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.

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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.

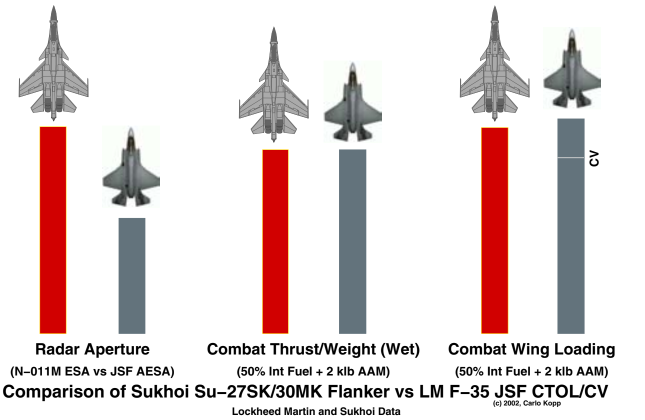
The second important force structure issue flowing from a JSF commitment is the number of Wedgetail AEW&C aircraft required to support the fighter fleet, and arguably the configuration of these aircraft. While the JSF radar is an improvement over the F/A-18A radar, it is much less capable in its detection 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.

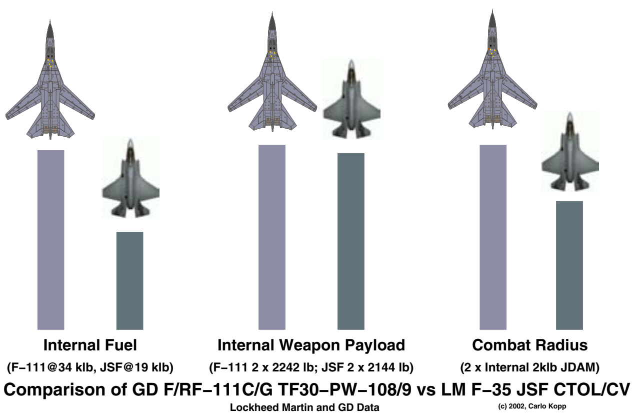
The JSF is a single engine fighter and thus an engine failure can put the pilot into the sea at any point along the flightpath between the operating base and target. In practical terms the result of this is that CSAR assets with the range and capability to penetrate contested airspace and waters will 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 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.

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

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.