

Cruise Missile Options for Australia

by Dr Carlo Kopp



Until recently long term RAAF planning envisaged that the 'Follow-On Stand-Off Weapon' for the F-111 was likely to be a shorter ranging cruise missile class weapon, and the AGM-158 JASSM was named in some reports as the preferred contender.

As of November last year, this plan has been restructured to put the weapon on the F/A-18A and AP-3C instead and later the JSF, with the F-111 retired early. The addition of cruise missile class weapons to the RAAF inventory raises a good number of important issues relating to tactics, force structure and operations.

Three weapons have been shortlisted for AIR 5418, the Boeing AGM-84H/K SLAM-ER, EADS/LFK/Bofors KEPD-350 and the Lockheed Martin AGM-158 JASSM.

Boeing AGM-84H/K SLAM-ER

The SLAM-ER (Stand-off Land Attack Missile – Expanded Response) is the most mature of the contenders, but also the smallest and shortest ranging. It is in service with the US Navy on F/A-18 and S-3s and is being acquired by South Korea for F-15Ks (an F-15E derivative).

SLAM-ER is a development of the AGM-84 Harpoon, the most widely used anti-shiping missile worldwide (including by the RAAF). The air launched AGM-84A entered service during the late 1970s, it was followed by the improved AGM-84C Block 1B in 1982, the AGM-84D Block 1C in 1985, and the first generation AGM-84E Block 1E SLAM (Stand-off Land Attack Missile) in 1990.

While the baseline Harpoons were specialised AN/DSQ-28 radar guided sea skimming anti-ship missiles, the SLAM was primarily a land attack missile, using an entirely new guidance and seeker package, but retaining the Teledyne/CAE J402 turbojet engine, the 221kg (488lb) WDU-18/B blast/frag warhead and the existing airframe.

The SLAM's guidance package uses the thermal imaging WGU-10/B seeker designed for the AGM-65 Maverick, a GPS receiver and the AN/AWW-13 Walleye glidebomb datalink. Launched like a Harpoon, but with programmed waypoints, the SLAM would activate its datalink and transmit the seeker image to the launch aircraft prior to impact, allowing the operator to use datalink commands to adjust the aimpoint.

The limitation of the SLAM was its Harpoon airframe constrained standoff range and warhead size, and limited autonomy. The US Navy initiated the AGM-84H SLAM-ER program during the early nineties, with Initial Operational Capability achieved in 2000.

The 725kg (1600lb) SLAM-ER is the most radical evolution of the Harpoon, with a new pop-out swept wing, larger 360kg (800lb) WDU-40/B penetrating warhead from the Tomahawk Block III, and a revised AN/DSQ-61 guidance/seeker package with a new nose window design. The new guidance added a five channel GPS receiver common to JDAM, a Ring Laser Gyro, an improved datalink with better jam resistance and range, and software enhancements. The latter permitted reprogramming aimpoints in flight and 'search while track' selection of alternate aimpoints without breaking lock. Later blocks of the SLAM-ER include the Automatic Target Acquisition (ATA) function, which allows the weapon to autonomously select an aimpoint using a stored bitmap image. Cited range for the SLAM-ER is in excess of 150nm (280km).

EADS/LFK/Bofors KEPD-350

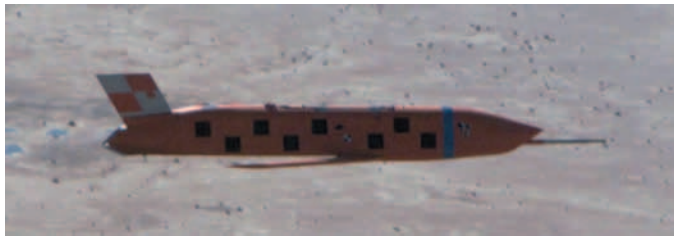
The 1300kg (2800lb) weight class KEPD-350 is the largest and longest ranging of a modular family of powered and unpowered standoff weapons developed in Europe during the 1990s. The glide only DWS-39, AFDS/MW2, rocket boosted DWS-39R/MW-2R, KEPD-50, PDWS 2000 and KEPD-350 all share structural components, warheads, submunitions and guidance elements. The smallest DWS-39, AFDS/MW2, DWS-39R/MW-2R are equivalents to the AGM-158 JSOW, but using stub wings. The larger PDWS-2000 and KEPD-350 use pop-out swept planar wings and a turbojet engine, the latter claimed to provide in excess of 190nm (350km) of standoff range.

The KEPD-350 was designed from the outset as a cruise missile, and a variant was offered to compete against the US JASSM contenders. The airframe has a trapezoidal section centre fuselage containing the fuel tanks and payload dispensers or warhead, with the wing pivots mounted on the upper fuselage. The tapered aft fuselage module with cruciform wings and side mounted inlet scoops is a self contained propulsion/control/guidance package including a Williams International F122-15 turbojet. The nose has provisions for a thermal imaging terminal seeker.

The 'Tri-Tec' guidance package combines a GEM III GPS receiver, a Ring Laser Gyro, and the European TERNAV system for terrain contour matching navigation updates – a similar package to the Tomahawk series. The weapon includes software for optimising terrain following flight to defeat air defences, and autopilot algorithms for pop-up terminal attacks. Earlier this year Israeli manufacturer Tadiran Spectralink won a contract to develop a digital datalink for the weapon, to permit inflight waypoint and aimpoint updates and bomb damage assessment imagery transmission.

Perhaps a unique feature of the KEPD-350 in its class is that it was built for the outset for submunition and penetrating warhead payloads. Submunitions available included the ATM anti-armour mine, the AMS anti-armour bomblet, the ADM area denial mine, the AMS fragmentation bomblet, the radar fused AMS 2 anti-armour bomblet, and the RCB runway cratering bomblet.

The launch customer for the KEPD-350 is Germany's Luftwaffe, who intend to use the weapon initially on the Tornado IDS.



The JASSM (above and title pic) is intended to become the 'standard' US cruise missile, carried by fighters and bombers. A replacement for the cancelled TSSAM, the JASSM is a highly stealthy weapon with excellent range performance. It is to also become the basis of the longer range JASSM-ER, a genuine AGM-86 CALCM replacement for US heavy bombers. (LM & US Air Force)

Lockheed Martin AGM-158 JASSM

The JASSM (Joint Air-to-Surface Standoff Missile) is the intended US multi service tactical cruise missile, intended to arm USAF B-52s, B-1Bs, B-2s, F-15Es and F-16Cs, and likely also USN/USMC F/A-18s. Initiated during the mid 1990s, the JASSM was devised as a cheaper replacement for the cancelled Northrop AGM-137 Tri-Service Standoff Attack Missile (TSSAM) and is often described as 'son of TSSAM'. While the TSSAM was considered technologically exceptional, and arguably the most stealthy vehicle then devised in the US, its high cost was its downfall during the post Cold War downsizing period.

Boeing and Lockheed Martin competed for JASSM, with LM the winner. The JASSM is perhaps unique in that from the outset mass production unit cost was a major issue, with a lower than \$US400,000 (\$A540,000) unit cost being cited, half or less the cost of a typical \$US1m (\$A1.4m) cruise missile or standoff missile. Like the TSSAM, JASSM was designed for high performance stealth.

The 1020kg (2250lb) JASSM uses an unconventional configuration, with a stealthy fuselage, planar swept wings and a single vertical tail. The cited engine is the Teledyne/CAE J402-CA-100 turbojet, providing a range in excess of 200nm (370km) with a 450kg (1000lb) WDU-42/B (J-1000) penetrating warhead. The guidance and seeker package includes an inertial unit, a jam resistant GPS receiver, a datalink, and a thermal imaging terminal seeker, incorporating a similar autonomous pattern matching terminal guidance capability to the ATA in the SLAM-ER.

A 500nm+ (925km+) range AGM-158B JASSM-ER (Extended Range), powered by a more frugal turbofan and carrying extra fuel, is in development as a replacement for the AGM-86C/D Conventional Air Launched Cruise Missile



The KEPD-350 is the latest European weapon in the cruise missile class, a development of a family of powered and unpowered standoff weapons. While lacking the stealth of the JASSM, it has been designed from the outset for submunition and unitary warheads, and has a modern guidance package combining GPS, inertial and TERCOM with a thermal imaging terminal seeker. (EADS)

(CALCM – produced by rebuilding Cold War stocks of the AGM-86B) carried by the B-52H. The JASSM-ER is to first deploy on the B-1B in 2008.

Other proposed upgrades to the JASSM include submunition payloads and a specialised deep penetrating warhead, as well as a Synthetic Aperture Radar imaging all weather seeker. Like the KEPD-350, the JASSM is in low rate early production.

The JASSM is the technologically newest of the three contenders, and by far the stealthiest in its airframe shaping, but also the least mature. Available data suggests it outranges its

The SLAM-ER is the ultimate evolution of the Harpoon, using a Tomahawk derived warhead, GPS/inertial midcourse guidance, and a datalink system for man-in-the-loop terminal guidance, exploiting a nose mounted thermal imaging seeker. The SLAM-ER is the most mature of the FOSOW contenders, but is likely to be supplanted in US Navy service by the JASSM as the latter matures (Boeing).





competitors by a respectable margin. The upcoming JASSM-ER is a genuine AGM-86 substitute, and has the range to defeat airborne fighter defences.

To better appreciate the factors which should be applied to selecting a weapon type and putting it to use, it is necessary to explore the basics in delivery tactics and in operational economics.

Tactical Considerations

Modern air launched land attack cruise missiles are mostly distinguishable in two key performance/capability metrics, which are range performance and stealth performance. Range performance in available western missiles spans the 150 to 600+ nautical mile (275 to 1110+ kilometre) bracket, with stealth performance driven mostly by airframe shaping, at one extreme the Tomahawk/Harpoon derivatives, at the other the JASSM/TSSAM derivatives.

The purpose of all modern cruise missiles is to provide an autonomous precision weapon which provides enough range performance for the launch vehicle to remain outside the footprint of opposing air defences, and to deliver the warhead to the target with reasonable odds of weapon survival. The weapon provides the defence penetration function, as compared to the delivery platform.

The current generation of tactical or shorter ranging weapons, such as the contenders for AIR 5418, are designed to defeat theatre air defences, reflected in their range performance. This is distinct from the larger and longer ranging AGM-86 ALCM/CALCM, designed to penetrate strategic air defences in depth.

The established technique for cruise missile strikes is to choose a release point for the weapons which presents as much difficulty for an opponent as possible, launch as many weapons as may be

required, usually budgeting multiple rounds per aimpoint to account for weapon survivability and reliability, and then rapidly egress while the weapons converge on their targets. The tactical issues thus break down into delivery platform tactics and missile penetration tactics.

Delivery platform tactics should aim to maximise platform survivability, but also to achieve surprise. It should come as no surprise that B-52 cruise missile strikes typically involve low level profile segments as the aircraft nears the opposing air defence perimeter, as this conceals both the B-52 and its missiles below the defender's radar horizon.

In practical terms, the range performance of all AIR 5418 contenders if launched from lower altitudes defeats all surface based air defences, assuming the launch platform does not need to deeply penetrate a landmass to reach its launch point – less likely in an archipelagic and littoral region.

The same is not always true of fighter defences, especially if supported by an AEW&C/AWACS system. Under these conditions, if the AEW&C/AWACS orbit is above the target, and fighter CAPs well positioned, the range of the AIR 5418 contenders may well permit early detection and engagement. In this game, the lower and faster the launch platform can fly to its release point, and the faster it can egress, the better. The F-111 does this much better than either the F/A-18A or the AP-3C does.

If there is any prospect of long range fighter patrols, and especially AEW&C/AWACS support, then fighter escorts are necessary for all three platforms, to draw opposing interceptors away from the launch platforms, and to frustrate attempts to intercept the cruise missiles. Suffice to say the high speed of the F-111 minimises its exposure and thus demands lesser numbers of escorts – the F/A-18A 'self escort'



A pair of F-111s can carry as many JASSM class standoff weapons as far as four tanker supported F/A-18s. (Paul Sadler)

idea is simply not feasible. Faced with fighter threats the cruise missile armed AP-3C idea is crazy.

The range limitations of the AIR 5418 contenders indicate that where opposing AEW&C/AWACS/fighter defences exist, surprise will be lost. Only a missile with range well in excess of 250nm (465km), delivered from low altitude, offers genuine surprise.

Cruise missile penetration tactics are equally so oriented toward survivability and surprise. The basic technique used is missile flightpath routing to bypass defensive SAM/AAA batteries, and to exploit terrain to remain undetected – in effect planning a cruise missile strike profile differs little from planning a direct attack profile using a low level penetrator like an F-111, Tornado, F-15E or B-1B, except that the aircraft is replaced with an expendable missile.

Planning a cruise missile attack properly is a complex task, as the opposing air defences must be carefully mapped out, terrain must be studied, and appropriate ingress headings and waypoints chosen to minimise weapon exposure time to the target's terminal SAM/AAA defences. This can be further complicated in environments with intense GPS jamming, as terrain contour matching (TERCOM/TERPROM) and optical correlator (DSMAC) guidance techniques require overflight of sufficiently complex terrain features to provide good navigational fixes.

In practice this results in cruise missiles often having to fly complex, multi-waypoint, if not circuitous, paths to the their targets. For instance a coastal target might see the missiles cross the coastline 50nm (95km) away from the target, and approach from a heading opposite to the line between the launch platform and target.

This means that range extension is minimised with shorter range weapons such as the AIR 5418 contenders, as up to 50% of the achievable range may be soaked up by flightpath routing to the target. Only RGM-109/AGM-109 Tomahawk, AGM-86 and Kh-55 class weapons can be genuinely relied upon to add significant range.

Cruise missiles are at greatest risk during the terminal dive at the target, as they will usually be directly exposed to terminal defences. SAM systems like the S-300PMU(SA-10)/S-400(SA-20) and S-300V (SA-12) systems were specifically designed to kill cruise missiles, and the Russians have actively marketed the 9M331 Tor (SA-15) for this purpose. The cancelled AGM-137 TSSAM and its replacement AGM-158 JASSM were built for high stealth for exactly this reason. As highly mobile SAM/AAA systems further proliferate in this region, non-stealthy cruise missiles will become increasingly less credible. It is worth noting that the digital datalinks now being sold on cruise missiles with the aim of 'inflight retargeting' may actually prove more useful for 'inflight rerouting' to bypass mobile SAM/AAA batteries.

The tactical issues expose two longer term realities. The first is that AIR 5418 should favour stealth performance and range in the weapon very strongly. The second is that the F-111 is a far better platform for this role than the F/A-18A and AP-3C. A JSF equipped with external cruise missiles inevitably loses much of its stealth advantage, and is thus driven into the low level flight regime where it displays no evident advantages over the F-111 as a cruise missile carrier.

Operational Economics of Cruise Missiles

While tactical considerations are important, the cost of cruise missiles and their targeting and delivery technique are no less important.

Targeting cruise missiles requires the ability to produce high resolution imagery of intended targets which may be hundreds or thousands of nautical miles from the launch aircraft's basing, and may be heavily defended. The US has used primarily satellite imagery for this purpose, a practice we can expect to see regional cruise missile users also pursue.

In principle, any source of high quality targeting information is usable, with the caveat that weapons with TERCOM/TERPROM will also require terrain elevation databases, and weapons with DSMAC-like midcourse or terminal guidance

schemes will demand timely and high quality radar or optical imagery.

Strategic targets such as airfields, naval bases, hardened command posts, communications nodes, fixed or semimobile radars etc can be undemanding in terms of timeliness, but the same is not true of much more mobile battlefield targets, or strategic leadership targets. The latter remains a problem even for the US, in environments where UAVs, U-2s and other atmospheric ISR platforms cannot survive.

Australia without its own ISR satellites will remain dependent on foreign military and commercial imaging satellites, access to which may prove highly politically sensitive in times of crisis. While the intended purchase of high altitude surveillance UAVs (RQ-1/RQ-4 variants) will provide some strategic and tactical ISR capability to support these weapons, issues will arise with their survivability where Su-27/30 fighters are present, and satellite bandwidth of tens of Megabits/sec to support combined optical and radar land imaging will also remain an issue. Availability of robust and timely targeting imagery will remain an issue for the RAAF – threat environments requiring a cruise missile rather than a direct JSF bomb strike are not conducive to the use of the JSF for reconnaissance.

The cost of all current weapons, including the new 'low cost' Tactical Tomahawk and AGM-158 JASSM, still remains of the order of 20 or more times greater than a typical smart bomb, presenting genuine issues with the size of RAAF warstocks and sustainability in combat. Sustained cruise missile bombardments won't be viable for the RAAF, making the AIR 5418 FOSOW a niche weapon for high value and well defended targets. With 450kg (1000lb) class warheads, the AIR 5418 contenders have half the punch of a 900kg (2000lb) smart bomb, driving up required numbers with larger targets.

Longer term we may well see UCAVs armed with JDAMs and SDBs wipe out cruise missiles in the market precisely because the 'reusable cruise missile' regime of UCAV use is economically cheaper to sustain than high rate cruise missile bombardments.

In the near term the economic equation in cruise missile delivery is driven by the overall cost of putting a weapon on to a target, accepting that a high kill probability will require targeting typically two rounds per aimpoint. To cripple a well defended airfield or larger missile battery would require one to two dozen rounds per strike.

The ongoing debate over F-111 retirement has been centred on strikes to a 1000nm (1850km) radius, a 'single point' which conceals the extent of capability loss.

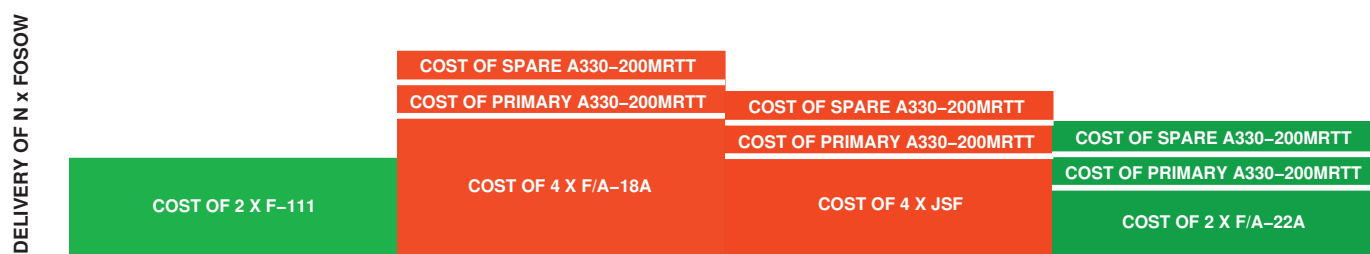
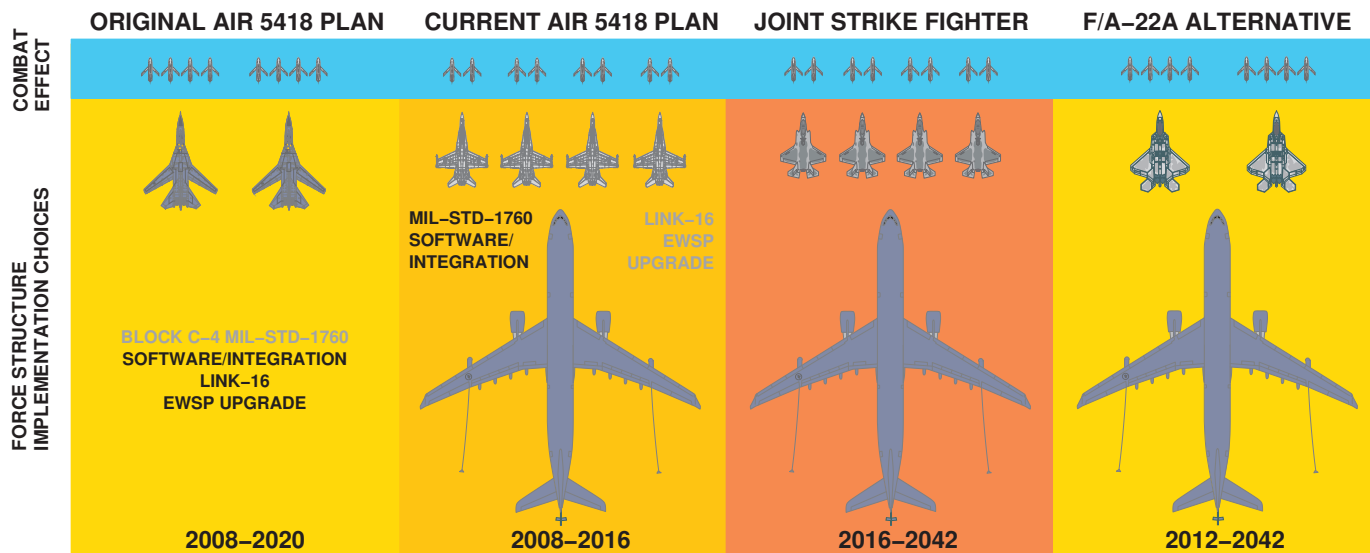
Historically cruise missile delivery has been the province of bombers, especially heavy bombers. It is only within the last decade, with the advent of more affordable cruise missiles, that carriage by fighters has even been considered by major operators. This is a byproduct of two factors – the limited cruise missile payload lifted by tactical fighters, and the required tanker support to achieve a viable striking radius. The most pronounced examples are heavy bombers like the B-52 (20 x AGM-86), B-1B (24 x JASSM) and Tu-95MS-16 (16 x Kh-55) striking to several thousand miles without refuelling. To match the capability of a single such bomber requires up to a dozen fighters each with two cruise missiles, and up to a half a dozen tankers. Size matters.

It is well worth testing the proposed standoff weapon + F/A-18A + A330-200 solution against a standoff weapon armed F-111 in this context, assuming an identical cruise missile in the 1000kg (2500lb) weight class. We can safely assume the F-111 on such a profile has bomb bay fuel tanks fitted temporarily replacing the Pave Tack, providing it with an unrefuelled striking radius of around 900nm (1650km) or more with four weapons, flying a hi-lo-lo-hi profile, most of which is at medium altitude.

The competing configuration is an F/A-18A with a pair of external tanks and a pair of like cruise missiles. At the fuel burn required a single A330-200 will support around four to five F/A-18As to such a radius, accounting for some tanker loiter time while the F/A-18As penetrate to their launch points. A conservative number of four F/A-18As provides for eight cruise missiles, equivalent to the combat effect of two F-111s.

The benchmark for current air launched cruise missiles is the 1970s designed Boeing AGM-86 series, a fast and long ranging weapon. Since the 1980s, warstocks of nuclear armed AGM-86B have been converted into AGM-86C/D/E Block I/II/III CALCMs, seeing replacement of the nuclear warhead with a conventional blast or penetrator warhead, and retrofit of a modern GPS/inertial guidance system. (US Air Force)





OPERATIONAL COST CONSTANT WEAPONS/AIMPOINT

SOURCE DATA: US AIR FORCE, ICAO, RAAF, LOCKHEED-MARTIN

OPERATIONAL ECONOMICS OF CRUISE MISSILE DELIVERY

The baseline for comparison is thus two F-111s vs four F/A-18As supported by a A330-200 tanker. In practice, two tankers would be sortied to cover against a tanker abort, lest F/A-18As end up in the water, and at least two F/A-18As would be committed as escorts for the tankers – the baseline comparison model is not designed to favour the F-111.

It is worth observing that sortiing two F-111s exposes two aircraft and four aircrew, whereas sortiing four F/A-18As and a tanker exposes twice as many combat aircraft plus a tanker and its crew – if the cost of losing assets and crews is counted as a ‘cost’ consideration, in circumstances where losses are expected, the F-111 solution comes out cheaper.

In terms of operating costs per target killed, numbers in previous Defence Annual Reports, when distilled down, indicate that a single F-111 costs the taxpayer around 36% more than a single F/A-18A to operate, with the caveat that mid 1990s US Government Accountability Office data showed a similar cost for the F-111F and F/A-18C. Were the RAAF to operate a similar number of F-111s to F/A-18As, the gap in RAAF costs between the types would be much less than 36%.

Applying this to the test scenario, the relative running cost of two F-111s is equivalent to 2.72 F/A-18As, so using two F-111s costs the taxpayer around 68% of the cost of four F/A-18As, without the cost of the A330-200 tanker counted.

Replacing the F/A-18A in the equation with the JSF does not produce a dramatic cost advantage. While the JSF is hoped to be around 30% cheaper to operate, the two cruise missile payload, being standard rounds externally or the mooted ‘shortbody JASSM’ internally, and limited range results in a similar cost structure.

This changes if the JSF is replaced with the larger F/A-22A which is big enough to carry four standard JASSMs on its 5 klb rated pylons. Halving the number of fighters reduces the fighter cost component, but not the tanker cost component.

The A330-200 tanker cost component can only be estimated in the absence of empirical data. US Air Force figures for the KC-10A indicate it is 56% more expensive to operate than the commercial DC-10-30, despite lower accrued and annual hours, reflecting a different maintenance regime and refuelling equipment costs. Applying this scaling ratio to ICAO figures for the A330-200 results in an hourly cost somewhere between 75% and 100% of the hourly cost of a US Navy F/A-18C/E. A safe estimate for a small fleet is thus that the A330-200 will cost about the same to run as an F/A-18.

With one tanker, the cost of using four refuelled Hornets to deliver the combat effect of two F-111s is 70% greater. If we count an airborne spare tanker, it is 100% greater. Economically, using either F/A-18As or later JSF’s with tanker support as F-111 replacement in cruise missile delivery is a folly.

Summary

The acquisition of the AIR 5418 FOSOW cannot provide a capability to replace the F-111. From the perspectives of survivability, tactical surprise and operational economics the F-111 is a far better suited FOSOW launch platform than tanker supported F/A-18As, JSF’s, or AP-3Cs. As the range of these weapons defeats all known surface based air defences in the region, the only survivability issues arise with opposing fighter patrols, which will present issues for the F-111, F/A-18A and JSF unless properly escorted. If escorts are required, the use of the F-111 frees up tankers to support escorts, resulting in a significantly better capability than that provided under the existing plan.

In perspective, an F-111 armed with JASSM or JASSM-ER provides a more flexible and effective capability than tanker supported F/A-18s. ➔



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