increasing demand for ‘counter-ISR’ weapons and the Sukhoi fighter equipped with missiles like the Vympel R-77M, R-37, Novator KS-172 and – Zvezda-Strela Kh-31 variants qualifies exactly as that.

It is clear that the Su-30 has at least two decades more of yet to be exploited technological growth capacity, especially in systems and weapons. The excellent kinematics, large airframe and large apertures give it a decisive long term advantage in growth potential against all teen series types, and with an increasingly borderless international upgrade market, regional users with the cash required will be able to fit some very capable upgrades over time.

Part 2 of this feature will explore the longer term implications of the Su-30 fighter in the region.

by Carlo Kopp

Ongoing sales of the Su-30 Flanker family of long range fighters in the region are progressively changing the strategic landscape. This will have a profound long term impact across the region as the baseline in regional airpower capabilities rises. Part 2 of this feature explores some of the longer term issues.

Su-30 vs RAAF ALTERNATIVES

Many readers will be asking the obvious question of how the Sukhois stack up against the F/A-18A HUG, the F-35 JSF and possible interim fighters such as the F/A-18E/F.

Against all three types the Su-30 derivatives, especially with later engine subtypes, will always have a significant kinematic advantage – there is no substitute for thrust in the kinematic performance game. There is another factor to consider here, which is the superlative 10 tonnes of internal drag free fuel the Sukhoi carries. When not operating at extended combat radii, the Sukhoi driver has more fuel to convert into energy, and that energy can nearly always be used to an advantage.

With mutually competitive WVR missiles and Helmet Mounted Sights/Displays for close-in combat, all three types will live or die in a close in engagement with an advanced Su-30MK variant by pilot ability and good or bad luck. The Sukhoi combines high alpha manoeuvre capabilities with excellent thrust/weight performance, and is apt to have an energy advantage entering and prosecuting a close-in fight. A JSF driver opting to engage a thrust vectoring late model Su-30MK in a knife fight may not survive to speak of the experience, unless the Sukhoi driver is unable to exploit his advantage properly.

In close-in air combat terms the JSF qualifies as 'double inferior' against the later model Sukhois, since the Sukhois have an advantage in both thrust/weight ratio and in wing loading (interested readers refer R.L. Shaw's *Fighter Combat*), and with its canard and thrust vectoring capability will generally be able to gain a firing solution quicker. Because the JSF is designed within the kinematic performance class of the F/A-18 and F-16, it is right in the middle of the performance envelope of aircraft the Sukhoi was designed to kill.

In Beyond Visual Range (BVR) combat, the Sukhoi will again have a kinematic advantage, which may be exploitable at the bounds of engagement radii, as the Sukhoi can gain separation in and out of the missile envelope of the F/A-18's and JSF's faster – it has the extra thrust and combat fuel to play kinematic games both smaller fighters cannot.

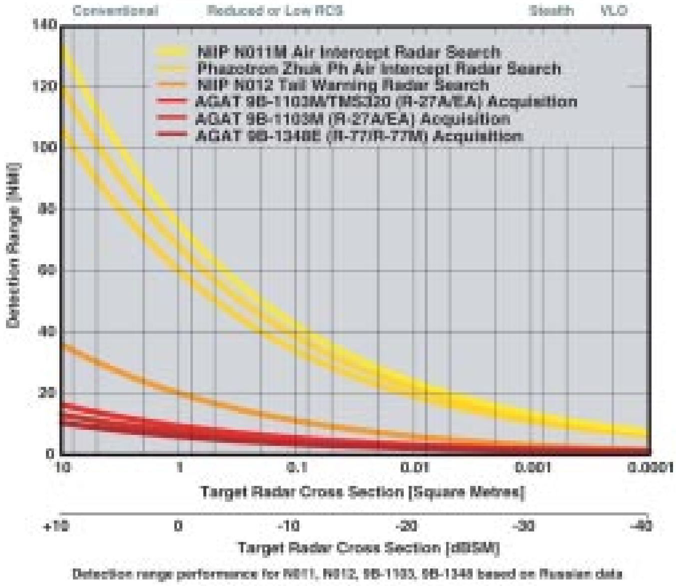
The BVR game is however dominated by sensor capabilities, both onboard and offboard the fighters, and long range missile capabilities. The F/A-18A HUG is wholly outclassed by an Su-30MK with an N011M phased array and R-77M ramjet missile. A late model F/A-18E with minimal external stores and the APG-79 AESA fares much better due to its radar signature reduction measures and better radar power aperture performance, but with external stores its margin of survivability is eroded and it is likely to fall well within the engagement envelope of the Sukhoi and also come to grief (refer radar/missile plot). A post 2010 AESA equipped Sukhoi could almost certainly take on the F/A-18E with confidence as it will have much better power aperture capability in the radar, enough to offset the radar signature reduction measures in the F/A-18E/F, with an advanced IRST to supplement radar data.

A clean JSF will have the advantage of a very low Xband radar signature in the forward quarter which will significantly degrade the Sukhoi's otherwise overwhelming radar power-aperture advantage over other types. However, the JSF is not designed to be a hot supersonic performer and like the F/A-18s will need to generously use afterburner to effect an intercept against a rapidly penetrating Sukhoi.

This exposes the JSF to detection and tracking by a newer technology IRST, and engagement by long burn heatseeking or optically guided AAMs such as the R-27ET, R-77T or likely future variants with imaging seekers analogous to the AIM-9R and ASRAAM seekers. With the latter seekers an R-77/R-77M acquires many of the capabilities of the RAAF's superlative ASRAAM, especially jam resistance, but in a long range missile with datalink midcourse guidance. A new two-colour infrared seeker with 10.8nm (20km) acquisition range has been announced by the Arsenal infrared systems house, ostensibly for use on the R-77 series. Professionals might contemplate that these are not 1980s 36T series seekers.

Russia and the Ukraine have a competent infrared systems industry – eg Cyclone JSC recently described its QWIP single chip thermal imagers with 128x128 and 320x256 resolution, competitive against the latest EU technology and suitable for missile seekers and thermal imaging IRST detectors. Therefore an advanced derivative of the OLS-30/31 series with capabilities similar to the Eurofighter PIRATE thermal imaging IRST, but with better detection range, will be implementable with Russian hardware in three to five years given the current rate of evolution.

In the beam and aft sectors the JSF may also be quite vulnerable to an active or semiactive radar guided missile shot – its beam and aft sector radar signature reduction is



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

The NIIP N011M phased array is the most capable fighter radar produced by Russian industry and is designed to support the R-77M family of ramjet missiles. The depicted detection range curves are based on publicly disclosed Russian performance figures for co-altitude BVR engagements. It is evident that inside the 10-20 nautical miles envelope the radar will be able to challenge aircraft with quite good stealth characteristics. The curves for the Agat 9B-1103M and 9B-1348E seekers are based on the most recent Agat data release, and include the TMS320 equipped digital variant. The 9B-1101K has not been included (Author – NIIP, Phazotron, Agat data).

much less refined than that in the forward sector. Another factor for the JSF is its radar emission – making it vulnerable to a long range shot with an anti-radiation seeker equipped R-27P, R-27EP, R-77P or when eventually deployed, ramjet R-77MP. While some Low Probability of Intercept (LPI) techniques may reduce vulnerability to anti-radiation missiles, radar modes for closing missile shots typically require high update rates and favour the anti-radiation seeker. Since the R-77/R-77M has a midcourse inertial package – Agat is developing FOG (fibre) gyro technology to avoid dependency on Western Ring Laser Gyro technology – transient loss of the JSF radar emission may not defeat the R-77P/R-77MP – or late model R-27P/EP.

Soviet and more recent Russian BVR doctrine has always emphasised firing pairs of missiles, one with heatseeking guidance and one with radar guidance, to defeat countermeasures. With the option of active radar, heatseeking and anti-radiation seekers, and by the end of the decade an imaging seeker, the result is a very lethal cocktail from a defensive countermeasures perspective – a defending fighter may only have datalink transmissions to provide warning and no indication of the seeker mix on the inbound missiles. With three of the four seeker technologies passive defeating such weapons is not trivial.

On publicly available data the JSF is likely to be detected and engaged by an N011M ESA equipped Su-30 inside the 10 to 20nm (19 to 37km) head on range envelope, unless the JSF can get the first shot off and successfully kill the Sukhoi. If the Sukhoi can close with the JSF, all bets are off on the JSF's ability to survive the close in engagement.

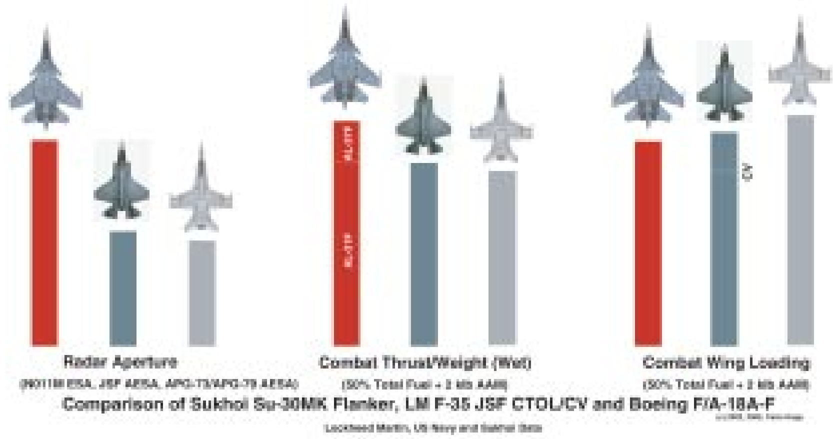
But will the use of the Wedgetail AEW&C to provide offboard targeting for the JSF provide a decisive advantage over the Sukhois, will 'Network Centric Warfare' offset all other deficiencies in the force structure and platform capabilities? This argument is clearly contingent upon a great many 'ifs' – if the Sukhois do not shoot very long range missiles at the Wedgetail to force it to shut down or indeed kill it, if the Wedgetail MESA is not jammed, if the JTIDS/MIDS or other datalinks to the fighters are not jammed, if the Sukhois are not carrying advanced IRSTs or X-band homing receivers, and if the Sukhois are not supported by HF or low VHF band radars.

If a JSF were deployed today with a supporting Wedgetail and existing Su-30 capabilities, then the argument probably holds most of the time. However, in a post 2010 environment it is most likely not going to hold up most of the time. If Iraq could acquire smuggled Russian GPS jammers during a UN arms embargo, there is no guarantee that equipment like high power L-band jammers, advanced IRST, ESM receivers, long range ramjet powered anti-radiation missiles and low band radars will not proliferate into the region – the Kh-31R has been already reported in use with the PLA-AF. Given the mistrust of the US and its allies we see in many regional players, be it the PRC or lesser nations, the odds are very good that the existing

Notes: O/B – seeker off-boresight acquisition angle; IRH – heatseeking, single or dual colour scanning seeker; SARH – semi-active radar homing seeker; DL – datalink for midcourse guidance corrections – either analogue or digital; IMU – inertial package for midcourse guidance; Passive RF – passive radio frequency anti-radiation seeker; ARH – active radar homing seeker; Acquisition Range is that at which the seeker can acquire its target; Kinematic Range is A-pole or F-pole; Target G – max load factor of target vehicle; Launch G – max load factor of launch aircraft; APU – Aviatsionnaya Puskovaya Ustanovka (rail launcher); AKU – Aviatsionnaya Katapultnaya Ustanovka (ejector); This is a current open source compilation based on manufacturers' and third party data therefore figures should be treated with appropriate caution (Author).

Type	Seeker	Model	Acquisition Range	Kinematic Range	O/B	Target G	Launch G	Length	Dia	Weight	Adaptor
Units	-	-	[NM]	[NM]	[deg]	[G]	[G]	[in]	[in]	[lb]	-
R-73	IRH	MK-80	5.4-8.0	16	45	12	8	114.2	7.0	232	APU-73
R-73M	IRH	MK-80M	8.0	21	60	12	8	114.2	7.0	232	APU-73
R-73R	IRH	MK-80M	8.0	5.4-6.5	60	12	8	126.0	7.0	253	APU-73
R-73E	IRH	MK-80E	8.0	16	75	12	8	114.2	7.0	232	APU-73
R-74ME	IRH	MK-80ME	8.0	21	75	12	8	114.2	7.0	232	APU-73
R-27R1	SARH/DL/IMU	9B-1101K	~16.0	43.2	-	8	5	157.5	9.0	560	AKU/APU-470
R-27T1	IRH	MK-80/M	5.4-8.0	38.9	45/60	8	5	145.7	9.0	561	AKU/APU-470
R-27P	Passive RF	9B-1032	-	38.9	-	8	5	157.5	9.0	560	AKU/APU-470
R-27A	ARH/DL/IMU	9B-1103M	10.8-13.5	43.2	-	8	5	157.5	9.0	560	AKU/APU-470
R-27ER1	SARH/DL/IMU	9B-1101K	~16.0	70.2	-	8	5	185.0	9.0	773	AKU/APU-470
R-27ET1	IRH	MK-80/M	5.4-8.0	64.8	45/60	8	5	177.2	9.0	753	AKU/APU-470
R-27EP	Passive RF	9B-1032	-	64.8	-	8	5	185.0	9.0	773	AKU/APU-470
R-27EA	ARH/DL/IMU	9B-1103M	10.8-13.5	70.2	-	8	5	185.0	9.0	773	AKU/APU-470
R-77	ARH/DL/IMU	9B-1348E	8.6	54.0	-	12	8	141.7	7.9	386.3	AAKU/AKU-170
R-77T	IRH/DL/IMU	MK-80M	8.0	54.0	60	12	8	141.7	7.9	386.3	AAKU/AKU-170
R-77P	Passive RF	9B-1032	-	54.0	-	12	8	141.7	7.9	386.3	AAKU/AKU-170
R-77M	ARH/DL/IMU	9B-1348E	8.6	86.5	-	12	8	145.7	7.9	496.7	AAKU/AKU-170
Kh-31R	Passive RF	L-111E	-	59.4	N/A	N/A	N/A	185.0	14.2	1324.5	AKU-58
Kh-31RA	ARH/Passive RF	-/L-111E	~10.0/-	59.4	N/A	N/A	N/A	185.0	14.2	1324.5	AKU-58
KS-172	ARH/DL/IMU	-	-	215.0	N/A	N/A	N/A	291.3	20.0	1656.0	-

This chart compares some cardinal design parameters for the Su-30MK series, the JSF and the F/A-18 family, using manufacturer's data. The effective wing loading of the Su-30 is better than depicted, since the aircraft's configuration delivers a considerable amount of body lift. While in the near term the AESAs in the JSF and F/A-18E/F will be competitive, in the longer term the retrofit of AESA technology in the N011M series radar will see the advantage in power aperture go to the Sukhoi – both the JSF and F/A-18E/F are aperture size and cooling capacity limited in growing AESA performance (Author).



trend will persist and the most advanced Russian hardware, and indigenous equipment, will be widely used. While this will not put a dent into the US Air Force's stealthy supercruising F/A-22A fleet, it is likely to make life very difficult for the USN with a planned force structure of F/A-18E/Fs and JSFs. If the RAAF opts for the JSF as its single type solution it is likely to experience similar grief.

In the long term the Russians will find a growing market for 'Counter-ISR' (ISR - Intelligence, Surveillence, Reconnaissance) weapons – the 215nm (398km) KS-172, 160nm (296km) R-37 and 60nm (111km) Kh-31 series. In any engagement against a western air force, the first wave of Sukhois would shoot long range 'AWACS-killer' weapons such as the KS-172, R-37, Kh-31 – or types as yet unknown – to either destroy the AEW&C/AWACS or force it to shut down and retreat – the 'AWACS-killer' theme is frequently seen in Russian marketing literature and statements.

The result is that forward defending CAPs have to then light up their radars to attempt to function autonomously – in turn making them vulnerable to detection by ESM and shots by anti-radiation missiles like the R-27EP or R-77P/MP. This Russian doctrine of a deluge of long range missiles is not new – it is a variation on their proven theme of attacking naval task forces with long range missiles. It is an evolutionary adaptation to the growing dependency of western air forces on large and vulnerable ISR platforms – the E-3 AWACS, RC-135V/W Rivet Joint, E-8 JSTARS, E-10 MC2A and of course the RAAF's new Wedgetail.

The reality is that of an evolving technological landscape in which advanced conventional weapons and supporting technologies proliferate often very rapidly. The rate of Su-30 uptake in the region is a good case study – any nation with the cash can acquire very quickly large numbers of top-tier combat aircraft often with the latest western avionics and Russian weapons and sensors fitted.

STRATEGIC IMPACT OF Su-30 IN THE REGION

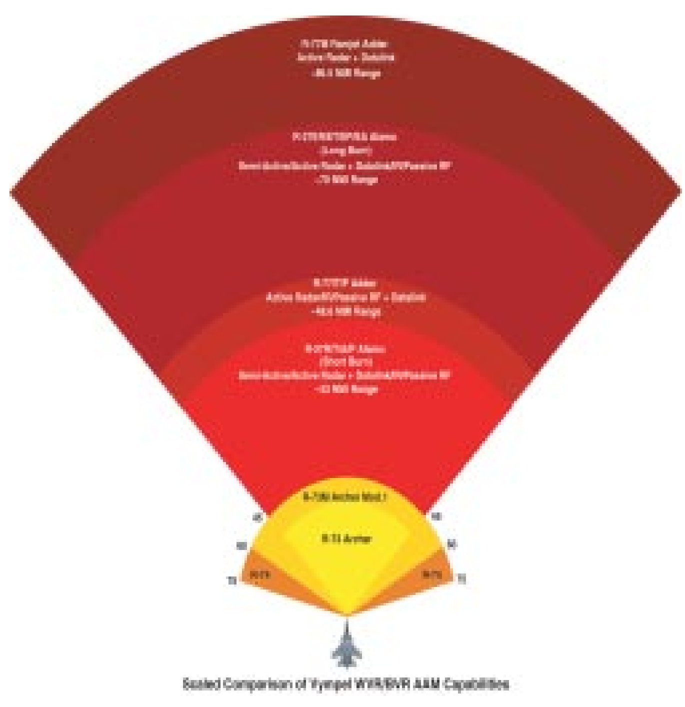
We have yet to see the full strategic impact of the Su-30 proliferating in the nearer and wider region. India and China will not have most of their Sukhoi force structures deployed until 2015 or later, and it is unclear how many Sukhois both Malaysia and Indonesia will ultimately operate.

In the near term, both Indonesia and China will have difficulties with fully exploiting the aircraft as they have steep learning curves to climb in training and support – India and Malaysia are apt to fare much better with western based training systems. We can expect to see regional users of the Su-30 maturing their capabilities to use the aircraft in the latter part of this decade. Much has been said about China's difficulties in recruiting and training competent Sukhoi drivers – with a population base of over a billion it is however only a matter of time before they learn to do this properly.

Much has been made of the serviceability and support problems experienced by the IAF and the PLA-AF with their initial Sukhoi aircraft, indeed the Indian government audit public report lists a litany of contractual problems and Su-30K/MK servicabilities as low as 50%. These problems should be seen in the proper context as they represent the transient state experienced when introducing a radically new piece of technology and supporting systems. The Sukhois are a generation beyond the MiG-29s flown by the IAF and two generations ahead of the 1950s technology which makes up the backbone of the PLA-AF.

With HAL and Shenyang to perform domestic assembly and part production, in time both nations will have the ability to domestically manufacture high failure rate components, and perform factory/depot deep overhauls. As a result what we see now in the support base for the aircraft will not persist and should not be used as an indicator of the long term supportability of the aircraft. With large fleet sizes even a large proportion of grounded aircraft still leaves strategically significant numbers to cause mayhem with.

Another factor in time will be the availability of third party Indian and Chinese made spares to other Sukhoi users in the region. Bottlenecks in the supply of Russian made spares may not persist past 2010 since the commercial incentives to bypass Russian suppliers are considerable – and many regional Sukhois will use substantial fractions of western avionics hardware. In time we can expect to see more bilateral deals, of the ilk seen between India and Malaysia for MiG-29 support, emerging between regional play-



ers and this will change the support environment seen by smaller regional users of the aircraft.

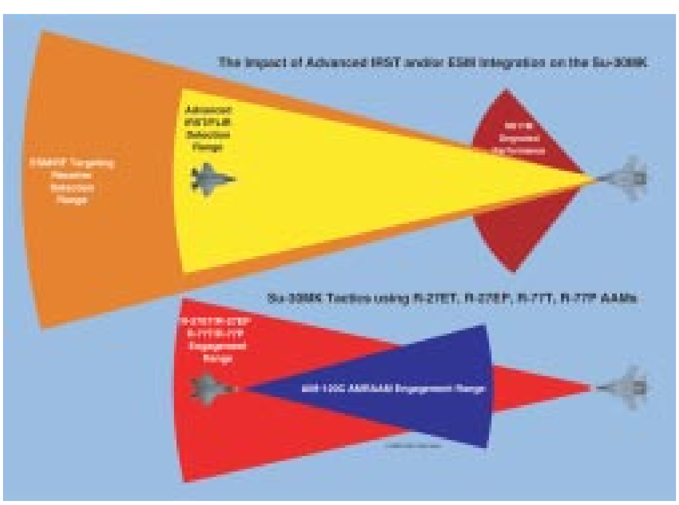
With four sources of spare component supply rather than one – Irkut, KNAAPO, HAL and Shenyang lines and subcontractor pools – market forces will have their impact. To assume that historical case studies of Russian aircraft support will be representative of the longer term future in this region is arguably to misunderstand the developing dynamic across the region. The era of Cold War technology monopolies is long gone – only the US can sustain such due to its commanding lead in stealth, propulsion and computing technologies. This model is not a valid one for assessing the longer term regional situation in Russian and third party hardware.

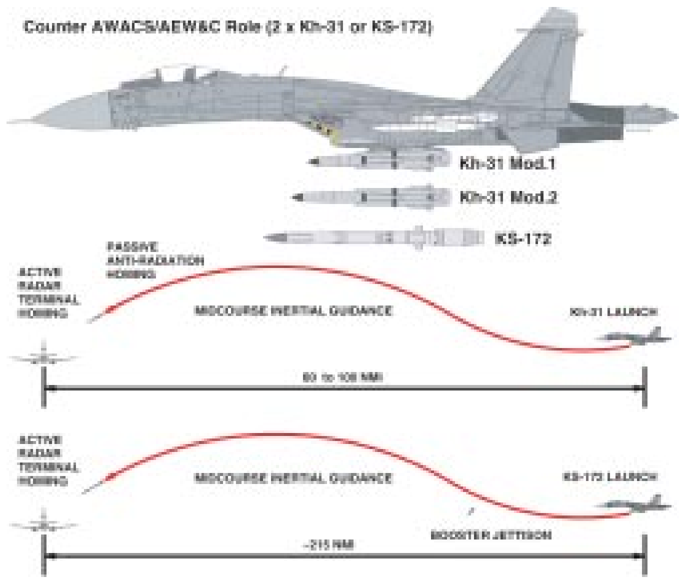
The Su-30s are 'honest' 700+ nm (1300+km) radius class fighters, with plenty of combat gas to burn at shorter radii. This provides all of the Sukhoi operators with a much larger air defence footprint than we have ever seen before. India is now taking delivery of its six Il-78 Midas tankers and will be able to robustly project its Sukhoi force well beyond its borders – China has had a long standing interest in tanking but no firm orders are reported as yet.

Even without a proper tanking capability, lesser regional players have the option of buddy refuelling Su-30s with the UPAZ hose/drogue pod – at the expense of half of the force committed to tanking sorties. On a buddy refuelling sortie the shooter gains around 200-250nm (370-464km) of radius – yielding a radius very close to 1000nm (1850km). With a 200nm (370km) class standoff missile such as a 3M-54E or Kh-41 variant, both advertised on Sukhois, this provides a limited strike capability beyond a 1000nm (1850km) radius. While such a strike refuelling technique is not viable for sustained high intensity operations, it is feasible for nasty pinprick raids against very high value assets, such as airfields, petrochemical/gas plants, shipping, aircraft carriers and other targets, the destruction of which could be highly politically embarrassing to the victim.

What this means in practical terms is that Su-30 users will have the potential to contest airspace up to 500nm (925km) or

What happens when the existing OLS-27/30/31 series IRST is replaced with a newer longwave Focal Plane Array device – such as a single chip QWIP device? The result will be a capability to engage opposing aircraft under clear sky conditions regardless of RCS reduction measures. While the supercruising F/A-22A can defeat such techniques by kinematics alone, fighters in the teen series performance envelope will have to contend with BVR shots using the R-27ET, R-77, R-77T and R-77M cued by the thermal imaging search and track set. Similar issues arise with the deployment of modern ESM receivers on the Su-30MK, analogous to a number of existing Western systems. The Su-30MK series can then launch long range BVR missiles such as the R-27ET, R-77T with infrared seekers, or the R-27EP and R-77P with passive radio-frequency anti-radiation seekers. If cued by such sensors or offboard sources, these weapons will permit the Su-30MK to engage the JSF despite the JSF's good forward sector radar stealth performance (Author).





Recent overseas reports claim the existence of an enhanced variant of the Kh-31R, which combines an active radar seeker with passive anti-radiation homing. This weapon is specifically built to kill AEW&C aircraft – if the AEW&C aircraft shuts off its radar, the missile switches to active radar terminal homing. The weapon is credited with a standoff range of around 60 to 100 nautical miles. The Novator KS-172 is a 200+ nautical mile range active radar guided missile, also intended to kill AWACS and AEW&C aircraft, and promoted on Sukhoi fighters. Such 'Counter ISR' weapons have evolved in response to overwhelming Western superiority in ISR systems (Author).

further from their runways, and launch limited strikes out to around a 1000nm (1850km) radius. While the latter is not the kind of heavy iron 1000nm (1850km) radius capability Australia possesses in its F-111 fleet, it is nevertheless enough capability to cause considerable mayhem, if used cleverly.

In the longer term the Sukhoi will have several strategic effects. The first is that it will provide its users with the ability to threaten or intimidate neighbours with lesser capabilities, if they fall within the footprint of the Sukhoi. The second is that the US Navy's carrier battle groups will lose much of their ability to intimidate by gunboat diplomacy – the ability to threaten a CVBG with a mixed package of shooter and escort Su-27/30s to radii essentially greater than that of the F/A-18E/F and JSF mix on a carrier deck drives up the risk for the US Navy in a nasty political stand-off. Unless the US is prepared to take the gloves off early in a dispute and deploy the F/A-22A centric US Air Force Global Strike Task Force, the US Navy may cease to be a viable tool for coercive diplomacy.

Even for the US Air Force the Su-30 presents some interesting challenges, since it has the radius to threaten both tankers and large ISR platforms in a shooting contest. While the F/A-22A would deal with the Sukhois quickly and effectively, in many scenarios the Sukhois could create genuine complications by forcing a relatively high ratio of F/A-22A escort sorties to F/A-22A strike sorties, thus diminishing the strike sortie rate – a major issue for the dual role tasked F/A-22A fleet.

Another factor to consider is the ongoing proliferation of advanced guided munitions and other hardware produced by competing Russian vendors. Just as we have seen Irkut and KNAAPO competing in the sales of Sukhois, we have seen a wide range of Russian weapon makers like Vympel, Zvezda, Raduga and others selling their products across the accessible market. Many of these products incorporate modern western digital COTS technology, an example being the upgraded second generation 9B-1103M active radar seeker for the Vympel R-27A/EA missile, which is built around a Texas Instruments TMS320C44 digital signal processor chip and achieves a 25% acquisition range improvement over the baseline seeker, derived from the R-77's first generation 9B-1348E – a second generation '9B-1348ME' will almost certainly carry the same TMS320C44 digital signal processor.

Some of the air-surface weapons being offered for the Sukhois are genuinely capable. The Raduga Kh-41 Moskit (3M-80/82 SS-N-22 Sunburn) has been integrated on the Sukhois' centreline station (refer AA 9/2000) and is considered to be one of the most lethal supersonic sea skimming anti-ship weapons in existence. The NPO Soyuz/Turayevo TKMB ramjet powered Mach 4 class Zvezda-Strela Kh-31 (AS-17 Krypton) is offered on Sukhoi variants, both in the active radar anti-shipping A model (PLA-N) and anti-radiation R model (PLA-AF). The latest advertised Kh-31 variant includes a dual mode air-air seeker, incorporating an active radar seeker and passive anti-radiation seeker, optimised for engaging 'non-maneuvering airborne targets such as AWACS' out to 100 nautical miles. Both the supersonic OKB-52 P-800/3K-55/3M-55/Kh-61 Yakhont (SS-N-26) and Novator 3M-54 Alfa (SS-N-27) have been publicly discussed as options for the Sukhoi fighters, especially the Su-34 series, but it is unclear whether any integration work has taken place to date.

For strikes against land targets, the 1500lb class Molniya Kh-29 (AS-14 Kedge) is available in television (Kh-29T), thermal imaging contrast lock homing (Kh-29D) and semi-active laser homing (Kh-29L) variants – the weapon is a direct equivalent to the very effective French Aerospatiale AS.30 series, with the television and thermal imaging guided variant seeker equivalent to the AGM-65 Maverick series. The smaller semi-active laser homing S-25LD and Zvezda Kh-25ML (AS-12 Kegler) are also on offer. An equivalent to the RAAF's AGM-142 is available in the 2000lb class 50nm (93km) range turbojet sustained Raduga Kh-59M (AS-18 Kazoo), which uses a conceptually similar TV/datalink guidance scheme, using an APK-9 Tekon datalink guidance pod carried on the left inlet pylon. An anti-radiation variant, the Kh-59 (AS-13 Kingbolt) is available but has not been advertised on the Sukhoi – the newer Kh-31R series appearing to be favoured by the market.

The Russians are also actively marketing guided bomb kits for the Sukhoi fighters. The KAB-500L is a direct equivalent to the GBU-16 using the 27N series laser seeker, the KAB-500Kr is equivalent to a TV contrast lock guided 1000lb GBU-8 HOBOS fitted with a bunker busting or fuel air explosive warhead. The KAB-1500 is a family of guidance kits for 3000lb class dumb bombs, available with unitary or bunker busting warheads. The KAB-1500L is a semi-active laser homing kit, the KAB-1500TK a TV command link guided kit

Su-27/30/35 FLANKER CAPABILITY GROWTH

Su-30MKK vs Su-30MKI Crew Stations (KNAAPO/Irkut)

analogous to the GBU-15 but 50% bigger, and the KAB-1500Kr a TV contrast lock guided system. Either three of the 1500kg weapons, or six of the 500kg weapons can be carried by an Su-27/30 with suitable avionics.

To date most regional users have invested in Sukhois primarily to provide air superiority capabilities. The availability of a wide range of competitively priced Russian guided weapons is likely to result over time in an increasing broadening of the role of regional Sukhoi fleets. The principal impediment to the wider use of Russian laser guided bombs has been a shortage of good targeting pods – with suitable laser coding modifications third party pods are likely to evolve to fill this niche over the next decade. The impact of the US GBU-12 in Afghanistan and Iraq will not have gone unnoticed.

The television guided KAB-500Kr and KAB-1500Kr kits are also worth closer scrutiny, since they provide a fire-and-forget capability very similar to the long retired GBU-8, or a GBU-15 used in lock-on-before-launch mode – highly accurate and devoid of the need for a targeting pod. With the potential for a pre-programmed scene matching correlation capability (ie pre-loading the bomb with a digitised target image not unlike the early Tomahawk DSMAC), a technology the Russians do have, this presents the prospect of a 'JDAM-like' capability to attack multiple aimpoints on a single pass, albeit daylight limited. The large volume of the KAB series seekers would easily permit a lot of evolutionary growth in the design, and low cost commodity processing chips and QWIP thermal imagers would facilitate this. It is likely that we will see more of this family of bomb seekers in time.

Russian sources claim China has ordered the Kh-59ME standoff missile, the Kh-29T TV guided missile, the Kh-31R anti-radiation missile, and the KAB-500Kr electro-optically guided bomb kit. PLA-AF Su-27SKs have been seen carrying paired KNIRTI L005-S Sorbtsya wingtip jammer pods designed to defeat the APG-63/65/68/70/73 radars and Hawk/Patriot SAM systems.

CONCLUSIONS

For Australia the Su-30 presents the prospect of a more difficult to defend sea-air gap. While we might choose to argue ad nauseam as to whether a future Indonesian regime might opt to get into a fight with Australia, or debate the likelihood of PLA-AF Sukhois being based in the northern approaches at a future date, or debate India's future role in the near region, the stark reality is that the tyranny of distance which has protected Australia for decades is being rapidly eroded by developing capabilities across the region.

In this context the JSF decision last year, and ongoing lobbying for F/A-18E/F interim fighters, seem both to be quite incongruous. Neither aircraft offers a decisive capability margin against the Su-30 series, especially longer term as the sensors, avionics and weapons evolve in the Sukhois and regional players possibly acquire AEW&C aircraft and other supporting capabilities.

Indeed, one idea popular in some Canberra circles seems to be that the RAAF is now less needed and should be downsized to save money since Indonesia is in a state of chaos and all the RAAF is needed to do is participate in the odd US coalition force – of course if anything goes really bad in our neighbourhood the US will instantly assist!

This is a particularly lame argument insofar as the US Air Force is already badly stretched with worldwide commitments, and is having genuine difficulties with a poorly ageing tanker and fighter fleet – in a crisis the US may not be in the position to deploy sufficient assets quickly enough, even if the then incumbent US administration wants to do so. There is of course no guarantee that a future US leadership group will have the kind of relationship with Australia which we observe today.

The Americans may not solve their block obsolescence problems until later in the next decade, leaving a genuine window of strategic vulnerability should the more vocal proponents of RAAF capability reduction have their way in Canberra.

The belief in some Canberra circles that the JSF will somehow solve all of the RAAF's force structure problems does not stand up to scrutiny, in the light of the known capabilities and demonstrated growth potential of the Sukhoi Su-30 which is rapidly becoming the 'standard' fighter across the region. Similarly the belief that interim fighters will somehow address the capability gap in the F/A-18A HUG fleet is hard to accept. The belief that the F-111's heavyweight counter-air strike capability is now irrelevant also conflicts with the reality that the best way to fight an Su-30 without an F/A-22A is to shut down its basing from day one of a conflict – and if possible convert the Sukhois to scrap metal in situ – neither achievable with a handful of standoff missile shots.

Strategy has always been a game of positional advantage, and in the modern age this positional advantage lies largely in airpower. If Australia is to retain its relative strategic position in the region it must start thinking realistically about its long term force structure and abandon the quick fix panacea solution mindset which seems to be so prominent in the current Canberra defence debate. There are no quick or cheap fixes in this game.

BOOK REVIEW

Su-27 Flanker Story

byAndrei Fomin

Andrei Fomin's 300 plus page *Su-27 Flanker Story* (translated by Yevgeniy Ozhogin) is by far the best single technical and historical reference text on Sukhoi's T-10 family of fighters, strike fighters and bombers. Making excellent use of access to and direct support from the Sukhoi Bureau, KNAAPO, IAPO and the Russian Air Force, Fomin's glossy reference book provides a comprehensive insight into the history of the aircraft, including its early development, and provides often remarkably detailed descriptions of the various variants and offshoots.

With a reference bibliography of 95 titles, 60 colour profiles, 18 pages of precise scale line drawings, numerous four page wide foldout illustrations and cutaways, and a plethora of mostly colour photographs, the book is by far the most complete and detailed open source reference to date. While the book is a little short on hard technical specifications and detail in places, it makes up for this in its sheer breadth and completeness of coverage, which includes all variants up to the Su-30MKI and Su-30MKK, but excluding the Su-30KN.

The text includes chapters covering development history, production, navalised variants, the Su-35/37 derivatives, operational use, and a chapter surveying air-to-air and air-to-ground munitions carried by the Flanker family. Fomin's text should be not only of interest to a traditional market of enthusiasts, modellers, and lay observers - it is by any measure a good enough basic reference for defence professionals in this country. This reviewer can thoroughly recommend this title to any military aerospace professional with an interest in regional air power.

Su-27 Flanker is published by RA Intervestnik of Moscow, www.airfleet.ru.

Available from Crusader Trading: 02 6239 2332
9 Townsville Street, Fyshwick ACT 2609

by Carlo Kopp

NEXT GENERATION SAMS FOR ASIA A WAKE UP CALL FOR AUSTRALIA

Recent Russian press reports about Jakarta's interest in acquiring S-300 Surface-to-Air Missile (SAM) systems underscore the now well developed trend for nations in Asia to shop for the best technology Russia's military industrial complex can offer.

While the proliferation of Russia's top tier SAMs into the Asian market has been dominated by Chinese large volume purchases, with India still negotiating, we are now seeing a second wave of 'me too' buys by smaller nations intent on matching their larger neighbours. Without the attached political strings of US equipment, and often much cheaper than US equivalents, top tier Russian products often match and sometimes exceed their US competitors in key performance specs or capabilities.

The Almaz S-300P/S-400 (SA-10, SA-20) and Antey S-300V (SA-12) SAM systems are excellent examples, the former widely acknowledged to be 'Russia's Patriot' and the latter having no direct equivalents in the west, but some similarities to Israel's Arrow Anti-Ballistic Missile system.

Both of these systems grew out of the disappointments of Vietnam and the Yom Kippur war, where 'single digit' S-75/SA-2, S-125/SA-3 and 3M9/SA-6 series SAMs were soundly defeated in combat by the US and Israelis respectively. Designed for the high density battlespace of late Cold War central Europe, the S-300P and S-300V series of SAMs represent the pinnacle of Soviet Cold War era SAM technology, with no effort spared to push the technological envelope.

Since the fall of the Soviet Union, both systems have continued to evolve, benefiting immeasurably from large scale access to western technology markets, and western computational technology to support further design efforts. Against the current benchmark in western SAM technology, the Raytheon Patriot PAC-3 system, both the S-300P and S-300V series remain highly competitive.

It should come as no surprise that the US publicly expressed concerns about the possibility of Serbia and Iraq acquiring these systems prior to the Allied Force and Iraqi Freedom air campaigns – the presence of these systems could have dramatically changed the nature of both campaigns. With superb missile kinematics, high power-aperture phased array radar capability, high jam resistance and high mobility, the S-300P series and S-300V would have required unusually intense defence suppression efforts, changing the character and duration of both air campaigns. The political fracas surrounding the Cypriot order for S-300PMU1, and the long standing intent of both North Korea and Iran to purchase large numbers of late model S-300Ps underscore this point.

In US terminology, the 'double digit' S-300P series and S-300V systems represent 'anti-access capabilities' – designed to make it unusually difficult if not impossible to project air power into defended airspace. The B-2A Spirit and F/A-22A Raptor were both developed with these threat systems in mind, and are still considered to be the only US systems capable of robustly defeating these weapons. The technique for defeating them is a combination of wideband all aspect stealth and highly sensitive radio frequency ESM receivers, combined with offboard sources of near realtime Intelligence Surveillance Reconnaissance (ISR) data on system locations.

Aircraft with no stealth, reduced RCS capabilities, or limited aspect stealth, such as the F-15E, F-16C, F/A-18E/F, Eurofighter Typhoon and F-35 JSF are all presented with the reality that high to medium altitude penetration incurs a very high risk of engagement by either of these weapon systems. It is perhaps ironic that the only reliable defence for aircraft lacking top tier all aspect stealth capability is high speed low altitude terrain masking using Terrain Following Radar, supplemented by offboard near-realtime ISR data, support jamming and standoff missiles. Australia's F-111s, if used cleverly, are arguably much more survivable against this class of technology than the vast majority of newer types in service – it should come as no surprise that the Bundes-Luftwaffe in Germany developed the terrain following Tornado ECR Wild Weasel precisely around this regime of attack on the SA-10/20/12.

That the DoD leadership have opted to wholly ignore the arrival of the S-300P/S-300V series SAMs in their long term force structure planning is nothing less than remarkable and raises some very serious questions about how well the capabilities of these systems are understood in the halls of Russell Offices. Despite repeated proposals by a great many parties, there are no plans to equip the RAAF with anti-radiation missiles or support jamming aircraft, persistent lobbying for F-111 retirement, and the F/A-22A Raptor, the US solution to the S-300P/S-300V problem, is generally dismissed as being "too good for Australia".

Unlike Sukhoi Su-27/30 fighters which many expect will require a robust support infrastructure, intensive training, good tactics and talented fighter pilots to operate, all taking time to mature into a viable capability, the S-300P/S-300V series SAMs were designed for austere support environments, to be operated and maintained largely by Soviet era conscripts. Therefore the integration of these weapons into wider and nearer regional force structures will not incur the delays and difficulties expected by some observers with the Sukhois.

A package of S-300P/S-300V batteries could be operationally viable within months of deployment in the region, and earlier if contract Russian or Ukrainian personnel are hired to bring them online faster. The notion of '15 years warning time' looks a little absurd, given that these systems can proliferate and operationally mature as capabilities within one to two years.

With the first generation of these SAMs deployed during the early 1980s, currently marketed variants are third and fourth generation evolutions of the basic design, mature systems built with characteristic Russian robustness and simplicity where possible.

In recent years the accelerated marketing tempo of the sales hungry Russian industry has seen a surprisingly large amount of detailed technical material on these weapons appear in the public domain, with publications like *Military Parade*, *Vestnik PVO* and *Russkaya Sila* posting detailed summaries and data on internet websites, albeit mostly accessible only to readers of Russian. Other former Warpac nations have also been surprisingly open in sharing information on these weapons. Given the availability of this data it is now possible to compile more comprehensive analyses of these weapons, than of equivalent US products such as the Patriot. This two part analysis is consequently based largely upon Russian sources.

Variant	Designation	Surveillance Radar	Low Level Radar	Engagement Radar	Semi-Mobile TEL	Mobile TEL	Missile	Options
SA-10A	S-300PT	36D6 Tin Shield	76N6 Clam Shell	30N6 Flap Lid	5P85PT	-	5V55KD/R	30V6M/MD Mast
SA-10B	S-300PS	36D6 Tin Shield	76N6 Clam Shell 96L6E	30N6E Flap Lid	5P85PT	5P85DU/S U	5V55KD/R	30V6M/MD Mast
SA-10C	S-300PMU	36D6 Tin Shield	76N6 Clam Shell 96L6E	30N6E Flap Lid	5P85PT	5P85DU/S U	5V55KD/R	30V6M/MD Mast
SA-10D	S-300PM/PM U1	36D6 Tin Shield 64N6E Big Bird	76N6 Clam Shell 96L6E	30N6E1 Flap Lid	5P85TE	5P85SE	48N6E	30V6M/MD Mast
SA-10E	S-300PMU2 Favorit	64N6E2 Big Bird	96L6E	30N6E2 Flap Lid	5P85TE	5P85SE	48N6E2 48N6E	30V6M/MD Mast
SA-20	S-400 Triumf	64N6E3 Big Bird	96L6E	30N6E3 Flap Lid	5P85TE	5P85SE[1]	9M96E 9M96E2 48N6E2 48N6E 5V55KD/R	30V6M/MD Mast

Almaz S-300/S-400 Surface to Air Missile System (Note [1]: S-400 variant subtype designations not disclosed at this time).

THE ALMAZ S-300P/SA-10 SAM SERIES

The earliest origins of the S-300P series lie in the mid 1960s, when the Soviet Voyska PVO and Ministry of Military Production initiated its development. The aim was to produce an area defence SAM system capable of replacing the largely ineffective S-75/SA-2 Guideline and S-200/SA-5 Gammon systems, neither of which performed well against low flying Wild Weasels, low RCS targets or US support jamming aircraft.

The original intent was to design a common SAM system for the Voyska-PVO (Air Defence Forces), Voenno-Morskiy Flot (Navy) and the PVO-SV (Air Defence Corps of the Red Army), but divergent service needs across these three users soon saw commonality drop well below 50%. Ultimately the V-PVO's S-300P series and PVO-SV's S-300V series diverged so completely to become largely unique systems.

The design aims of the original S-300P were to produce a 'strategic' area defence SAM system, intended to protect fixed targets such as government precincts, industrial facilities, command posts and headquarters, military bases, strategic and tactical airfields and nuclear sites. This weapon system was to initially defeat SAC's SRAM firing FB-111As, B-52Hs and then anticipated B-1As, and later the Boeing AGM-86B Air Launched Cruise Missile. The deployment model of the first generation systems was based on the existing S-75/SA-2, S-125/SA-3 and S-200/SA-5 systems, with a semi mobile package of towed trailer mounted radars and missile Transporter Erector Launchers (TELs).

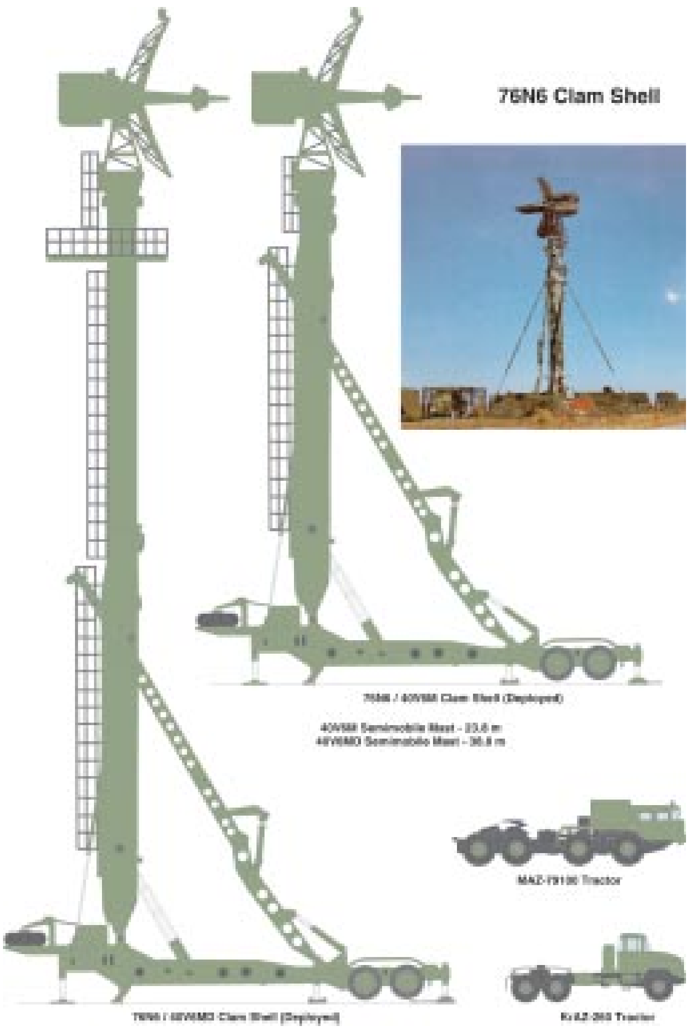
The S-300P series systems have seen several generations of progressively more capable TELs deployed. The semi-mobile SA-10A 5P85PT TELs were supplanted by road mobile 5P85TE series TELs which remain an option even for the latest export models. The off-road mobile 5P85D/S series TELs arrived with the SA-10B/C and are used by the PLA, with more recent SA-10D/E and S-400 systems using the improved 5P85SE TELs – all are derived from the original MAZ-543 Scud launcher vehicle (Author/Almaz).

The S-300P introduced some important technological innovations. The first generation V-500/5V55 missile used a single stage solid rocket motor, and conceptually is closest to the baseline US Army MIM-104 Patriot. The missile was deployed and handled in a sealed cylindrical launch tube/canister, with a 'cold start' gas generator used to eject the missile vertically before its motor was initiated. The 5P85 TEL was a semitrailer arrangement, with the forward booms splayed when deployed as stabilisers. The four launch tubes were mounted on a hydraulically elevated frame, retained in later TEL designs. A typical battery would be equipped with three 5P85 TELs, each with four SAMs, or double the SAM complement of the S-75/SA-2 it replaced and permitting two rounds per launch.

The first generation of the S-300P's 30N6 Flap Lid A engagement/fire control radar was also innovative, and clearly influenced by the Raytheon MPQ-53 engagement radar for the MIM-104 Patriot. The Flap Lid, like the MPQ-53, uses a transmissive passive shifter technology phased array, with a space (aka optical) feed into the rear plane of the antenna, using a microwave lens rather than a horn feed. The Flap Lid's antenna stows flat on the roof of the radar cabin, which was initially deployed on a trailer towed by a Ural-357, KrAZ-255 or KrAZ-260 6x6 tractor. The whole radar cabin is mounted on a turntable and used to slew the phased array to cover a 60 degree sector of interest.

The 30N6 was a huge generational leap in technology from the Fan Song, Low Blow and Square Pair mechanically steered and scanned engagement radars on preceding V-PVO SAMs. With electronic beam steering, very low sidelobes and a narrow

The 30N6E series engagement radars are conceptually similar in design to the Patriot's MPQ-53 engagement radar, but are available in off-road mobile and mast mounted variants. A high power phased array, the radar is used for Track Via Missile guidance of later variants of the SA-10/20 (Author/Almaz).



The gargantuan continuous wave Clam Shell low altitude acquisition radar has no analogues in the West, and is used to detect low flying aircraft and cruise missiles. It has been widely used on the enormous 40 metre 30V6MD semi-mobile mast intended to extend low altitude coverage footprint (Author/LEMZ).

pencil beam mainlobe, the 30N6 phased array is more difficult to detect and track by an aircraft's warning receiver when not directly painted by the radar, and vastly more difficult to jam. While it may have detectable backlobes, these are likely to be hard to detect from the forward sector of the radar. As most anti-radiation missiles rely on sidelobes to home in, the choice of engagement geometry is critical in attempting to kill a Flap Lid.

Unlike the Patriot's MPQ-53 engagement radar which has substantial autonomous search capability, the 30N6 is primarily an engagement radar designed to track targets and guide missiles to impact using a command link channel. The absence of dedicated directional antennas on this system indicates that the commands are transmitted via a specialised waveform emitted by the main array. The first generation of the 5V55K missile was command link guided, following the design philosophy of the S-75/SA-2 and S-125/SA-3, with a cited range of 25nm (46km) and altitude limits between 80ft and 80,000ft.

This variant was designated the S-300PT (P – PVO, T – Transportiruyemiy) and incrementally upgraded models the S-300PT-1, it entered service in 1978. NATO labelled it the SA-10A Grumble.

Two search and acquisition radars were introduced to support the S-300PT, both with 360 degree coverage. The 3D 36D6/ST-68UM/5N59 Tin Shield was used for high and medium altitude targets, and the 2D 76N6 Clam Shell for low altitude low RCS targets (refer AA 10/95 for detailed analysis). An important feature of the S-300PT was the introduction of the semi-mobile 40V6, 40V6M and 40V6MD masts, towed by a MAZ-543 derived tractor, in turn based on the 1966 Scud launcher vehicle. The 23.8 metre tall 40V6, 40V6M could be used to elevate the Clam Shell, Tin Shield and Flap Lid radars to extend their radar horizon and improve clearance in uneven terrain. The 'double height' 37.8 metre tall 40V6MD appears to have only been used with the Clam Shell and its recent 96L6 replacement. The masts take one to two hours to erect.

The unique 40V6 series masts permit static or semi-mobile S-300P series SAM systems extended low level coverage not available in any competing western designs, and were clearly introduced to defeat SAC's low level FB-111A, B-52G/H and B-1B force – and the AGM-86B cruise missile. These masts continue to be marketed as an accessory for the latest production variants of S-300P radars.

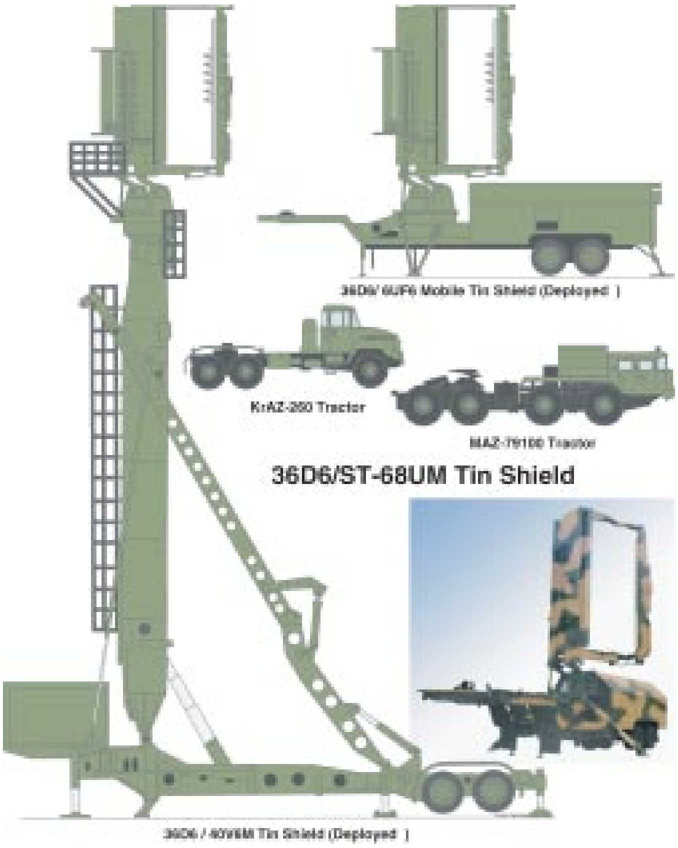
The 36D6 Tin Shield is semi-mobile and towed by a KrAZ-255 or -260 tractor, it can be deployed or stowed in one hour, or two with the mast. The design uses a large paraboloid cylindrical section primary reflector and a linear element array deployed on a pair of booms to provide electronic beam steering in elevation from -20 to +30 degrees, the antenna can perform a full 360 degree sweep in five to 10 seconds. With a transmitter peak power rating cited between 1.23 MegaWatts and 350 kiloWatts, the manufacturer claims the ability to detect a 0.1 square metre RCS target at 300ft AGL out to 24.8nm (46km), and at medium to high altitudes to 94.5nm (175km). Clutter rejection is claimed to exceed 48 dB, and the system can track 100 targets. An IFF system is integrated in the radar.

Its sibling, the 76N6 Clam Shell low level early warning radar, is an unconventional frequency modulated continuous wave design, using a split antenna arrangement with a large 'beak' to prevent spillover from the receiver. Quoted performance figures include the detection of targets with a radar cross section as low as 0.02 square metres, at speeds of up to 1400kt (2595km/h), with a bearing resolution of 1 degree, velocity resolution of 9.3kt (17km) and range resolution of 2.15nm (4km). Quoted RMS tracking errors are 0.3 degree in bearing, 4.7kt (8.7km/h) in velocity and 1nm (1.9km) in range. Chaff rejection performance is quoted at better than 100 dB, detection range is stated to be 50nm (92km) for targets at 1500ft altitude, and 65nm (120km/h) for 3000ft altitude. The transmitter delivers 1.4 kW of CW power at an unspecified carrier frequency, system MTBF is quoted at 100hr with an MTTR of 0.5 hr.

The Tin Shield/Clam Shell/Flap Lid combo provided the V-PVO with the first all altitude acquisition and engagement package on a semi-mobile SAM system and was a key factor driving the development of the F-117A and B-2A bombers. Had the balloon gone up in 1984, the F-117A would have been tasked first and foremost with obliterating the V-PVO's S-300P radar systems.

Growing US electronic combat and SEAD capabilities, in the EF-111A Raven and F-4G Weasel forces, were clearly considered a serious threat and this spurred the further evolution of the S-300PT system. In 1982 the V-PVO introduced a fully mobile variant of the system, designated the S-300PS (P – PVO, S – Samochodnyy/Self-propelled), labelled by NATO the SA-10B.

The S-300PS saw the 30N6 Flap Lid engagement radar and 5P85 TEL transplanted on to the high mobility 8x8 MAZ-7910 vehicle derived from the MAZ-543. This permitted the engagement radar and TELs to set up for firing in five minutes, and rapidly scoot away after a missile shot to evade US Air Force Weasels. Two improved variants of the 5V55 missile were introduced. The 50nm (92km) extended range 5V55KD was supplemented with the 5V55R, the latter using a Track Via Missile (TVM) semi-active seeker similar in concept to the MIM-104 Patriot seeker. The TVM system relays to the ground station radar data produced by the missile seeker, and offers better jam resistance and accuracy against a pure command link guidance package, especially as the missile nears the target. Later variants of the Flap Lid are designated as 'Radiolokator Podsvieta i



The most widely used high/medium altitude acquisition radar on SA-10 systems is the Tin Shield, which is only recently being supplanted by the Big Bird and 96L6. This radar has been marketed as an upgrade component for older 'single digit' SAM systems (Author/Defense Systems).

Navedeniya' (RPN – Illumination and Guidance Radar).

The improved 30N6 Flap Lid B radar had the capability to concurrently engage six targets, and guide two missiles against each target. The phased array beam steering angular range was extended to permit instantaneous coverage of a 90 degree sector, comparable to the SPY-1 Aegis radar.

Improvements were not confined to the radar and missiles. Two variants of the MAZ-7910 based TEL were introduced. The 5P85S with the characteristic large accessory cabin and the 'supplementary' 5P85D TEL/Transloader, were both equipped with 5S18/19 series autonomous electrical power generators. A fully mobile 54K6 command post was introduced, also carried by a MAZ-7910. A typical battery would include one 5P85S TEL, two 5P85D TEL/Transloaders and one mobile 5N63S/30N6 Flap Lid B radar.

The S-300PS/SA-10B was a close technological equivalent to the MIM-104 in all respects, but was significantly more mobile, and offered a better low altitude footprint due to the semi-mobile mast mounted Tin Shield and Clam Shell systems.

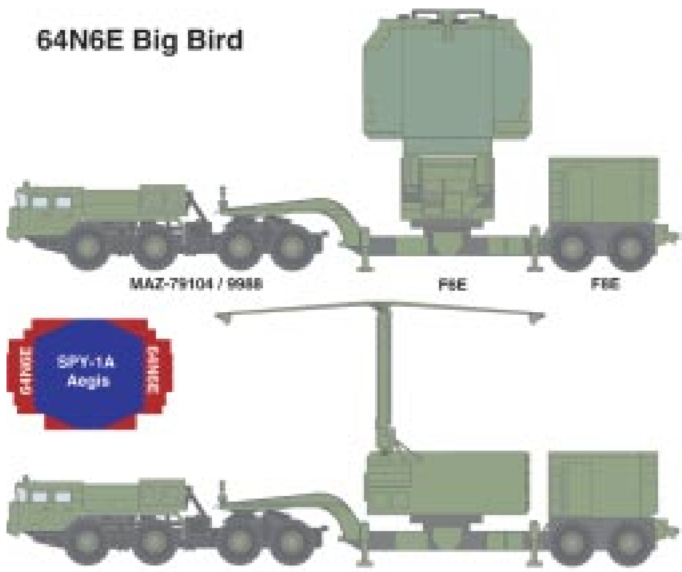
The first export variant of the S-300P series was the S-300PMU/SA-10C, which was in most respects identical to the Soviet S-300PS/SA-10B and made available in 1989. The S-300PMU saw the introduction of a third TEL variant, the semitrailer based 5P85T series usually towed by a 6x6 KrAZ-260 tractor. Unlike the earlier road mobile 5P85 TEL, the 5P85T was designed for rapid erection and launch preparation, and was equipped with an integral electrical power generator and a radio datalink package for autonomous operation. The key distinction is that the 5P85T is a road mobile TEL rather than off-road mobile TEL, quite unlike the semi-mobile 5P85 TEL.

The next big evolutionary step in the S-300P system was the introduction of the enhanced S-300PM and its export variant the S-300PMU-1/SA-10D, in 1993. The SA-10D was subjected to what Russian sources describe as a 'deep modernisation', with design changes to most key components of the system. The aim was to improve its basic capabilities as a SAM, extend radar and engagement footprints, increase the level of automation in the system, and introduce an anti-ballistic missile capability against ballistic missiles with re-entry speeds of up to 2.8 km/sec. It is intended to engage combat aircraft at all altitudes, cruise missiles and tactical ballistic missiles, making it an equivalent to the PAC-1 and PAC-2 Patriot variants.

Incremental changes were made to the Flap Lid, yielding the 30N6E1 variant, capable of guiding the new 48N6 missile, the manufacturer claims an ability to engage targets with an RCS as low as 0.02 square metres at an unspecified range, and an autonomous search capability. The 30N6E1 retains the capability to deploy on the 40V6M mast. An improved 54K6E1 mobile command post was introduced, the 76N6 Clam Shell was retained. While the 36D6 Tin Shield remained available, the S-300PMU-1 introduced the new highly mobile NIIIP 64N6E Big Bird 3D search and acquisition radar, carried on a 8x8 MAZ-7910 series vehicle. The radar can be deployed or stowed in five minutes – the booms stow against the array, the outer panels of the array swing inward and the whole antenna stows forward to lie flat on top of the trailer.

The 64N6E Big Bird is the key to much of the improved engagement capability, and ballistic missile intercept capability in the later S-300P variants. This system operates in the 2 GHz

Much of the potency of the latest SA-10/20 variants comes from the large Big Bird phased array acquisition radar. Comparable in size to a SPY-1 Aegis, this 2 GHz band phased array is designed to detect ballistic missiles and low RCS aircraft, and is a highly off-road mobile package (Author/Rosvooruzheniye).



The S-300P series systems use a 'cold launch' technique where the missile is ejected from the launch tube and its motor initiated once it is clear. This dramatic shot shows a late model 48N6E missile launching from a 5P85TE series road mobile TEL. Note the raised datalink antenna behind the KrAZ-260B tractor cab. (Rosvooruzheniye)

band and is a phased array with a 30% larger aperture than the US Navy SPY-1 Aegis radar, even accounting for its slightly larger wavelength it amounts to a mobile land based Aegis class package. It has no direct equivalent in the west.

Like other components of the system, the 64N6E has a number of unique and lateral design features. The radar antenna is mounted on a cabin, in turn mounted on a turntable permitting 360 degree rotation. Unlike western phased arrays in this class, the 64N6 uses a reflective phased array with a front face horn feed, the horn placed at the end of the long boom which protects the waveguides to the transmitters and receivers in the cabin. The beam steering electronics are embedded inside the antenna array, which has around 2700 phase shift elements on either face. This 'Janus faced' arrangement permits the Big Bird to concurrently search two 90 degree sectors, in opposite directions, using mechanical rotation to position the antenna and electronic beam steering in azimuth and elevation. This design technique permits incremental growth in output power as the only components of the system which have to handle high microwave power levels are the waveguide and feed horn.

The 64N6E is a frequency hopper, and incorporates additional auxiliary antenna/receiver channels for suppression of sidelobe jammers – NIIP claims the ability to measure accurate bearing to jamming sources. The back end processing is Moving Target Indicator (MTI), and like the Aegis the system software can partition the instantaneous sector being covered into smaller zones for specific searches. To enhance MTI performance the system can make use of stored clutter returns from multiple preceding sweeps. Detection ranges for small fighter targets are of the order of 140 to 150nm (260 to 465km) for early variants. Per 12 second sweep 200 targets can be detected, and either six or twelve can be individually tracked for engagements.

While the Big Bird provides an excellent acquisition capability against aerial and ballistic missile targets, the 5V55 missile was inadequate. The S-300PM/PMU-1 introduced the 48N6 which has much better kinematics – cited range against aerial targets is 81nm (150km), ballistic missile targets 21.5nm (40km), with a minimum engagement range of 1.6 to 2.7 nautical miles. Low altitude engagement capabilities were improved – down to 20 to 30ft AGL. The missile speed peaks at 2100 metres/sec or cca Mach 6. The missiles can be fired at three second intervals, and Russian sources claim a single shot kill probability of 80% to 93% for aerial targets, 40% to 85% for cruise missiles, and 50% to 77% for TBMs.

A typical S-300PM/PMU-1 battery comprises a 30N6E1 engagement radar, a 76N6 low level early warning/acquisition radar and up to 12 5P85S/5P85T (SE/TE export variant) TELs, each with four 48N6 rounds. A PVO battalion then combines up to six batteries, using a shared 64N6E acquisition radar, supported by a 54K6E command post.

China has to date been the principal export client for the system, acquiring between 4 and 6 batteries of the S-300PMU between 1991 and 1994, and supplementing these with further buys. The People's Liberation Army (PLA)'s systems include both fully mobile 5P85SU/DU and road mobile 5P85T series TELs. The total PLA inventory has not been disclosed publicly. The most recent buy has been of two S-300F/SA-N-6 navalised systems for the Chinese navy. The principal impediment to export sales numbers has remained cost – a well equipped battery is typically cited at around $US100 million.

An option for the S-300PS/PMU, S-300PM/PMU-1 and follow-on S-300PMU-2 cited by two Russian manufacturers is the new LEMZ 96L6 early warning and acquisition radar, a planar array design with electronic beam steering in elevation and mechanical steering in azimuth. It is intended as a replacement for the Tin Shield and Clam Shell. The 96L6/96L6E is available in semi-mobile towed versions, a semi-mobile mast mounted version using variants of the 40V6M/MD, and a fully mobile version on an 8x8 MZKT-7930 vehicle, based on the MAZ-543M chassis. LEMZ claims a detection range of 160nm (295km), and the ability to track up to 100 targets, an IFF array is collocated with the antenna. The system has an interface for digital data transmission directly to a 30N6E/E1/E2 Flap Lid, using cabled links to the S-300PMU/PMU-1 and optical fibre cables or microwave links to the S-300PMU-2. Deployment and stow time is five minutes for the mobile variant, and 30 to 120 minutes for the semi-mobile and mast mounted variants respectively.

Part 2 discusses the latest S-300P variants, and the S-300V systems.

by Carlo Kopp

ASIA'S NEW SAMS

PART 2

Further evolution of the S-300P design took place between 1995 and 1997, yielding the S-300PMU-2/SA-10E 'Favorit' system, intended to compete directly against the Antey S-300V and Patriot PAC-2/3 systems as an AntiBallistic Missile (ABM) system.

The Favorit incorporates incrementally upgraded 30N6E2, 64N6E2 radars and a 54K6E2 command post, and the 96L6E as its early warning and primary acquisition system. While the system retains compatibility with earlier 48N6 missiles, a new extended 108nm (200km) range 46N6E2 missile was added. The Favorit's new command post has the capability to control S-300PMU, S-300PMU-1 batteries, and also S-200VE/SA-5 batteries, relaying coordinates and commands to the 5N62VE Square Pair guidance and illumination radar.

While the Favorit superficially appears like the SA-10D, it has a wide range of incremental improvements internally, and a range of optimisations to improve performance in the antiballistic missile role. Almaz, the system integrators, and Fakel, the missile designers, claim to have repeatedly caused Scud target vehicle warheads to detonate during test intercepts at the Kapustin Yar range in 1995.

The Almaz S-400 Triumf or SA-20 system is the subsequent evolution of the S-300PMU-2, trialled in 1999. The label S-400 is essentially marketing, since the system was previously reported under the speculative label of S-300PMU-3.

The principal distinctions between the S-400 and its predecessor lie in further refinements to the radar and software, and the addition of three new missile types in addition to the 48N6E/48N6E2. As a result, an S-400 battery could be armed with arbitrary mixes of these weapons to optimise its capability for a specific threat environment.

The first missile added to the system has not been named publicly, but is a long range weapon with a cited range of 215nm (400km), intended to kill high value assets like AWACS and JSTARS. Further details of this weapon remain undisclosed – some sources speculate it is a variant of the Novator KS-172 long range AAM with a bigger booster (AA 08/03).

The further missiles are in effect equivalents to the ERINT/PAC-3 interceptor missile recently introduced to supplement the MIM-104 in Patriot batteries. These are the 96M6E and 96M6E2, largely identical with the latter version fitted with a larger booster. Fakel claims the 96M6E has a range of 21.6nm (40km), and the 96M6E2 64.8nm (120km), with altitude capabilities from 15ft above ground level up to 66,000ft and 100,000ft respectively.

The 96M6 missiles are 'hittiles' designed for direct impact, and use canards and thrust vectoring to achieve extremely high G and angular rate capability – they are not unlike a scaled up R-73/AA-11 Archer dogfight missile in concept. An inertial package is used with a datalink from the 30N6E radar for midcourse guidance, with a radar homing seeker of an undisclosed type. The small 24kg (53lb) blast fragmentation warhead is designed to produce a controlled fragment pattern, using multiple initiators to shape the detonation wave through the explosive. A smart radio fuse is used to control the warhead timing and pattern. It is in effect a steerable shaped charge.

The S-300V/S-300VM/Antey-2500 is the world's only truly mobile Anti Ballistic Missile system, and later variants are claimed to be capable of intercepting 4.5km/sec re-entry speed targets. The large size of the Grill Pan phased array and TELAR command link and illuminator antennas is evident. The system provides the capability to engage very low RCS aircraft at ranges in excess of 100nm (185km). (Rosvooruzheniye)

The smaller size of these weapons permits four to be loaded into the volume of a single 48N6E/5V55K/R launch tube container – a form fit four tube launcher container is used. So a single 5P85S/T TEL can deploy up to 16 of these missiles, or mixes of 3 x 48N6s/4 x 96M6E/E2s, 2 x 48N6s/8 x 96M6E/E2s, or 1 x 48N6/12 x 96M6E/E2s. The stated aim of this approach was to permit repeated launches against saturation attacks with precision guided weapons – in effect trading 96M6 rounds for incoming guided weapons. Fakel claims a single shot kill probability of 70% against a Harpoon class missile, and 90% against a manned aircraft.

What future developments can be expected for the S-300P/S-400 series? With the exception of further evolutions in missile and radar technology, and active radar or dual mode seekers, it is likely that additional passive targeting sensors such as wideband interferometers/ESM receivers (external Kolchuga ESM systems are an option already) and FLIR/IRST (already an optional retrofit for S-125/SA-3, 2K12/SA-6) could find their way on to the 30N6E Flap Lid. Modern ruggedised multi-GigaHertz COTS computing hardware is clearly an option for the 54K6E and other system components. At some point, Almaz will transition to active phased array technology, but cost will remain a challenge given the maturity of the current design.

In summary the S-300P/S-400 is in its latest variants a highly capable and modern dual role SAM/ABM system, with exceptionally good mobility and resistance to jamming. While its radar and back end data processing systems may not match the technology in the latest western products, the excellent kinematics of the missiles, and large power aperture capability of the phased array radars make these formidable weapons.

Variant	Designation	Surveillance Radar	BM Acquisition Radar	Engagement Radar	Mobile TELAR	Mobile TEL/TL	Missile	Options
SA-12A	S-300V	9S15 Bill Board	9S19 High Screen	9S32 Grill Pan	9A83	9A85	9M83	-
SA-12B	S-300V	9S15 Bill Board	9S19 High Screen	9S32 Grill Pan	9A82	9A84	9M82	-
SA-12A[1]	S-300VM	9S15M Bill Board	9S19M High Screen	9S32M Grill Pan	9A83	9A85	9M83M	-
SA-12B[1]	S-300VM	9S15M Bill Board	9S19M High Screen	9S32M Grill Pan	9A82	9A84	9M82M	-

Table 1: Antey S-300V/S-300VM Surface to Air Missile System (Note [1]: Antey 2500 NATO designation as yet not disclosed).

THE ANTEY S-300V/SA-12 SAM SERIES

While Antey's impressive S-300V family of SAM systems shares its earliest conceptual origins with the Almaz S-300P family, the two product lines diverged dramatically very early in their development histories. As a result, they share the same technology base but are essentially unique designs, optimised respectively for the needs of the prime customers, the V-PVO and PVO-SV.

While the PVO-SV shared some static and semi-mobile radar systems with the V-PVO during the early 1960s, the PVO-SV deployed its own unique inventory of fully mobile SAM systems, reflecting its role of providing air defence cover for highly mobile Soviet tank and motorised infantry divisions. By the end of the 1960s the PVO-SV had deployed a three tier system, with the cumbersome ramjet powered 2K11/3M8 Krug/1S12 Long Track/1S32 Pat Hand/SA-4 Ganef system providing long range area defence, the quite effective 2K12/3M9 Kub/1S91 Straight Flush/SA-6 Gainful system providing medium range area defence, and the 9M33 Osa/9K33 Romb/SA-8 Gecko, 9M31 Strela 1/SA-9 Gaskin, and ubiquitous ZSU-23-4P SPAAG providing low altitude point defence.

With the exception of the 3M8/SA-4, this package was widely exported throughout the Arab world and Africa, and while achieving some initial success against the Israelis in 1973 generally suffered grievously when applied against western airpower and electronic combat forces. By the early 1970s it was clear that a new generation of systems would be needed to challenge growing western SEAD and EW capabilities. The S-300V system was to provide the top tier in the new air defence umbrella.

Unlike first generation PVO-SV systems the S-300V would have a much broader role, encompassing both long range high altitude air defence but also defence against US tactical ballistic missiles, specifically the Lance and Pershing I/II, the FB-111A's supersonic AGM-69A SRAM standoff missile, and the new US Air Force MGM-109 Ground Launched Cruise Missile – a trailer launched nuclear armed Tomahawk variant based in the UK and Western Europe. As a result the S-300V would have to provide exceptionally good detection and tracking performance against low radar cross section targets, at very high and very low altitudes, while retaining the very high offroad mobility so typical of established PVO-SV tracked area defence SAM systems, and possessing exceptional resistance to the US EF-111A Raven jammer force.

The S-300V was the result of these pressures – an expensive, complex but highly capable dual role SAM/ABM system which remains without equivalent to this day. It was to be an 'Army level' or 'Corp level' asset, protecting the centre of gravity of the Red Army's mechanised land forces against attack by nuclear and conventionally armed systems.

The baseline S-300V entered production during the very early 1980s, and was accepted into service by the PVO-SV in 1983 under the designation S-300V-1, but was limited in capabilities. Difficulties with the complex technology delayed service entry of the fully developed package with ABM capability until 1988, under the designation S-300V.

The only export customer to date has been India who has since acquired a pair of Israeli Green Pine ABM early warning radars, as a counter to Pakistan's nuclear armed ballistic missile force. The order for six S-300VM systems remains in negotiation while the Israeli Arrow and S-300PMU-2/S-400 are evaluated. A marketing drive in the Persian Gulf some years ago fell foul of US influence in the region – Patriots being bought instead, amid Russian allegations of dishonest marketing tactics by the US.

All principal components of the S-300V system are carried on the MT-TM 'Item 830' series of tracked vehicle, with gross weights between 44 and 47 tonnes per vehicle – the S-300V is not a lightweight system – and has similar offroad mobility to a medium tank.

The S-300V system comprises no less than eight vehicles, the 9S457 mobile command post, the 9S15 Bill Board acquisition radar, the 9S19 High Screen ABM early warning radar, the 9S32 Grill Pan engagement radar, the 9A82 and 9A83 TELARs (Transporter Erector Launcher and Radar), and the 9A84 and 9A85 TEL/Transloader vehicles.

The fully mobile 9S15 Obzor 3/Bill Board acquisition radar is a mechanically rotated 3D radar system, with electronic beam steering in elevation and an IFF array. It provides long range early warning of aerial threats and low end tactical ballistic missiles (TBMs) such as the Scud A and Lance.

The 9S15 has two basic modes of operation. The first is optimised for a 12 second sweep and is claimed to provide a 50% probability of detecting a fighter sized target at 130nm (240km). The second mode employs a faster six second sweep period, and is used to detect inbound tactical ballistic missiles and aircraft, with a reduced detection range of about 80nm (150km) for fighters, and 50 to 60nm (92 to 111km) for (TBMs) like the Scud A or Lance. Russian sources are unusually detailed on ECCM techniques used, claiming the use of three auxiliary receiver channels for cancelling side lobe jamming, automatic wind compensated rejection of chaff returns, and provisions in the MTI circuits to reject jamming. A facility for

The S-400 Triumf/SA-20 introduces three new missiles, two of which are highly agile equivalents to the ERINT/PAC-3 and one of which is claimed to have 200nm (370km) range. The system retains compatibility with earlier 5V55 and 48N6 series SA-10 SAMs, while the latest SA-10/20 command posts can also control very long range SA-5 Gammon batteries. (Author)

precise angular measurement of jamming emitters is included. RMS tracking errors are quoted at 250 metres in range and about 0.5 degrees in azimuth/elevation, with the ability to track up to 200 targets. The system has an integral gas turbine electrical power generator for autonomous operation – a feature of most S-300V components.

This radar provides a highly mobile 3D search and acquisition capability, but is limited in low level coverage footprint by its antenna elevation. Its limited scan rate makes it unusable for high performance IRBM acquisition and tracking, which is the role of the 9S19 High Screen radar.

The specialised 9S19 Imbir is a high power-aperture, coherent, X-band phased array designed for the rapid acquisition and initial tracking of inbound ballistic missiles within a 90 degree sector. To that effect it uses a large passive phase shift technology array, using a conceptually similar space feed technique to the MPQ-53 and 30N6 series radars, producing a narrow 0.5 degree pencil beam main lobe.

The primary search waveform is chirped to provide a very high pulse compression ratio intended to provide very high range resolution of small targets. The design uses a high power Travelling Wave Tube (TWT) source, very low side lobes and frequency hopping techniques to provide good resistance to jamming.

Three primary operating modes are used. In the first the 9S19 scans a 90 degree sector in azimuth, between 26 and 75 degrees in elevation, to detect inbound Pershing class IRBMs within a 40 to 95nm (75 to 175km) range box, feeding position and kinematic data for up to 16 targets to the 9S457 command post. The second mode is intended to detect and track supersonic missiles such as the AGM-69 SRAM, and sweeps a narrower 60 degree sector in azimuth, between nine and 50 degrees in elevation, within a range box between 10 and 90 nautical miles, generating target position and velocity updates at two second intervals.

The third mode is intended to acquire aircraft in severe jamming environments, with similar angular and range parameters to the second mode. The radar is claimed to produce RMS angular errors of around 12 to 15 minutes of arc, and a range error of a mere 70 metres (at max range 0.04%!). The peak power rating remains undisclosed.

In function the 9S19 most closely resembles much newer western X-band ABM radars, but is implemented using seventies generation antenna and transmitter technology, and is fully mobile, unlike the semimobile US THAAD X-band radar and Israeli Green Pine.

The third radar in the S-300V suite is the 9S32 Grill Pan, an engagement radar similar in concept and function to the MPQ-53 and 30N6, but larger with the antenna turret capable of slewing through +/-340 degrees. It will automatically acquire and track targets provided by the 9S457 command post, control the operation of TELAR mounted illuminators and generate midcourse guidance commands for up to 12 missiles fired at six targets concurrently. The S-300V system uses continuous wave illumination of targets and semi-active radar terminal homing, not unlike the US Navy RIM-66/67 SAM series – the illuminators are carried on the 9A82 and 9A83 TELARs.

Like the 9S19, the 9S32 is a high power-aperture, coherent, X-band phased array, but specialised for missile guidance. Cited detection ranges are about 80nm (150km) for fighter sized targets, 40nm (75km) for SRAM class missiles and up to 80nm (150km) for larger IRBMs. The radar uses monopulse angle tracking techniques, frequency hopping in all modes to provide high jam resistance, and chirped waveforms providing a high compression ratio. Three auxiliary receiver channels are used for cancelling sidelobe jamming.

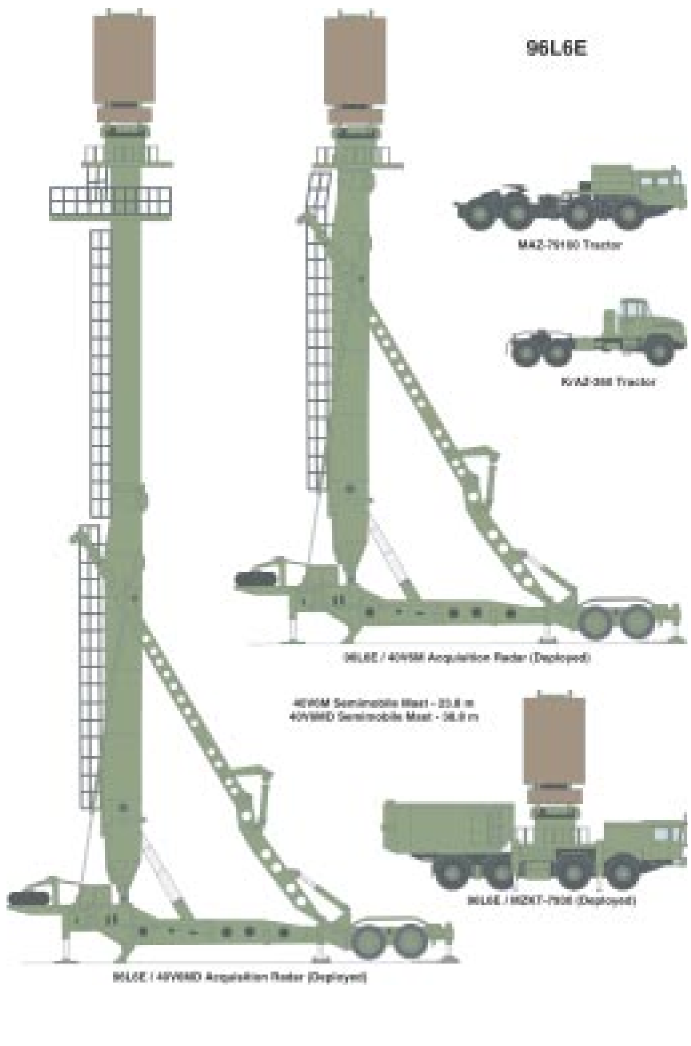
Two basic operating modes are used. In the first the 9S32 is controlled by the 9S457 command post and acquires targets within a narrow 5 x 6° field of view, alternately it can autonomously search and acquire targets within a 60° field of view. A datalink antenna is mounted aft of the array.

The 9A82 and 9A83 TELARs carry two Novator designed 9M82 Giant long range SAM/ABMs, and four 9M83 Gladiator SAM/ABMs respectively. Each TELAR is equipped with a steerable high gain antenna used to transmit midcourse guidance commands to the missiles and provide continuous wave illumination of the target for the missiles' semi-active radar seekers during the terminal guidance phase. The TELARs are controlled by the 9S32 Grill Pan using either cables or a bidirectional radio datalink, permitting the TELARs to return status information to the guidance radar.

The 9A82 TELAR is optimised for engaging targets at higher altitudes, and can slew its antenna through 180 degrees in azimuth, and 110 degrees in elevation, while the 9A83 TELAR has an elevating and telescoping mast providing antenna coverage of the full upper hemisphere – this arrangement is intended to extend the engagement footprint against low altitude targets. The TELARs are supplemented by the 9A84 and 9A85 TEL/Transloaders, essentially 'dumb' launchers which can be used only with guidance/illumination from a nearby TELAR, and equipped with loading cranes instead of antenna booms.

The smaller 9M83 Gladiator SAM/ABM is intended to engage aerial targets at all altitudes, including cruise missiles, and smaller TBMs. The much larger 9M82 Giant has higher kinematic performance and is intended to kill IRBMs, SRAM class supersonic missiles, but also standoff jamming aircraft at long ranges. Both weapons employ two solid propellant stages, with thrust vector control of the first

The new LEMZ 96L6 is intended to replace the Tin Shield and Clam Shell acquisition radars with a single high performance system and is available as an upgrade component for existing IADS. (Author)



stage (4636kg/10,225lb mass in the Giant and circa 2275kg/5000lb the Gladiator) and aerodynamic control of the 1270kg (2800lb) second stage, using four servo driven fins, and four fixed stabilisers. The guidance and control packages, and much of the weapon airframes are identical, the principal distinction being the bigger booster stage of the Giant and its larger stabilisers.

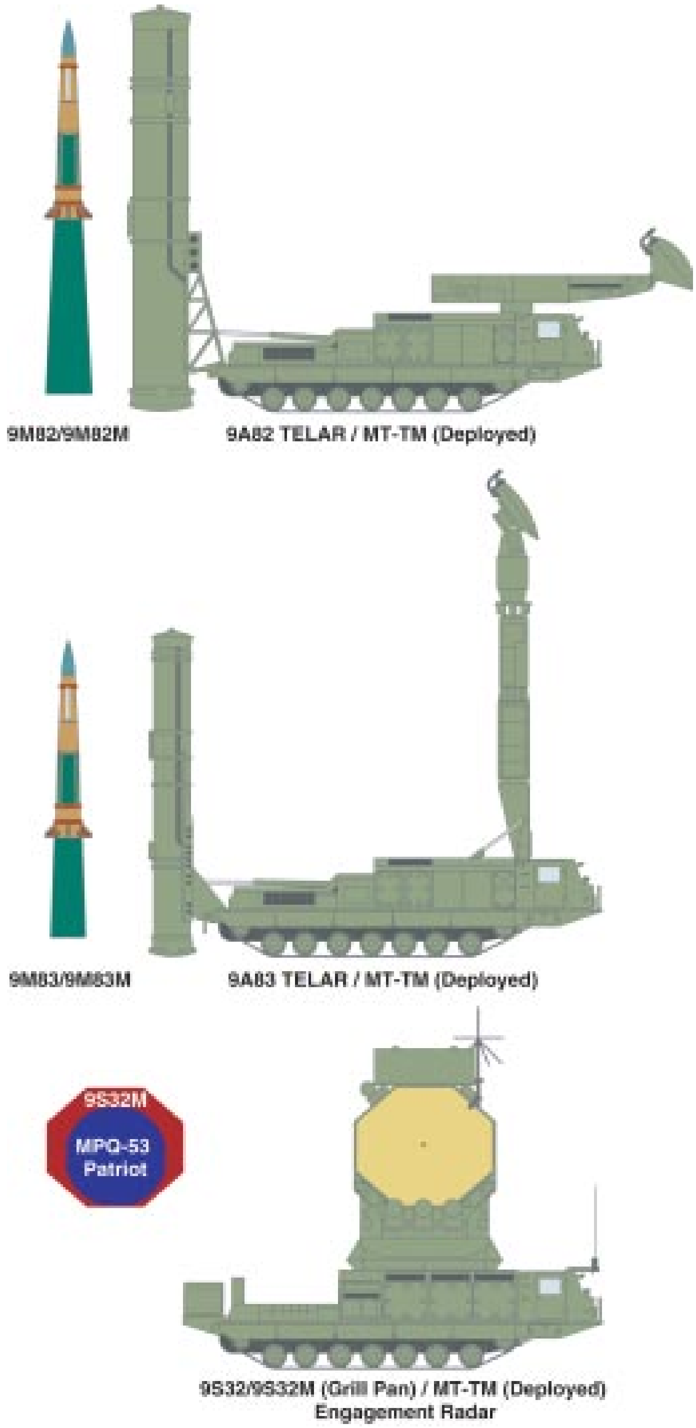
A cold start ejector is used to expel the missile from the launch tube, the first stage burns for about 20 seconds, then the missile transitions to its midcourse sustainer. During midcourse flight the missile employs inertial navigation with the option of command link updates. In the former mode it transitions to its semi-active homing seeker during the final 10 seconds of flight, in the latter three seconds before impact – a technique preferred for heavy jamming environments. Russian sources claim the semi-active seeker can lock on to a 0.05 square metre RCS target from 16.2nm (30km). The midcourse guidance system attempts to fly the most energy efficient trajectory to maximise range. A two channel radio proximity fuse is used to initiate the 150kg (330lb) class 'smart' warhead which has a controllable fragmentation pattern to maximise effect.

The engagement envelope of the baseline Gladiator is between 80ft AGL to 80,000ft, and ranges of 3.2 to 40nm (5.9 to 74km), the Giant between 3200ft AGL to 100,000ft, and ranges of 7 to 54nm (13 to 100km). The system can launch the missiles at 1.5 second intervals, and a battalion with four batteries can engage 24 targets concurrently, with two missiles per target, and has a complement of between 96 and 192 missiles available for launch on TELAR/TELs. A TELAR can arm a missile for launch in 15 seconds, with a 40 second time to prepare a TELAR for an engagement, and five minute deploy and stow times – a genuine 'shoot and scoot' capability.

The cited single shot kill probabilities for the Gladiator are 50% to 65% against TBMs and 70% to 90% against aircraft, for the Giant 40% to 60% against IRBMs and 50% to 70% against the AGM-69 SRAM – ballistic missiles with re-entry velocities of up to three km/s can be engaged.

The Soviets were terrified of the USAF's EF-111A force and equipped the S-300V system with a facility for passive targeting of support jammers. The 9S15, 9S19 and 9S32 have receiver channels for sidelobe jamming cancellation and these are used to produce very accurate bearings to the airborne jammer, this bearing information is then used to develop angular tracks. The angular tracks are then processed by the 9S457 command post to estimate range, and the 9S32 then develops an estimated track for the target jammer. A Giant missile is then launched and steered by command link until it acquires the target.

The S-300V has been supplanted by the enhanced S-300VM, using the 9S15M2, 9S19M, 9S32M and 9S457M components, and improved 9M82M and 9M83M missiles. This system has been marketed as the 'Antey 2500', intended to highlight its capability to engage 2500km range IRBMs with re-entry velocities around 4.5 km/sec. The 9M82M has double the range of the 9M82 against aerial targets, at 108nm (200km), and increased terminal phase agility – a single shot kill probability of 98% is claimed against ballistic targets.



An SA-12 battery will have several fire units, each centred on a Grill Pan phased array engagement radar, and some mix of 9A82 and 9A83 TELARs and 9A84 and 9A85 TEL/Transloaders. The Grill Pan controls the TELARs' command link/illuminator antennas and remotely fires the missiles. (Author)

Commercially the S-300V/VM has been much less successful than the S-300P series, in part due to its higher cost and capability – the Indian sale has yet to materialise, compared to the large number of S-300P systems sold to China. Earlier this year the Russian government authorised a merger between Almaz, Altair and Antey to produce what theoretically is likely to be the world's largest SAM system manufacturer. However, in typical post soviet tradition a series of murders of corporate executives followed and it is unclear at this stage how the merger will proceed. Novator has been verging on bankruptcy for some time, ostensibly due to the inability of the Russian defence ministry to pay its bills.

In the longer term the S-300V is likely to acquire similar evolutionary enhancements to the S-300P series, if not identical should the Almaz/Altair/Antey merger proceed, increasing its range and already superb lethality. It is likely that GPS aided navigation hardware will be added at some stage to both the S-300P/S-300V to increase the accuracy of the inertial/compass navigation systems on the radars and TELAR/TELs.

CONCLUSIONS

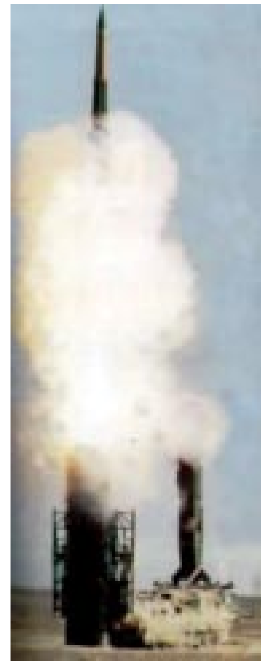
The arrival of S-300P and S-300V missile systems in the region radically changes the strategic environment, both from the perspective of the US and Australia.

These highly capable systems are not invincible, but require significant investment into capabilities to defeat them – prohibitive losses in expensive aircraft and irreplacable aircrew otherwise might occur. As they are less demanding to operate than modern combat aircraft, operators across the broader region will be able to achieve combat effective proficiency faster than with the Su-27/30.

In practical terms the S-300P/S-300V SAMs are a viable deterrent against air forces without the technological and intellectual capital to tackle them – and in many respects better value for money than the Su-27/30. Their failure to sell in larger numbers reflects more than anything poor marketing and support credibility by Russia's industry.

The US Air Force's approach to defeating these SAMs is conceptually simple: the F/A-22A exploiting its all aspect wideband stealth, supercruise, high altitude and sensitive ESM warning capability will kill the engagement and acquisition radars using guided weapons. High power standoff support jamming will be provided by B-52Hs equipped with electronically steerable high power jamming pods, and standoff ISR support will be provided by systems such as the RC-135V/W, E-8C and forthcoming E-10 MC2A. Standoff or highly stealthy ISR capabilities will be necessary – the current generation of high altitude UAVs like the RQ-1B and RQ-4A are not survivable in airspace covered by the S-300P/S-300V systems.

Conventional unstealthy, or partially stealthy (ISF) combat aircraft will have difficulty surviving within the coverage of the S-300P/S-300V – the high transmit power, large radar and missile seeker apertures, low sidelobes, generous use of monopulse angle tracking and extensive ECCM features make these systems difficult to jam effectively. Self protection jammers will need to produce relatively high X-band power output, and exploit monopulse angle tracking deception techniques – Digital RF Memory techniques with high signal fidelity are nearly essential. Even so the challenges in defeating these systems with a self protection jammer are not trivial – raw power-aperture does matter in this game.



(right) Like the S-300P, the S-300V uses the 'cold launch' technique, ejecting the missile before its motor is fired. This 9M83 SAM is being launched from a 9A83 TELAR, which uses its elevated directional antenna to provide the 9M83 with both midcourse command updates and terminal phase high power continuous wave illumination of the target. Antey claims the semi-active seeker will acquire a 0.05 square metre RCS target at 16nm (30km). (Rosvooruzheniye)

In practical terms, low level terrain masking to remain below the radar horizon of these systems, combined with good standoff ISR, support jamming and a low radar signature standoff missile, is the only reliable defence for an aircraft with anything greater than insect sized all aspect radar signature. For instance the F-35 JSF's forward sector stealth is likely to be adequate, but its aft sector stealth performance may not be, especially considering the wavelengths of many of the radars in question – an F-35 driver runs a real risk of taking a 1360kg (3000lb) hypersonic SAM up his tailpipe if he cannot kill the target SAM engagement radar in his first pass. For the JSF, integration of a terrain following radar mode in its AESA radar is not an unusual technical challenge, incurring only modest development cost. The bigger bite will be in shortened airframe fatigue life resulting from fast low level penetration with a modestly swept wing design.

Of the current crop of fighters in western service, the most survivable are those with good TFRs – the F-111, Tornado and F-15E if fitted with the LANTIRN TFR pod – all requiring a high performance EW suite.

A weakness of both the S-300P/S-300V systems is that they are severely radar horizon limited in a fully mobile configuration. The addition of mast mounted acquisition radars to extend their low level footprint severely impairs the mobility of the battery.

The popular idea of shooting cruise missiles, anti-radiation missiles or standoff missiles at the S-300P/S-300V battery, assuming its location is known, is only viable where such a weapon has a sufficiently low radar signature to penetrate inside the minimum engagement range of the SAM before being detected – anything less will see the inbound missile killed by a self defensive SAM shot. The current Russian view of this is to sell Tor M1/SA-15 Gauntlet self-propelled point defence SAM systems as a rapid reaction close-in defensive system to protect the S-300P/S-300V battery by shooting down the incoming missile if it gets past the S-300P/S-300V SAMs.

In conclusion, current RAAF force structure plans do not provide for a robust long term capability to defeat the S-300P/S-300V class of SAMs – weapons which are very likely to be encountered during coalition operations, and most likely, regional operations over the coming two or more decades. If the RAAF wishes to remain competitive in this developing regional environment, further intellectual and material investment will be needed.

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.

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.

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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.

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.

LWC

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.

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.

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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.

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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.

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

by Dr Carlo Kopp, PEng

Taking the 'Force' out of Air Force?

On November 7, Defence Minister Senator Robert Hill announced that Cabinet had accepted a case put by the Department of Defence to retire the F-111 fleet from 2010 onwards, essentially without replacement. A gap filler capability comprising a standoff missile on the F/A-18A and AP-3C Orions was presented as the alternative until Joint Strike Fighters are acquired.

This is the most radical downsizing in RAAF firepower seen since the post WW2 demobilisation and raises a series of very important questions about where Australia is heading longer term in firepower and strategic posture, and where it is putting its priorities in force structure development. This month's analysis will focus on the arguments supporting this decision and identify key incongruities.

THE DECISION

The public announcement capped off a three year long debate within the Department of Defence on when to retire the F-111. The specifics of the announcement, presented as part of the briefing on the Defence Capability Review conducted last year (2003), are best presented verbatim:

"The Air Force also has plans for the acquisition of Global Hawk unmanned aerial vehicles and a replacement for the AP-3C under the further maritime patrol and response capability. In such circumstances, the Air Force has advised that by 2010 – with full introduction of the AEW&C aircraft, the new air-to-air refuellers, completion of the F/A-18 Hornet upgrade programs including the bombs improvement program and the successful integration of a standoff strike weapon on the F/A-18s and AP-3C – the F-111 could be withdrawn from service. In other words, by that time the Air Force will have a strong and effective land and maritime strike capability. This will enable withdrawing the F-111 a few years earlier than envisaged in the White Paper."

Senator Robert Hill: "in light of the increasing strike capability that's going to be attached to principally the F/A-18s, but also the Orions as I've detailed in this paper, it's believed that the retirement date of the F-111s can be brought forward a few years. That's a decision, that's guidance that's been given to government by Air Force and guidance that government has accepted. ... Can I just say that the existing projects such as the AGM-142 will continue."

Chief of Air Force AM Angus Houston: "There will be no gap and I think that's the important message to get across. Essentially the F-111 will not be withdrawn until such time as we've fully upgraded the F/A-18. We have the much more capable tankers. We have the AEW&C. We've upgraded our weapons. The F/A-18 will be capable of dropping not only laser guided precision munitions but also satellite guided precision munitions and will also be capable of delivering a follow-on standoff weapon, which will also be fitted to the AP-3C. ... Well what will dictate the retirement of the F-111 will be the achievement of a suitable capability to replace the F-111. Now we think that will be somewhere from 2010 onwards. And we're very

If the Federal Government follows through on the Defence Department plan to kill off the F-111 after 2006, Australia will mostly likely achieve parity in strike capabilities against regional nations like Indonesia, who are acquiring Su-30MK variants. The Defence proposal to put a standoff missile like the JASSM on the AP-3C Orion and use it for strike is not unlike flying B-29s into MiG Alley in a Sukhoi rich neighbourhood – great recruiting poster material for prospective RAAF aircrew. (Paul Merritt)

much focussed on the capability that the Joint Strike Fighter will provide. And of course what you've seen in recent times is the increasing fragility of our F-111 capability. By 2010 it will be almost 40 years old. And our studies suggest that beyond 2010 it will be a very high cost platform to maintain and there's also a risk of losing the capability altogether through ageing aircraft factors ... No I don't think you will and frankly I, as the Chief of Air Force, would not want to see it flying beyond 2015. Because I think we've got a very old platform there and the risks of capability failure will increase with age. By 2020, if we were to go that far, the F-111 would be 50 years of age. That's a pretty old platform. ..."

The central thesis of the argument presented is that the F-111 is perceived to be old, with the risk of an unspecified catastrophic structural fatigue problem which would ground the fleet permanently, and will become significantly more expensive to maintain over time.

The new strike strategy will instead be to substitute for the F-111 until the Joint Strike Fighter is delivered by putting a shorter ranging cruise missile such as the AGM-158 JASSM on the F/A-18A and AP-3C, and by supporting the former with the four or five new tankers. So the trigger point at which the F-111 would be withdrawn from service is likely to be attainment of the second generation standoff weapon's Initial Operational Capability, and the new tankers (either KC-767s or A330-200MRTTs) replacing the current Boeing 707s.

The plan presented would most likely see the completion of the F-111's Block C-3A upgrade with the Elta 8222 self protection jammer, and the Block C-4 upgrade which entails the addition of a Mil-Std-1760 weapons interface and integration of the AGM-142 Stand Off Weapon. Whether the GBU-31/38 JDAM is cleared as part of the Block C-4 upgrade package remains unstated. Block C-4 is in the prototyping phase and likely to enter production post 2004.

Follow-on Block C-5 and later upgrades, which were intended to integrate a new Radar Warning Receiver, a new internal self protection jammer, the AGM-158 JASSM, possibly ASRAAM, JTIDS datalink and other capabilities would be dropped. As a result F-111 software development and integration work would begin to wind down after the completion of Block C-4. Longer term airframe maintenance such as fuel tank deseal-reseal will also begin to wind down around the middle of the decade.

The 2010-2015 timeline discussed in the briefing does not fit the stated model for the phase out criterion. Weapons like the JASSM are very easy to integrate – they are not unlike a large Harpoon in delivery method and supporting software in the aircraft is relatively simple. Therefore an IOC for a weapon like the AGM-158 JASSM in RAAF service could be as early as 2006 to 2008. The IOC for the replacement tanker was originally intended to be 2006, with slippages perhaps to 2008.

Therefore the likely outcome would be that the F-111 would be withdrawn earlier than 2010, perhaps starting as early as 2006. The initial leaks to the press over this matter proposed 2006 as a withdrawal date, and it is not unreasonable to conclude that this is the actual target withdrawal date. With allowances for slippage in the gap fillers, any date post 2006 is possible.

THE STRIKE CAPABILITY GAP

The statement claiming there will be no gap in strike capability does not stand up even to basic analysis.

In terms of the capability to deliver raw firepower, the F-111 typically performs the work of two F/A-18A Hornets and about one half of a supporting medium sized tanker. This is regardless of the type of weapon carried – tonnage is tonnage. For most scenarios a pair of F-111s does the work of four F/A-18As and one tanker, making the F-111 operationally cheaper.

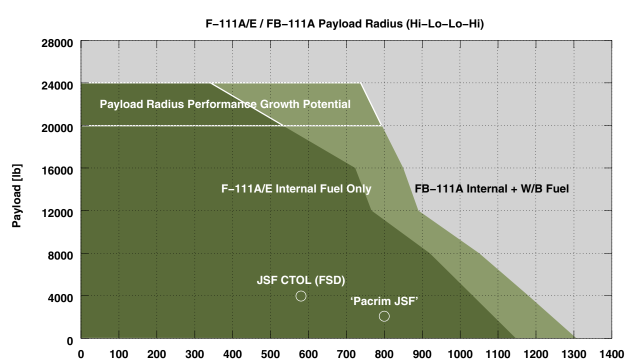
A range of starting assumptions can be applied, but all essentially lead to the same conclusion – the F-111 provides around 50 percent of the RAAF's total strike firepower. Therefore, for any gap filler capability to be credible strategically, it must double the firepower available once the F-111 fleet is removed from the force structure.

Assuming that Hornets are employed and there is no demand for any air combat activity which diverts Hornets away from strike work, this argument in effect asserts that the proposed gap filling measures will permit a doubling of the total firepower deliverable by the F/A-18A fleet. It takes very little to show that this argument is essentially wrong and not supportable by hard numbers.

The public statement claims that this aim can be achieved by integrating JDAMs on the F/A-18A, a weapon like the JASSM on the F/A-18A and AP-3C, and supporting the F/A-18As with the planned number of four to five tankers.

The notion that the AP-3C armed with a JASSM or similar weapon presents a credible strike capability is also unsupportable. The survivability of the AP-3C in a regional environment where many nations will be flying the Su-30 or Su-27 is minimal. Arming the AP-3C with a 200nm (370km) class range weapon doesn't change the basic reality that it is a slow moving turboprop with a

What sets the F-111 apart from contemporary fighters is its prodigious fuel capacity, combat payload radius and supersonic performance. This diagram based on a General Dynamics P-chart compares the payload radius of the F-111 against the baseline full scale development JSF and proposed 'Pacrim JSF' hybrid, which replaces one of its two GBU-31 bombs with a fuel tank. Both the JSF and F/A-18A require significant tanker support to compete with the F-111. (Author)



With enough tanking you could take JSFs or F/A-18As easily to 1500nm (2800km), perhaps further. Over Afghanistan the USN flew 3000nm+ (5560km+) round trips, but that required enormous USAF KC-135 tanker support. Current RAAF tanker fleet planning covers perhaps 30% of what numbers are needed to simply offset the loss of the F-111, without allowances for escort CAPs. Claiming the JASSM as a "range extender" ignores the need for tactical routing of the missile flightpath which might cut 50% off its range.

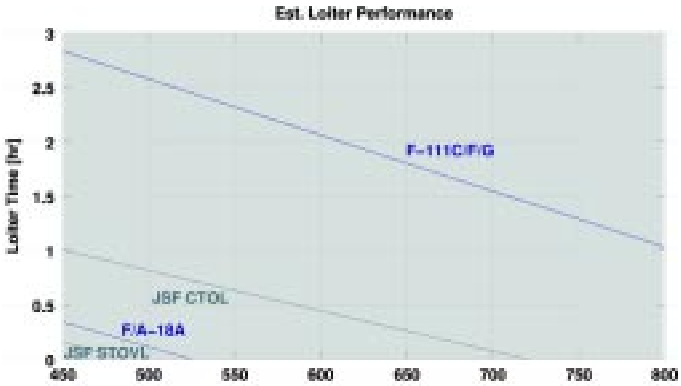
large radar cross section, which on a long range profile will have limited dash endurance at 400kt (740km/h) speed.

The Sukhoi fighters have an on station endurance of around 2.5 hours without refuelling at 200nm (370km) from base. Against a high radar signature target like a P-3C they have a radar detection range around 200nm (370km), and an effective weapons range of 50nm (95km) or more. A combat air patrol with two Sukhois flying a paired racetrack pattern using only their N011 radars can cover an effective footprint of around 300nm (555km) diameter. Even a dozen Sukhois could provide effective air defence coverage of a focal area against a missile armed AP-3C. In practical terms the AP-3C idea would result in a very high probability of AP-3C aircraft being destroyed in combat – it is akin to flying missile armed B-24s into harm's way.

If we assume 18 AP-3Cs available and wholly committed to strike operations, each carrying four JASSMs, the 200kt (370km/h) class cruise speed indicates that at best such a force can deliver firepower equivalent to only 4.5 F-111s. Each JASSM's J-1000 warhead is only 50% of a GBU-10/24/31, and the F-111 can sortie, launch, return and reload at twice the rate of the AP-3C, simply because it cruises twice as fast. Even without opposing interceptors and assuming the AP-3C fleet is needed for nothing else but strike sorties, in numbers alone the AP-3C is not a viable gap filler. Flying F/A-18A escorts to protect it would soak up the whole tanker fleet, actually reducing total strike capability.

Additionally, a single JASSM round, at $US400,00, would buy 20 2000lb JDAMs or Paveways.

Persistence over the battlefield is crucial to supporting ground forces in a rapdily moving network centric environment. A single F-111 can do the work of around nine F/A-18As in this regime at 450nm (835km) radius. Experience from Iraq indicates that frequently a ratio of two smaller fighters to one tanker was required for 'killbox interdiction', significantly driving up the cost of refuelled lightweight fighter operations. (Author)



Against the AP-3C, an F-111 delivering JASSMs has very good odds of survival against the Sukhois as it is harder to detect, is exposed for the fraction of the time an AP-3C is exposed, it can jam the N011 and can egress at supersonic speeds to evade engagement.

Given that the AP-3C provides little more than a paper capability for strike operations, the next question which arises is whether the strike capability of the F/A-18A fleet can be effectively doubled, and if so by what measures or means.

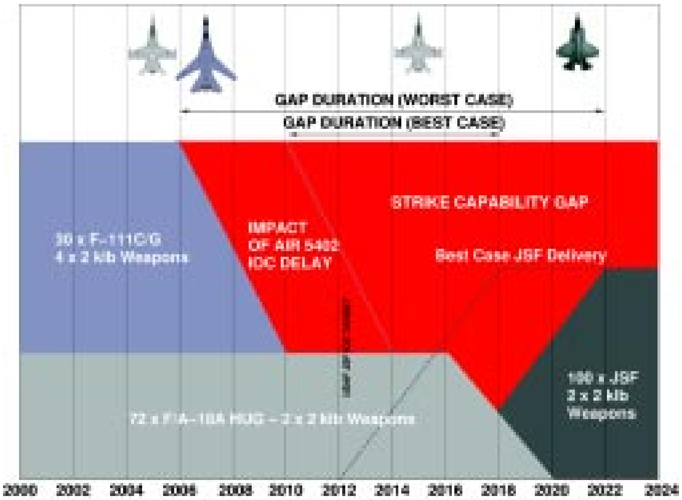
The basic restriction on the strike capability of the Hornet is its small size. Long range overwater operations supported by tankers will require that the aircraft carry two 1815 litre (480 US gal) drop tanks of fuel to provide a safe fuel margin for diversions if refuelling equipment fails. In practical terms this limits the aircraft to a pair of 2000lb class weapons, be they bombs or JASSM class standoff missiles. In such a configuration the aircraft will exhibit similar fuel burn to an F-111, or more if the weapons are draggier.

In terms of raw numbers of weapons deliverable the whole inventory of 71 Hornets equates in carriage capacity to 35 F-111s – F-111s have no difficulty in carrying four large weapons. Regardless of available tanker capacity to support the F/A-18A fleet, in raw numbers of aircraft the Hornet fleet simply cannot be made to double its strike capability. You can't beat the laws of physics.

What fraction of this fleet can deliver a long range strike capability? That number is bounded by the number of tankers and their size. If the preferred twin engine tankers are to be acquired, at the very best five aircraft will support between 20 and 30 Hornets. In terms of firepower, this is equivalent to between 10 and 15 F-111s. However, tactics will dictate that at least a third of the package is armed and loaded for escort. Therefore the reality is closer to 7 to 10 F-111s, yet again a fraction of the existing capability in the F-111 fleet, regardless of availability rates.

This argument will also apply to the Joint Strike Fighter, the ordained F/A-18 and F-111 successor. While it should achieve some range advantage over the F/A-18A as it carries its pair of 2000lb bombs and extra fuel internally, it will demand similar amounts of tanker support. The proposed extended range JSF using the navy carrier variant's bigger wing and a fuel tank filling one bomb bay essentially delivers 25% of the effective firepower of an F-111 to achieve an 800nm (1480km) plus unrefuelled radius – requiring four times as many sorties to achieve the effect of one F-111 sortie.

Another good measure for comparison is normalised 'throw weight', used extensively in arms control negotiations for sizing up strike forces. Throw weight is the product of striking range times weapon size – therefore it factors in aggregate firepower and combat radius effects. If

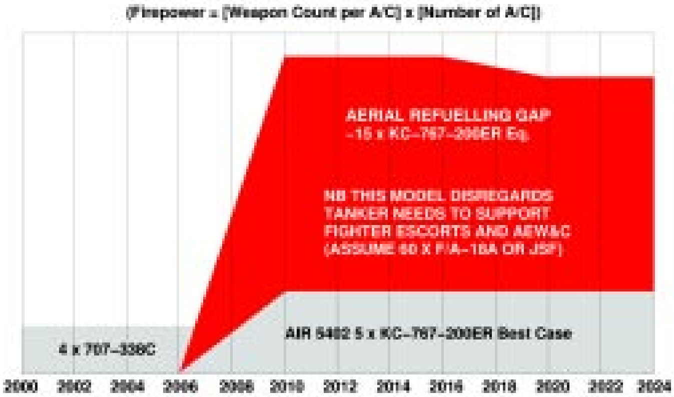


RAAF NORMALISED THROW WEIGHT

(Throw Weight = [Weapon Count] x [Combat Radius])

RAAF NORMALISED FIREPOWER

(Firepower = [Weapon Count per A/C] x [Number of A/C])



AERIAL REFUELLING TANKER GAP

(Number of tankers to offset F-111 loss disregarding DCA/OCA CAP needs)

(left) The Department of Defence deserves the greatest of accolades for sheer salesmanship, given what has been successfully put to Federal Cabinet in the JSF and early F-111 retirement schemes. This set of three charts illustrates the enormity of what the Department is aiming to do with the RAAF over the coming two decades. The first is Throw Weight, a measure used in arms control negotation, for the existing, the gap period and the final RAAF strength, assuming 100 JSFs – if less are bought the chart must be adjusted proportionately. The second shows firepower measured by the aggregate number of weapons which can be lifted by the RAAF combat fleet. The final chart shows tanker needs to match the existing RAAF capability in the mixed F/A-18A and F-111 fleet. All charts assume that F/A-18A or JSF can be committed without fighter escort CAPs. It is clear that the JSF as planned for represents a significant capability reduction were the F-111 retained until 2020. Current plans for aerial refuelling sit at about 25% of the numbers needed just to cover existing capabilities. Charts based on LM, Boeing and GD data. (Author)

we apply throw weight to compare future plans against current capability, excluding tankers, post F-111 we get a circa 62.5% reduction in throw weight, once 100 JSFs are online we get a circa 37.5% reduction.

Adding in the trivial number of five tankers lifts this to a 52% reduction post F-111 and post JSF around a 29% reduction. Factoring in a pessimistic assumption that the F-111 achieves at best 75% of the uptime of the F/A-18A alters the results very little. Yet again you can't beat the laws of physics.

It follows that the assertion of "no strike capability gap existing post F-111" is not supportable by fact. At best a fraction of the F-111's capability can be replaced, and doing so by diverting F/A-18As away from air defence tasks. The AP-3C armed with a standoff weapon is for all practical purposes unusuable in the regional environment – unless Australia intends to shoot stealthy JASSMs at Fiji or Vanuatu. The AP-3C is an excellent maritime patrol platform, but a strike platform it's not.

Removing around 50 percent of the RAAF's striking power cannot be explained away by any amount of well crafted language.

Given that Indonesia is likely to end up with something between 16 and 50 Su-27/30s by the end of the decade, the prospects are that the region will approach effective parity with Australia in strike capability once the F-111 is gone. The JSF will provide only an incremental improvement over an equivalent number of F/A-18As, and at least 130 JSFs would be required to match the raw firepower of the RAAF's current F-111/F/A-18 force mix.

With the prospect now of the US Air Force cutting JSF numbers to pay for more F/A-22s, the resulting cost impact is likely to drive down the number of JSFs the RAAF could acquire and thus the intended 100 JSFs are unlikely to fit into the currently planned budget. If the basic cost of the JSF creeps up this will be exacerbated. The use of smaller fighters supported by tankers typically costs 60 to 80% more in raw operational expenses, compared to the use of the F-111 for the same tasks, further driving up operational costs longer term.

An RAAF with a combat arm of 70 JSFs is in basic strategic effect marginally better than an RAAF with 72 F/A-18As.

THE AGE AND COST ARGUMENTS AGAINST THE F-111

CAF's statement referred to the "increasing fragility of our F-111 capability", the aircraft's age and "studies [which] suggest that beyond 2010 it will be a very high cost platform to maintain and there's also a risk of losing the capability altogether through ageing aircraft factors".

But these assertions are open to question as publicly available information on the F-111 and comparable overseas programs suggests.

The US Air Force fielded the B-52H in 1961 and intends to fly it until 2040, the planned withdrawal date for the last KC-135R/T tankers deployed during the mid 1960s. The B-1B was fielded in 1985 and is also expected to fly until 2040. The B-52H remains the cheapest to operate of the three US heavy bombers, and it is a much larger, more complex and older aircraft (by at least five years, or a decade in service years) than the F-111 is.

The argument that the operating costs of the F-111 will increase significantly over the coming decade runs contrary to what has been observed at Amberley since Boeing took over the F-111 depot, it runs contrary to US experience, and it runs contrary to the mathematics of basic reliability theory – every time an old component is replaced with new, reliability improves, running cost is reduced and service life is extended.

These incongruities run deeper as the Department of Defence has never kept the type of detailed component level failure rate statistics needed to develop a reliability model based projection of long term F-111 support costs – a mathematical model which tracks wearout 'bell curves' for each component or subsystem and which is used to produce a 'bathtub' curve for the aircraft. Therefore any assertions that the aircraft is in terminal wearout is not based on hard engineering facts.

Last year's Hansard is most revealing – DSTO's preliminary F-111 Sole Operator Program findings cited by the former Vice Chief of the Defence Force are that the F-111 structure and TF30 engines can be managed to 2020 with no difficulties. With around 200 mothballed AMARC F-111s there is an ample supply of spare bits to work with – many of these mothballed aircraft have less than 3000 hours of airframe time. As a refurbished set of AMARC wings can be swapped in three days, the RAAF could swap wings to extend fatigue life for decades to come. During the 1980s the US Air Force even swapped the Wing Carry Through Box on damaged F-111s – it is regarded to be the single most critical structural part after the wings.

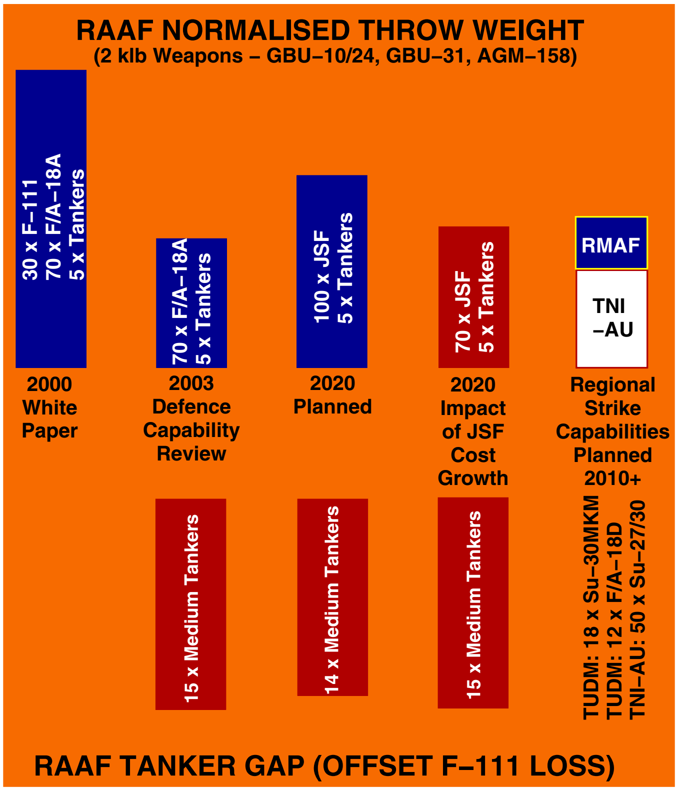
As structures are not the critical cost driving long term issue for the F-111, avionics, wiring and engines remain as the other key hotspots in older aircraft. Most of the wiring and core avionics in the F-111C and G were replaced in the AUP and AMP upgrades respectively, and later block upgrades. The idea that this quite new hardware will incur unusual cost growth over the next two decades doesn't stand up.

In terms of engines, the RAAF acquired all remaining P109 series engines from the retired USAF F-111D fleet, and could further acquire 77 shipsets of mothballed F-111F engines, and now also the TF30 engine stocks remaining from the US Navy F-14A fleet. The total pool of TF30 engines could last for decades. DSTO have stated that the existing pool of engines, with DSTO devised durability fixes, will last at least until 2020.

What is not well known in Australia is that General Electric initiated design work on adapting the F110 retrofit kit for the F-14B/D to the F-111 during the early 1990s. In principle, an F-111 retrofit with high thrust low maintenance F110 engines common to the massive F-16C/D fleet is a low risk low cost conversion. With an engine retrofit the F-111 can have a propulsion package supportable well past 2030 – using the F110, or later engine.

Recently published reliability analysis cost studies performed in the US indicate that the cost of engine maintenance dominates operating costs for all older aircraft. The F-111 cannot be any different, as it obeys the same laws of physics as its contemporary types in service.

Prior to details of the new Defence Capability Plan was released, Defence originally plan was to put JASSMs (or similar) on the F-111 since it can truck four of them rather than the F/A-18A's two, without tanker support. JASSM provides survivability for any platform which shoots it, so the question should be, what platform makes for the most dollar efficient means of carrying X JASSMs to the launch point?



This chart compares throw weight and tanker demand over time, and compares the former to current regional strike force plans. If the regional operators and Department of Defence both get what they have asked for, by the middle of the next decade the region will have defacto parity with the RAAF in strike capabilities. (Author)

The only potential issues longer term are the remaining original analog avionics – the steamgauge cockpit, analog radar and some boxes inside the Pave Tack. The overseas approach remains to replace such subsystems with new hardware and realise a net saving in total ownership costs usually within a decade – the plethora of recent glass cockpit, FLIR module, laser and radar retrofits seen in the US and Europe speaks for itself. Australian industry put forth unsolicited proposals for such cost saving F-111 maintainability upgrades two years ago – in compliance with former minister Reith's policy directives and the subsequent Defence Capability Systems Life Cycle Management Guide – but did not receive any responses from the Defence Department.

What must raise serious questions is the sudden turnaround in F-111 availability and reliability since Boeing took over the Amberley depot operation, and with Amberley F-111 SPO and DSTO Melbourne support launched an ageing aircraft engineering program. During last year's Red Flag exercise the F-111s were more reliable than all of the newer types at the exercise – a clear indication that significant effect was being achieved.

Historically such dramatic changes in aircraft availability are symptomatic of poor prior maintenance technique and planning being replaced with proper technique and planning. Events like the near loss of A8-112 due to the retention of 1960s cabling in a fuel tank, the tragic deseal/reseal saga, and the need for a fleetwide wing replacement program raise serious questions about the whole regime of F-111 support prior to the full commercialisation of the depot.

Of no less concern are assertions concerning the age of the F-111 and the risk of "loss of capability", essentially that some unsolvable structural fatigue problem will be found which cannot be easily fixed – engine and avionics problems by definition do not fall into this category. Given that the F-111 is one of the few aircraft which can be mostly

DSTO's preliminary F-111 Sole Operator Program findings cited by the former Vice Chief of the Defence Force are that the F-111 structure and TF30 engines can be managed to 2020 with no difficulties.

dismantled by hand tools, this is an extraordinary assertion by any measure.

The F-111 is arguably the structurally safest aircraft in ADF service and due to ongoing structural Cold Proof Load Testing the only ADF airframe where the primary structural integrity can be demonstrated to be safe. The F-111 fleet has considerably more remaining airframe structural fatigue life than the Hornet fleet does – if structural fatigue were the driving issue the Hornets would have to be retired first. While most contemporary fighters are built for a 6000 hour fatigue life, the F-111 was built for 10,000 hours, and that figure is driven by wing fatigue life.

The F-111 airframe was designed during the 1960s to be 85 percent common for both the land based air force variants and the catapult launched arrestor recovered naval F-111B variant. While the F-111B never made it to production, the land based F-111s inherited a heavily overbuilt, and slightly overweight, common structural design. So tough is this airframe that several aircraft seriously damaged in landing and takeoff accidents were rebuilt under the 'FrankenVark' program and continued in operational use. The RAAF's A8-112 flew home after a fuel tank explosion which would have torn a lesser aircraft to pieces – the explosion itself a consequence of another maintenance planning failure.

The principal fatigue issue in the F-111 has always been the wings, primarily the D6AC steel Wing Pivot Fitting (WPF) at the wing root. The often maligned Wing Centre Carry Through Box (WCTB) has had very few problems statistically, and a number of US Air Force F-111s had their WCTBs replaced. DSTO Melbourne regarded the WPF as a priority and during the SOP devised a modification which arguably 'fatigue-proofs' this critical component.

The RAAF's much publicised wing replacement program resulted from a confluence of historical gaps in the fatigue analysis of the FB-111A/F-111C 'long' wing and delays in analysing fatigue test articles in Australia – largely attributable to poor planning. With the wingtip extensions fitted – all F-111 wings are otherwise identical – the different stress distribution reduces the life of the 'long' wing against the 'short' wing.

With perhaps 90 percent or more of the key fatigue limited components in the F-111 airframe concentrated in the wings, the fatigue life of the current RAAF fleet can be extended by wing swaps for as long as surplus wings remain in AMARC mothballs – with 200 airframes many under 3000 hours of time this is a lot of fatigue life. Indeed, one F-111D went into the smelter with around 2500 hours of airframe time – a mere quarter of its design life. Additional hours can be added to F-111 wings by reskinning, fastener reworking and selective component replacement, as done with the B-52H, C-5B, KC-135, 707 and planned for the B-1B. Other key structural components such as undercarriage sets, wheels or WCTBs are available in abundance in AMARC.

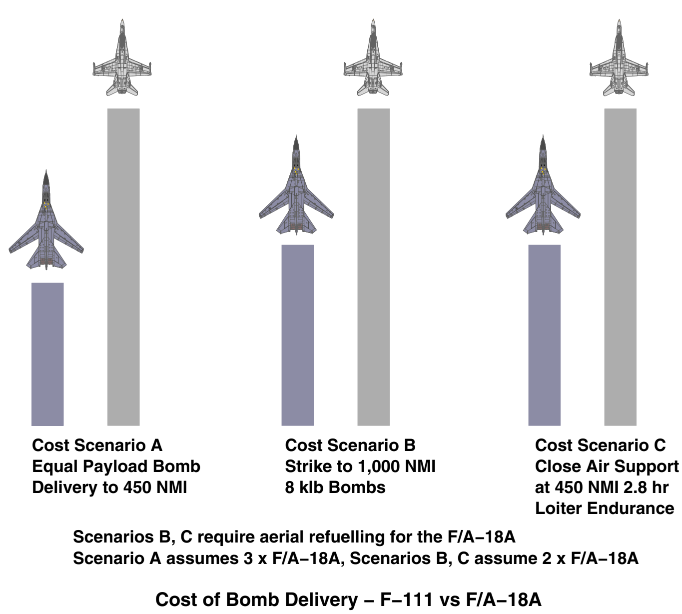
The F-111's aluminium honeycomb sandwich skins can be arbitrarily replaced with more durable and tougher carbonfibre composite replacements, using a DSTO devised reverse engineering technique.

There are no obvious engineering reasons why the F-111 cannot be life-extended into the 2030-2040 period, like the US Air Force B-52H and B-1Bs – both programmed for use until 2040, using small block retrofits during scheduled downtime.

The arguments put forth by Defence on both costs and risks of fatigue related catastrophic failure are paper thin at best, and essentially speculative. They are in engineering and strategic planning terms little more than guesswork, not supported by hard engineering analysis like we see in the US.

This analyst (and formerly reliability engineer) has previously challenged the Defence Department to provide a publicly available, comprehensive Mil-Std-756 compliant reliability and wearout analysis of the F-111, using hard statistical data at a component and subsystem level. An analysis without 'estimates' and 'projections'. The Defence Department did not respond to this challenge.

The argument that the F-111 is expensive is simply bunk. This diagram compares the operational cost of doing a task with a single F-111 against the use of F/A-18As, supported by tankers in the latter two scenarios. While each F/A-18A is about 30% cheaper, the need to use larger numbers and supporting tankers drives the costs of the Hornet up significantly over the F-111. The idea that 'small fighters with tankers are cheaper' is a deceptive fallacy. (Author)



How Survivable is the F-111?

Claims that 'the F-111 is no longer survivable' are demonstrably nonsense.

Given the weapons and systems upgrades until recently planned for the F-111, and the proposed alternatives in the F/A-18A and AP-3C, a converted 1950s airliner airframe, the opposite holds true.

A good sanity check is comparing the until recently planned JASSM armed F-111 against the proposed alternatives, JASSM armed F/A-18As and AP-3Cs, for likely regional air defence capabilities.

With well over 150nm (280km) of standoff range the JASSM essentially defeats all existing SAM systems, as the missile can be fired from below the radar horizon of the SAM acquisition and engagement radars. Therefore the principal threat to any JASSM shooter in this region will be prowling patrols of Su-30s (AA Aug/Sept 03).

The Sukhoi will rely on its large N011/N011M radar to perform sweeps of the expected threat sector, the CAP station being positioned between the defended area and anticipated threat sector. If the JASSM is fired from inside the Sukhoi's detection footprint and the Sukhoi can acquire the JASSM shooter, the issue is then one of whether the Sukhoi can effectively prosecute an engagement and achieve a kill.

For an unescorted JASSM shooter the best strategy will be to turn tail once the JASSM is fired and gain as much separation from the Sukhoi as possible, as early as possible, and use a trackbreaking jammer to disrupt the N011M. At the limits of N011M detection range, adding a reasonable number of miles quickly enough could cause the radar to lose the track, if not increasing distance affords an increasing advantage in Jam/Signal ratio.

The AP-3C has little hope – its speed is inadequate, and its large radar signature makes effective jamming difficult. At long ranges the F/A-18A will not have the spare gas to engage the Sukhoi, and since it is slower the Sukhoi will close the gap fairly quickly. The game is then whether the F/A-18A's jammers are good enough or the Sukhoi runs out of gas soon enough.

In this engagement scenario the F-111 is more survivable since it can sustain a much higher egress speed much longer than the F/A-18A, and its new Elta 8222 jammer is regarded to be the most capable in the Pacrim region.

This scenario is academic insofar as in the real world JASSM shooting F-111s (or F/A-18As) would be escorted by a tanker supported F/A-18A CAP intended to keep the Sukhois away. The US will escort the B-52H, the B-1B and even the B-2A in environments where a fighter threat exists. Asserting that the F-111 is not survivable when escorted is a non-sequitur. The F-111's speed minimises its exposure time to the Sukhoi and thus minimises the odds of detection and engagement, and the odds of the Sukhoi closing in to effect a successful missile shot, escorted or unescorted, compared to the F/A-18A.

Where the threat is a double digit SAM system (AA Oct/Nov 03) and the target is to be engaged using guided bombs, such as the Paveway, JDAM or HdH winged JDAM-ER, the contest between the F/A-18A and F-111 also favours the F-111. Assuming equally good defensive jammers on both aircraft, the key factors are speed and how low the aircraft can fly to the bomb release point. The F-111's terrain following radar and much higher low level speed give it a decisive survivability advantage over the F/A-18A in this scenario. Once the winged JDAM-ER is deployed, this scenario also becomes academic, since the weapon can be tossed from low level from well below the radar horizon of the threat SAM systems. For many SAM types the range of the winged JDAM-ER will permit drops from cruise altitude. Yet again asserting that the F-111 is not survivable compared to an F/A-18A is a non-sequitur – the opposite applies.

If Defence is constructively concerned about F-111 survivability and not simply concocting lame justifications for an internal budgetary politics driven decision to downsize the RAAF, then many alternatives exist to further improve upon the F-111's existing strengths. Options include introducing the EF-111A Raven, fitting the F-111 with AGM-88 HARM missiles, an AESA radar with TFR modes and AMRAAM guidance capabilities, an advanced optical fibre fed internal active jamming system, and radar signature reduction of the engine inlets and radar bay – all the subject of unsolicited industry proposals submitted over the last two years. Many affordable low risk options exist to ensure that the F-111 remains the most survivable strike platform in this region.

CONCLUSIONS

The arguments put forth to justify the early retirement of the F-111, and the arguments asserting that no strike capability gap will exist, are difficult to support by hard facts. It is unfortunate that Cabinet agreed to the early retirement proposal, as a policy change now presents a public embarrassment to the Federal Government – even if the responsibility for this situation rests squarely with the Department of Defence bureaucracy.

Delayed F-111 retirement increases budgetary flexibility for a future government by spreading the replacement expense over a longer period. Evidently budgetary flexibility was not a factor. Given the evident weakness of the strategic, cost and airframe life arguments against the F-111, the root cause of the drive to early retirement clearly lies elsewhere.

The long history of public embarrassments resulting from F-111 management, maintenance and planning blunders in the bureaucracy is without doubt the key factor which led to this situation. The early retirement of a number of key senior Air Force officers post 2000, all advocates of the F-111, left the aircraft without any champions in the upper ranks of the ADF and highly vulnerable to bureaucratic attack.

The strategic consequences of this decision, if followed through with, will be profound as Australia's strike capability dips to parity with other regional nations. The Amberley WSBU (Weapons Systems Business Unit) with its unique systems integration capability will wither away, damaging the industrial base possibly irreparably. Australia's credibility with the US will take a serious hit, as the US Air Force will have to beef up PacRim assets to offset a 50 percent reduction in effective RAAF combat strength, likely to persist with the introduction of the second tier JSF.

The RAAF is now well on track to becoming a strategically irrelevant force suited primarily for second tier support roles and with a very limited capability for independent combat operations. In a period of increasing strategic risk across the region and globally, this is not a path Australia can afford to take.

What do you think of the F-111's retirement?

Australian Aviation ***invites your letters to the editor on this very important defence debate.***

by Dr Carlo Kopp, PEng

RAAF Aerial Refuelling Where To Next?

This year will see a decision to purchase aerial refuelling tankers as replacements for the RAAF's four decidedly aged Boeing 707-338C tankers.

While senior defence personnel have made much of the value of project Air 5402 in various public comments of late, particularly in reference to new tanker's ability to help bridge the gap following the early retirement of the F-111, the reality is that aerial refuelling will remain as perhaps the greatest single capability gap in the RAAF force structure. With the now stated intent to retire early the long range/long endurance F-111s without replacement, Defence's lack of serious investment in an operational aerial refuelling capability is perplexing – it raises genuine concerns about the future of air power in Australia.

On the global scene we are seeing the initial steps in what is termed the 'recapitalisation' of aerial refuelling fleets in leading western air forces. The US Air Force has taken the first step with its plan to lease 100 KC-767A tankers as interim replacements for the oldest KC-135Es, a plan subsequently bent into a split hire/purchase deal by legislators unhappy with the leasing model (but currently on hold due to a US DoD investigation into ethics at Boeing). Britain is looking at a large scale replacement of its fleet of well used VC10s and TriStars, while Italy and Japan have ordered KC-767 variants to rebuild their force structures. These developments are taking place during a period of a significant downturn in airline activity, and an unprecedented glut in cheap used airliner airframes, which even the growing air freight market cannot absorb.

The Iraq campaign of March 2003, was a somewhat rude surprise for all western air forces, insofar as the shift to persistent strike operations, often termed 'killbox interdiction', saw the demand for aerial refuelling soar well above any previous air campaign. Typical fighter sortie lengths grew from two to four hours during the Cold War era to much longer six to 12 hour sorties. In turn, the demand for tanking almost doubled – clearly evident in the CENTAF report statistics published after the campaign. The rule of thumb ratios for fighter to tanker numbers in force structures were effectively halved. In campaigns where persistent strike against mobile targets dominates operations, typically one KC-135R sized tanker is required to support two to three fighters in combat.

Regionally, we are seeing 800nm (1480km) class Su-30 fighters being purchased in respectable numbers by Malaysia, Indonesia, India and China, most of these aircraft are equipped with retractable aerial refuelling probes. India has taken the lead in regional tanker acquisitions, with the de-

The four Boeing 707-338C tankers were acquired to provide a `training and limited operational capability'. The planned replacement fleet of similar sized 767 or A330 aircraft will provide only an incremental gain in total fleet fuel offload capability, yet is now seen to be a full operational capability. (RAAF)

The regional strategic environment is shifting, with the first Ilyushin Il-78MKI Midas tankers delivered to the Indian Air Force. India has been the 'trend setter' for Asian buys of Russian equipment, and we can expect a series of copycat regional buys over the coming decade, as observed with Su-30s and AEW&C aircraft. (Indian Air Force)

livery of its first batch of Ilyushin Il-78MKI Midas tankers from Russia. Historically China has followed India by acquiring like Russian aircraft to match capabilities, and the saga of regional 'me too' Sukhoi and A-50 AEW&C buys indicates that more Ilyushins are likely to appear across the region over the coming decade. The only constraint to regional growth in fighter, AEW&C and tanker numbers will be funding.

In the face of these global and regional developments, Defence's adherence to buying just four or five tankers is peculiar, but not surprising given the arguments put forth to support the case for RAAF combat fleet downsizing by early F-111 retirement. What is clear is that the current plan for the RAAF will see it progressively sink in relative force capability against the region.

How Many Tankers are Enough?

A question recently raised by a Parliamentary Committee in Canberra, and not answered by the Defence attendees on the day, is that of how many tanker aircraft the RAAF should be operating. This issue has been argued repeatedly, sadly to no avail given statements emanating from the Department in recent years. Evidently four to five tankers is the 'correct' number and the surrounding strategic environment must be made to fit this number.

How should we best estimate what number, and indeed what size of tanker aircraft the RAAF should be operating? Several models can be applied, and not surprisingly, none of these models say four to five medium sized aircraft.

The baseline for most force structure sizing models is the basic 'medium size' tanker typified by the Boeing KC-135R. The aircraft has a design payload just under 40 tonnes, and is essentially a dedicated narrowbody 'fast tanker'.

Rule of thumb sizing models are valuable since they are derived from gross air campaign statistics. Therefore they factor in the realities of aerial warfare – fighters burning more gas than planned for, fighters arriving late on station, tankers being diverted to cover unplanned for offload demands, airborne 'hot spare' tankers and the reality of chaos in the battlespace, whereby unanticipated enemy actions force unplanned changes to operations with all of the consequences this has for operational planning.

Not surprisingly, taking a set of fuel offload curves for a tanker and cruise fuel burn figures for a fighter always yield optimistic numbers against the rule of thumb estimate. This will become apparent to any observer who performs operational analysis modelling of tanker demand – the basic analytical method sets a lower bound on demand.

Prior to the advent of the persistent strike techniques, the gross statistics available from Desert Storm and Allied Force indicated that a single medium sized tanker was required to support four fighters, regardless of fighter type. This should not come as a big surprise since the cruise fuel burn of most fighters averages out around 2.7 tonnes (6000lb)/hr – dominated by drag, the additional external tanks carried by small fighters tend to drive their fuel burn up into the same bracket as the F-15 and Su-27/30 series – or indeed the F-111. The statistics for Allied Force were most interesting as the ratio was almost exactly 4:1, and this campaign saw limited refuelling of heavy aircraft as the ranges to targets from European NATO bases were very modest.

Applying this metric to the current RAAF force structure with around 100 combat aircraft, we end up with about two squadrons of 12 to 13 KC-135R sized tankers. This is not an unreasonable number insofar as it accords well with the results of offload simulations performed in 1999 to establish how many tankers were required to cover regional targets from northern Australia, using a strike force of around 60 aircraft – and with no persistence over the target.

The CENTAF report detailing statistics from Operation Iraqi Freedom graphically illustrates the growing demand for aerial refuelling which results from persistence over the battlespace. Crunching these numbers down shows a ratio closer to 2.5:1 between fighters and tankers. The doubling of typical fighter sortie durations, with most fighters loitering with draggy payloads of bombs, accords well with the gross statistics. Twice as much time on station demands twice as much offload from the available tankers. Unlike the 'classical' model during which fighters spend roughly equal time outbound and inbound to targets, burning more fuel due to stores drag outbound, the current persistent strike model sees perhaps 2/3 to 3/4 of the fighter sortie duration spent in a higher fuel burn regime due to loiter with yet to be expended stores.

Applying this raw metric to the current RAAF force structure model indicates that around 40 tankers would be required – or three overstrength squadrons each with 14 tankers. The implicit assumption is that all RAAF fighters would be applied to combat ops, and all would be flown in a persistent regime of operations. In practice, such persistent strike operations would only be localised, so the actual ratio would fall in between two and three squadrons.

The statistics from recent US led campaigns are directly applicable to Australia's strategic environment as the key factor – distance between basing and targets – is similar. The statistical distribution of distances from Darwin/Tindal to major regional airfields shows peaks at 1200 and 2200nm (4075km). While Learmonth provides a useful range advantage into the region, against Darwin/Tindal, its remoteness currently presents issues for resupply of fuel and other stores in sustaining high intensity operations.

The RAAF is now well on track to a force structure of 70 combat aircraft rather than 100 – the prospects are very good that the removal of the F-111 will see the future JSF fleet buy numbers adjusted down to match then current fleet numbers. If we scale down the number of tankers required, what we get is between 17.5 and 28 medium sized tankers.

What other models can we apply to estimating a proper size for the RAAF's tanker fleet?

If we look at putting up a strike package to 2000nm (3700km), with 24 F/A-18A or JSF aircraft (12 bombers, six strike escorts, and six to cover the Wedgetails and tankers), using tanker offload curves we end up with around seven tankers including an airborne 'hot spare' and no allowance for on station loiter. Two packages drives this up to 14 tankers. If we want to maintain a reserve of tankers at Darwin/Tindal and Learmonth to support defensive fighter CAPs at these bases, on demand only, we end up with at least four more tankers, as a spare will be required at each of these bases. The total comes in at 18 tankers. If we plan around having defensive CAPs airborne at Learmonth and Darwin/Tindal, or any significant loiter over the target, then we can start adding additional tankers into the model.

It takes very little to show that the rule of thumb tanker fleet sizing models hold up quite well against a basic operational analysis model using hard numbers for tanker offload performance and fighter cruise fuel burn. If we relax the striking radius distance numbers, and add commensurate loiter time over the target, the numbers change very little.

Can we apply scenarios other than strike operations into the region? One example scenario is placing continuous fighter patrols over the North West Shelf, Timor Sea and Darwin/Tindal areas to defend against a cruise missile strike. While JORN will provide excellent early warning of an outbound strike performed with fighters/bombers carrying cruise missiles, it cannot warn effectively against submarine launched cruise missiles. Even with JORN early warning, the reality is that successful intercepts will require early engagement of inbound cruise missile shooters – launching interceptors, Wedgetails and tankers on initial early warning becomes a race against time to get to the inbound shooter before it can release its missiles.

If we take 1000nm (1850km) as the baseline distance for this 'high noon' cruise missile shooting/interception game, the interceptor/AEW&C/tanker package travelling at similar speed to a Sukhoi Su-30 heading in the opposite direction needs to launch at exactly the same time to meet in the middle. Since targets of interest such as gas/oil platforms and onshore processing plants sit in between Learmonth/Darwin/Tindal and regional airbases, and there will be an implicit delay in identifying a JORN track as an inbound shooter, the reality is that standing airborne CAPs will be required. Lets assume the CAP orbits around 450nm (830km) out from an RAAF runway, and let's assume four hours on station and two hours for transit. Four fighters and a medium sized tanker will together burn around 16.3 tonnes (36,000lb)/hr on station, in four hours burning off around 65 tonnes) (144,000lb) of fuel – leaving a typical medium sized tanker with about nine to 14.5 tonnes (20,000 to 32,000lb) of spare gas to cover for combat burn by fighters.

To do this will require at least three tankers per CAP station – one spare on the ground and two swapping stations to support the CAP. In practice the three tankers would be continuously rotated through the CAP station. If we assume three CAP stations to cover the three most target rich sectors in the deep north, we end up with a bare bones minimum of nine tankers. Upping the size of the CAPs scales tanker numbers proportionately – CAPs of eight fighters each pushes tanker numbers up to 18 aircraft. If the RAAF is to concurrently fly any long range strikes of useful magnitude, the numbers again push out to 24 or more tanker aircraft.

Another scenario which is not unreasonable is the US 'Noble Eagle' model of providing CAP cover over major cities to defend against hijacked kamikaze airliners. While the risk of a domestic hijacking is relatively low due to good security in Australia, the same is hardly true of regional nations. Therefore a September 11 event in Australia is not outside the bounds of possibility.

Assuming that an airliner is hijacked and flown south to hit a target in Australia, there is a finite time window for an intercept determined by the fuel payload of the hijacked aircraft. This indicates that CAPs need only be airborne for several hours. However, if we make the assumption that all capitals need to be covered, and one each spare tanker is kept on the ground, the baseline number ends up being yet again of the order of 15 tanker aircraft.

The F-111 has in many respects been a critical asset for the RAAF as strike profiles to 1000nm (1850km) would see tanking used primarily by the F/A-18A escorts supporting the aircraft. Analysis (refer Jan/Feb AA) indicates that removing the F-111 from the force structure requires of the order of 15 tankers alone to make up the difference in aggregate fleet payload/radius performance, or 'throw weight'. It is worth noting that using the F-111 (which can carry the AIM-9 Sidewinder) rather than the F/A-18A in the 'Noble Eagle' model permits defensive CAPs to be flown without tanker support.

What is the impact of tanker size in this equation? The two current Air 5402 candidates, the KC-767 and A330-MRTT, are both medium sized tankers, the 767 providing around 10% more offload than the KC-135R, and the A330 around 20% more, making reasonable assumptions about the profile. The only other credible current production widebody airframe with a prior tanker conversion design is the 747-400, which comes in at around twice the offload of the medium class tankers, or more with lower deck auxiliary fuel. With around twice the cruise fuel burn of the medium class candidates, the 747-400 would roughly halve crew and airframe numbers to meet the same offload requirements.

In the balance, the faster and larger 747-400 works better for scenarios biased toward long range strike profiles, whereas the smaller and slower 767/A330 options work better for scenarios biased toward the 400-500nm (740-925km) CAP station orbit model. This is because the 747-400 has more gas to offload at long range, and its higher cruise

By far the best bang for buck offering in the used airliner market, Special Freighter conversions of used 747-400 passenger transports are now selling in the $US50 to 60m price bracket. A tanker conversion of the 747-400 using either the KC-767A or A330 MRTT refuelling packages could deliver more than twice the offload of the twin engine bids.(Boeing)

The A330 MRTT (above) and KC-767A (below) are conversions of the current late production variants of the A330 and 767 commercial airliners. With a range of configurations possible, including booms, fuselage hose drum units, and wing mounted pods, these aircraft are direct equivalents to the established KC-135R/T Stratotankers. While slower than the KC-135R, the newer widebodies are much more capable in the supplementary airlift role, and cheaper to operate with only two engines. While the Boeing offering has the advantage of a much more mature aerial refuelling package design, the Airbus offering can offload slightly more fuel, runways permitting. (EADS & Boeing)

speed does not impose speed restrictions on a strike package – the slowest aircraft in a package limiting its transit speed. As a result slower tankers on long range profiles keep the whole package airborne longer, which statistically impairs force productivity. In shorter ranging scenarios with smaller numbers of fighters, the higher fuel burn of the 747-400 favours the smaller tankers.

What does this all tell us? No matter what models we apply, it is clear that four to five medium sized tankers is not enough, and is not supportable by any type of analysis. It covers perhaps 20% of what would be required in any 'real world' defence of Australia scenario.

Tellingly, the Defence Materiel Organisation's website tacitly admits that the tanker project does not aim to purchase enough tankers to meet the number that would be required for real operational scenarios. "Since the early 1990s, the Royal Australian Air Force (RAAF) has operated four Boeing 707s as tanker aircraft to provide *a training and limited operational capability*," says the website's brief on Air 5402. "The aircraft were modified for air to air refuelling under Project Air 5080 by fitting two wing-tip mounted refuelling pods to refuel probe equipped aircraft such as the F/A-18. Due to issues associated with continuing to support the ageing B707 fleet, Air 5402 seeks to *replace and enhance* the air to air refuelling capabilities of the Australian Defence Force (ADF)."

So Air 5402 only aims to "replace and enhance" the RAAF's current "training and limited operational capability".

Assessing Air 5402

Air 5402 has had a long and somewhat convoluted history. Initiated during the late 1990s, the program started out essentially as a tradeoff study between the choice of extending and re-engining the existing 707s, or acquiring used 767 or A330 airliners for conversion into tankers. Considerable effort and investment was made into these studies in the 1998 to 2000 period. Part of this study included a survey of ageing aircraft issues, and a detailed corrosion and fatigue study of the 707 fleet (refer AA March/April 2001 – also http://F-111.net/CarloKopp/).

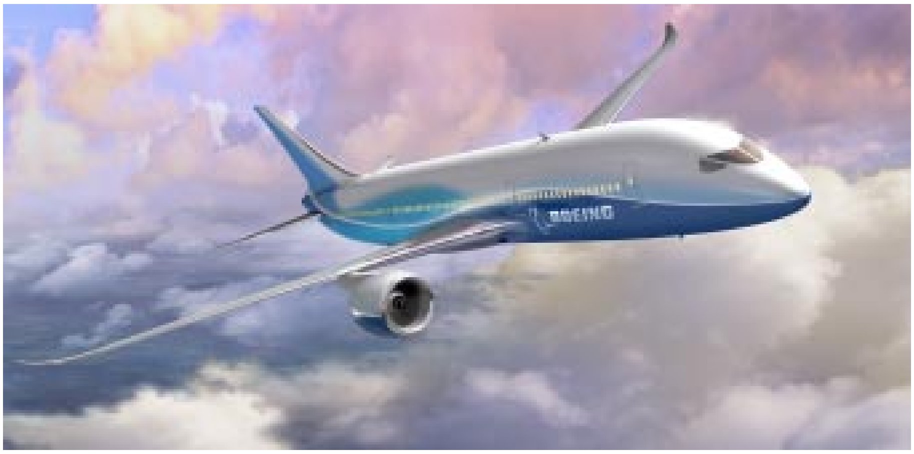
The findings of this effort were most interesting. Used airliners of seven to 10 years of age were identified as being the most economical basis for tanker conversion, compared to new build aircraft. Tankers were typically found to run out of airframe corrosion life well before they ran out of airframe fatigue life, reflecting the relatively low flight hours of tankers against their airline operated siblings. The corrosion problems seen with the US Air Force KC-135 fleet and the RAAF's 707s, while in part attributable to the absence of ageing aircraft programs in their earlier service histories, reflect the reality that airliner class airframes not subjected to the kind of deep overhauls done on tactical airframe tend to get into difficulties at around the 30 to 35 years of airframe age mark. With a proper ageing aircraft program introduced early enough in the life of the airframe, to pre-empt and/or manage corrosion, significantly greater airframe service life could be achieved – evidenced by US Air Force plans to fly B-52H and B-1B bombers into the 2040 timeframe.

The economics of tanker fleet operation are not driven by airframe maintenance alone. Recent studies into ageing aircraft problems carried out in the US by the Air Force and Navy indicate that the single biggest cost factors in older aircraft are engine maintenance costs and obsolescence of unique parts. The US KC-135 fleet rode on the back of the retiring 707 fleet, seeing large numbers of common components and JT3D engines cannibalised. The exhaustion of this pool of cheap spares is in part driving the current plans to replace the JT3D powered KC-135Es. The KC-135 is an interesting case study in that it has spent much of its service life to date feeding off the commercial 707 fleet, which resulted in exceptional economies of scale in spare parts.

After 2001 the Air 5402 program shifted into the acquisition phase, and primary responsibility moved to the Defence Materiel Organisation. During this period Air 5402 changed fundamentally, abandoning the model of buying cheap used airframes for conversion to tankers, and firmly espousing the idea of new or near new build tankers. The two principal contenders are bidding new aircraft. During this period the allocated budget for Air 5402 nearly doubled.

The histories of the US KC-135 and KC-10A raise some very interesting questions about the economics of new build 767 or A330 tankers over their life cycle. We can assume that the RAAF will exploit much of the ageing aircraft expertise gained on the F-111 program and apply this to the new tankers. It is reasonable to surmise these aircraft will remain in service for 40 to 50 years post delivery. At some point, perhaps 20 to 25 years into their life cycle, they would be re-engined to avoid obsolescence and improve operational economics.

Experience in the US with both the 20 year old KC-10 and 40 year old KC-135 suggests that the collapse of the parallel commercial fleets has had a large impact on operating costs, especially due to the rapid increase in the prices of high consumption spares. Commercial airliner fleets typically begin to contract around 15 years after the cessation of production for a type, reflecting largely the economics of operation. This should come as no surprise, as the economies of scale in 'cottage industry' manufacture of consumable spares cannot compete with full scale production operations, unless consumables are ordered in large batches.



Planned as a higher performance successor to the 767, the 7E7 Dreamliner is a much better fit to the tanking role than the 767 is, as it is faster and longer ranging. If the aim of the Air 5402 program is to maximise the longevity of the investment, holding off a few years until a 'KC-7E7' or its Airbus equivalent could be bid makes sense. (Boeing)

Were the 767 and A330 at the beginning of their respective production life cycles, the RAAF could be assured of production lives of 20 to 30 years and commercial fleet lives of around 35 to 45 years. During these parallel tanker and commercial fleet life cycles the RAAF could repeatedly borrow avionics, engine and system upgrades designed for the commercial fleets, at very economical costs. Pushing an engine upgrade into the 25+ years of life period would ensure that the fleet would remain relatively economical to operate past the 40 year mark (as evidenced by the almost 100 CFM56 re-engined DC-8-70 freighters).

However, the 767 in particular is in the twilight of its production life cycle (witness Boeing's decision last year to axe the concurrently developed 757). Boeing's new 7E7 Dreamliner – actually a better design for a medium tanker transport as it is faster, more fuel efficient and more voluminous – is apt to displace the 767 in commercial fleets from the end of this decade. To remain competitive in this niche, Airbus may have little choice other than to replace the A330 early in the next decade with a 7E7 clone, again faster and more fuel efficient than the A330.

As a result the commercial fleets of 767s and A330s are likely to start contracting after 2020-2025, driving up costs for all remaining operators of 767 and A330 fleets. The US Air Force KC-767A build may be the last large block of 767s made. As a result the cost advantages in operating new build KC-767s may drop off quickly in the 2020-2025 period, and A330s five to 10 years later, which would start to nullify the additional investment in new build jets.

The rationale is much better supportable were the basic airframe a new 7E7 or its yet to be defined Airbus equivalent – both would be better tanker airframes than the current Boeing and Airbus offerings. While this would necessitate stretching the 707 fleet a little further, or leasing gap fillers, the cost penalty is trivial against the very long term impact of a repeat tanker fleet replacement cycle in the 2025 timeframe.

Other interesting questions arise from the abundance of used widebody airframes. In November 2003 there were no fewer than 28 747-400s and 69 767s in storage, many of which are late build variants suitable for conversion. Freighter conversions of used 747-400s are now being sold for a mere $US50m-60m, making for a tanker transport at around $US80m to 90m each – compared to the order of magnitude $US100m+ unit cost of new build and much smaller KC-767 and A330 tankers.

Were the original Air 5402 plan to have been followed and used airliners converted to tankers, significantly more aircraft could be bought for the same total investment. While Boeing or EADS would have to forgo profit margin on the new airframes, the odds are this would be made up on aerial refuelling equipment and conversion/refurbishment costs. But this now won't happen as the Department has committed to new build airframes. If bang for buck really mattered in the Defence bureaucracy, used and relatively young 747-400s with over twice the fuel offload each compared to twin engine medium tankers would be at the top of the Air 5402 shopping list.

What is clear is that Air 5402 is not structured around strategic needs for aerial refuelling capacity, or tanker fleet longevity/economics, or even short term acquisition costs.

If maximising fuel offload out of the current budget came first, we would see used 747-400s being bought up and tenders out for conversion of these into tankers, fitting as many systems into the available budget as possible. Were acquisition cost minimisation the aim, then the tender would have been for the conversion of used 767s or A330s into tankers. Were fleet longevity the aim, then Air 5402 delivery would be deferred and the shortlist based on a KC-7E7 and its future Airbus sibling.

Where does this leave the Australian taxpayer? Much less bang for buck will be the direct consequence of the Air 5402 program being implemented in its current form.

An issue which is yet to be addressed in planning for tanker operations is provision of a sustainable fuel supply infrastructure for replenishing our northern bases. A single medium sized tanker will use around 90 or more tonnes of avtur per sortie – at any reasonable intensity of operations hundreds of tonnes would be consumed daily. Attempting to resupply by tanker truck is simply not feasible. While Tindal now has a nearby rail connection, Learmonth (pictured) does not. A future Analysis will explore this issue in further detail.

End of Submission