by Carlo Kopp

Expanding the Tanker Fleet

Part 2 – Aircraft Types for Fleet Expansion

The new White Paper is centred upon the use of air power to control the maritime and air approaches to Australia, and deliver long range strikes against hostile assets and bases which might be capable of threatening Australia. Both of these central tenets of our new defence strategy rely upon the RAAF having the reach and endurance to do the job, which over the longer term will demand a substantial fleet of tanker aircraft.

The optimal strategy for the RAAF is to aim for some high-low mix of medium and heavy tankers, as this provides an appropriate balance between the flexibility, training and low intensity operational use economies of a medium tanker, against the crewing and high intensity operational use economies of a heavy tanker. Fiscal realities will however most likely force the RAAF in the direction of a single type tanker fleet, which makes careful choices all the more important. In a single type fleet, crewing requirements for a full fleet strength strongly favour heavy tankers. The RAAF was at the time of writing uncommitted to a specific tanker fleet model.

In terms of candidate airframes for the heavy tanker role, the short and medium term optimum is a 747 derivative, with an MD-11 derivative in the required offload class but presenting some longer term support issues. Used 747s are cheap and plentiful, indeed quite a few Qantas -200s, -300s and SPs may soon become available. As a strategic tanker the smaller A340 will always be disadvantaged by its wing design, even if it becomes economically viable and supportable in Australia. The A340 is out of its league against the 747 as an airlift asset. Interested readers are invited to visit http://www.defence.gov.au/aerospacecentre/publish/paper82.htm for a more detailed analysis of these issues.

If the RAAF opts for a high-low mix strategy, or decides that it does not wish to ever economically expand its tanker fleet to full strength, opting for a long term strategy of limiting its growth potential to a 'half measure' fleet, then medium sized tankers would need to be acquired. Unlike the situation in heavy tankers, where both 747 and MD-11 derivatives are well known quantities, in medium tankers the situation is more complex.

Boeing 707-338C

While the new White Paper commits the RAAF to 'new technology tankers', it is worth examining the 707-338C to place this decision into its proper context. The RAAF's existing fleet of 707-338C tankers was intended to provide a training and limited operational capability. These aircraft were converted to tankers during the early nineties by IAI/HdH in Melbourne.

The AAR hardware installation is based upon a design produced by the Bedek Division of Israel Aircraft Industries for the Israeli Defence Force, which has several tanker aircraft in service. The system design had some detail changes to meet the RAAF's engineering requirements. Most of the hardware was sourced in the US and UK, with remaining components supplied as upgrade kits by IAI. The Mk.32B refuelling pods were manufactured and supplied by Flight Refuelling Ltd in the UK.

The fuel management strategy used during AAR operations differs from that adopted for regular 707 operation, as fuel from the inboard and outboard wing tanks is pumped into the centresection tank from where it is offloaded to receiver aircraft.

The aircraft do not have lower deck auxiliary fuel cells, since at 71,730kg (158,000lb) of internal fuel, the sixties technology JT3D-3B engines would be unable to get the aircraft airborne from most runways with the additional weight of fuel.

In terms of basic airframe aerodynamic performance, the 707-338C is without doubt the best medium tanker in existence. Indeed, the never implemented KC-135H and KC-135X upgrades would have seen the 707-320B wing retrofitted, with either TF33 or CFM56 engines, to KC-135A airframes. The 707-320B is the basis of the E-3 AWACS, E-6A TACAMO, E-8 JSTARS and KE-3A tanker.

The RAAF's 707 have little remaining fatigue life, with serious fatigue problems in key structural components of the wings and centresection. Moreover, other problems have arisen. The JT3D-3B engines, which are too noisy for most civilian airfields and underpowered, are now being obsoleted by the manufacturer. Old age is also taking its toll, with corrosion in some places and the electrical wiring approaching the end of its safe life. It is likely that the 'steamgauge' cockpit instrumentation will become harder to support over time, as the USAF puts Pacer CRAG glass cockpits into its 707 and KC-135 derivative fleet.

Replacing the engines is not a difficult task, the candidates being either the CFM56 common to the 737 and KC-135R, or the JT8D-219 common to the MD-80 series. Both engines deliver similar 21,000lb (93kN) class takeoff thrust, with the CFM56 offering slightly better SFC due to its much higher bypass ratio, while using a bulkier and less convenient nacelle size. While the CFM56 is the better performer, a retrofit is costlier due to the need for structural work to fit a very different pylon design. An engine replacement would come to around $US30m per aircraft. Replacing the electrical wiring is also straightforward, but potentially costing several million per aircraft, as the wiring is embedded in the structure in many places and difficult to access.

The biggest long term issue for the 707 will be corrosion. The USAF greatly regretted its decision to accept a political directive to use refurbished 707-320B airframes for the E-8 JSTARS, instead of new build 707-320/E-3/E-6 aircraft. Repair of all airframe corrosion pushed the price of the E-8 refurbishment close to that of new build airframes.

The JSTARS program yielded a large database of corrosion statistics on the 707 airframe. The most severe corrosion was generally found in four hot spots, the worst by far being around the nosewheel well and forward fuselage. Other problem areas were in the lower fuselage, at three points aligned with the leading edge of the wing, and ahead and behind the main undercarriage wells. Lesser but still significant corrosion was found in the wings, especially around the engines, and upper wing roots. These corrosion hot spots differ from those seen in the RAAF fleet, which has experienced most of its corrosion in the upper wing skins, fuselage roof and tail surfaces.

pic A

The RAAF's Boeing 707-338C tankers have much remaining performance and capability potential which could be exploited by fitting CFM56 or JT8D-219 turbofans, lower deck fuel cells, an APU package, a refuelling boom and a glass cockpit, utilising hardware common to the KC-135R. The decisive issue which will lead to their retirement is dealing with corrosion, structural fatigue, electrical wiring deterioration and ageing of other aircraft components, the repair costs alone being similar to the market value of a used 767 or 747 aircraft.

Herein lies the crux of the issue, in that the reskinning, structural repairs and rewiring required to give the 707s another 20 or more years of airframe life could prove to be as expensive as $US65m per aircraft, pushing the price close to that of a very good used 747, 767 or Airbus. Add in engines, a boom, avionics updates and the cost becomes very close to a 747, 767 or Airbus conversion.

In a sense this is unfortunate, since the 707 is aerodynamically a superb fast tanker, especially if fitted with new engines, a boom and lower deck fuel cells. Indeed it would be much like the proposed KC-135H.

Boeing KC-135E/R/T

Boeing built 820 KC-135A and derivative special purpose airframes between 1957 and 1965. No less than 732 were KC-135As. Today the USAF has 609 KC-135s of various models in service with USAF, Reserve and Air National Guard squadrons, and around 60 airframes of various subtypes remain at the AMARC boneyard. It remains the most numerous large aircraft in the US inventory.

The KC-135 is the forerunner to the 720/707 series, using a single lobe fuselage which is several inches narrower and less tall than the 707, and wing very similar to the now extinct 720/707-100 series. Up to 118,090 litres (31,200 USgal) of fuel is carried in 12 wing tanks and nine fuselage tanks, only one of which is above the floor.

The Airbus A330-200/300 could become a credible competitor to the 767, offering similar capabilities and performance. Like the 767, it is slower than the KC-135 and 707 families, and currently the tanker variant is a paper aircraft. With Qantas about to field 13 aircraft, the type will be well supported in Australia. Like the 767, more spares may be required on long range over water operations to guard against mission aborts through engine failures. The A330 looks a strong contender for the RAF's tanker requirement.

pic B

The aircraft have been through extensive upgrades over their service life. Known structural fatigue problems were addressed by a number of modifications. The WS360 fix alleviated a problem in a wing splice plate, ECP 405 replaced 7178-T6 alloy lower skins between the engines with stronger 2024-T351 alloy skins, and replaced around 62% of wing structure, including many spars, rib cords and stiffeners. These modifications add 26,000 hrs to the structural fatigue life of the airframe.

An ongoing upgrade has seen the replacement of the immersed fuel pumps with a safe dry running type. A number of aircraft were retrofitted with yaw dampers cannibalised from retired 707s.

Two major upgrade programs are currently active. The most significant of these are the KC-135R and KC-135T programs, which incorporate the replacement of the J57 turbojets with CFM56-2B1 (F108-CF-100) fans, the installation of a Flight Control Augmentation System (FCAS) incorporating a yaw damper and improved pitch trim control, the addition of a pair of T-62T-40 auxiliary power units (APU) in the rear fuselage for unassisted ground starting, improved brakes and electrical power generation, strengthened undercarriage, aft fuselage blister windows, a refuelling receptacle above and behind the cockpit, and the new technology improved refuelling boom using an extruded tube structure.

The original CFM56-2B1 had the thrust reversers removed, and the retrofit requires structural strengthening of the front wing spar, new pylons and unique nacelles. The engine has a static rating of 4970/22,000lbf and cruise SFC of 0.662lb/lb/h (cf JT8D-219 at 5250/21,700/0.737).

The other important upgrade is Pacer CRAG, which fits a modern technology glass cockpit, flight management system and GPS, intended to remove the need for the navigator. In practice, high workload sorties may still require a third flightcrew member.

An optional upgrade applied to a small number of USAF KC-135Rs is the Boeing Multi-Point Refuelling system, essentially an wingtip installation of Mk.32B pods similar to that in the RAAF 707s.

The ANG KC-135E upgrade involved the retrofit of TF-33-PW-102/JT8D-3 fans, in part cannibalised from retired 707s. Many ANG units are now receiving KC-135Rs.

The KC-135R is the best medium tanker available in the market at this time, in terms of capabilities and performance, and the nearest equivalent would be a 707-320 series with a similar package of upgrades applied to it.

The cost of a KC-135R is nominally around $US53m or slightly more with the Mk.32B pods and Pacer CRAG fitted, while the KC-135E is nominally worth $US30.6m, and the KC-135A nominally $US26.1m. Therefore the cost of raw boneyard KC-135A is similar to that of a pre-loved 747-200.

The big issue for the USAF is affordably stretching the life of the fleet to its expected fatigue life expiry in 2040. As the airframes are of similar age to the RAAF 707-338C and USAF E-8B JSTARS, the USAF has major concerns about corrosion and other effects of old age on the airframe and systems. While the USAF has plans for a new technology KC-X tanker to be fielded after 2013, the cost of replacing around 600 KC-135s with even a lesser number of new KC-X tankers makes any life extension effort on the KC-135 highly profitable. Even should an affordable long term fix to the corrosion problem be found, long term support will be hampered by poor availability of other system and airframe components. We may yet see the KC-X program initiated earlier than previously planned, and many reports from the US suggest the program may be accelerated.

In considering the KC-135R as a medium tanker alternative for the RAAF, the principal issue will not be performance or capabilities, both of which are excellent, but rather long term support costs, the same problem faced with the

The USAF KC-135R remains by far the most numerous and capable medium tanker in operational service today, with no less than 609 in USAF, AFRes and ANG service. Subjected to numerous structural upgrades, the aircraft has a projected structural fatigue life until 2040. At this time the USAF is more concerned about corrosion and long term support of the unique system components. The current KC-135R and T models are produced by refurbishing and modifying the KC-135A model KC-135Q models respectively, of which around 60 aircraft remain in the AMARC boneyard. (Boeing)

707. There would be a genuine risk that a KC-135R buy would soak up $US50m per airframe of corrosion repair and refurbishing costs per unit, at some time during the next two decades. Current statements from the RAAF and DMO would indicate that the KC-135 will thus not be considered.

Boeing 767 and Airbus MRTT/310/330

Both Boeing and Airbus have actively marketed tanker/transport derivatives of their widebody twins, as the KC-767 and MRTT (Multi Role Tanker Transport) respectively. Both types offer similar or better offload performance than the KC-135R (a KC-767-300ER about 15% better), and are also much better in the secondary airlift role due to larger internal volume and greater floor strength. In terms of simple metrics such as payload range, long range variants these aircraft make for excellent medium tanker, at the higher end of the performance scale. With a large support base worldwide in commercial use and large numbers of used airframes, albeit a little expensive at this time, both would be relatively easy to acquire and support.

The snag with the KC-767 and an Airbus MRTT A310 or A330 derivative is that nobody has yet paid for the design, prototyping and flight test of the conversion, which is likely to run into a considerable sum. Flight test against large numbers of inventory military types to be refuelled can be particularly resource hungry. Until this overhead is paid for either by the manufacturers or another air force, this cost overhead would make both types an expensive proposition for an RAAF fleet. A used 767-300ER costs between $US50-90m per unit, pushing the cost with an refuelling conversion close to the $US70m-110m mark, without the overhead of conversion design, prototyping and flight test.

An A330-200/300 derivative would offer slightly better offload performance than an equivalent 767-200/300, and pod installation on the wings is simplified by structural commonality with the A340. However, the smaller operating base will push the unit cost up. As recently announced, Qantas intend to operate seven A330-200 and six A330-300. The key issue for the A330 will be the cost of used airframes, even the oldest of which can fetch around $US90m per unit.

At the time of writing, Italy was yet to announce whether it had chosen the KC-767 or an Airbus MRTT-A330 derivative for its tanker requirement. Japan is recently reported to have authorised funding for tankers, the KC-767 being the most likely prospect given Japan's use of the E-767 AWACS, but as yet no announcements have been made on specific choices for the JASDF. Boeing has been very actively marketing the KC-767 as a direct KC-X replacement for the USAF KC-135R.

The limitation of both the KC-767 and MRTT-310/330 is their Mach 0.78-0.82 optimised wings, which is a byproduct of the original medium haul design optimisation of these types. This is especially an issue for the Airbus designs, and makes both families of aircraft less than ideal for military use where transit and dash speed is an issue, such as supporting reactive long range CAPs and maritime or long range strike sorties, or emergency refuelling.

Another key issue for both of these twin engine airframes is mission reliability on long duration or long range over-water sorties. While the loss of an engine does not mean the loss of the tanker, which can straggle home on one engine, it would most likely result in a 'mission abort' since the aircraft could not be expected to continue its refuelling mission on one engine alone. The practical consequence of this is that more airborne spare tankers will be required to ensure that a tanker abort does not result in a complete strike package or CAP mission abort. With the White Paper capping the fleet to five tankers, this would significantly complicate what the RAAF could do with a medium tanker based fleet.

Therefore, should the RAAF opt for either family of aircraft to replace the 707-338C as the standard medium tanker, the aircraft will be relatively expensive in offload per dollar due to commercial demand for used airframes, and tactics will need to be adapted to accommodate the dash speed performance limitations of these types, and the limitations of two engines over water.

Airlifters as Tankers

An alternative which is frequently raised in the public debate on aerial refuelling is the use of airlifters such as the C-130 Hercules, C-17 or A400M as tankers, by equipping these with refuelling equipment. Airlifters are a poor choice for aerial refuelling, since they cruise at much lower speeds than fighters, and cannot compete against airliners in fuel offload performance, the principal measure of a tanker's


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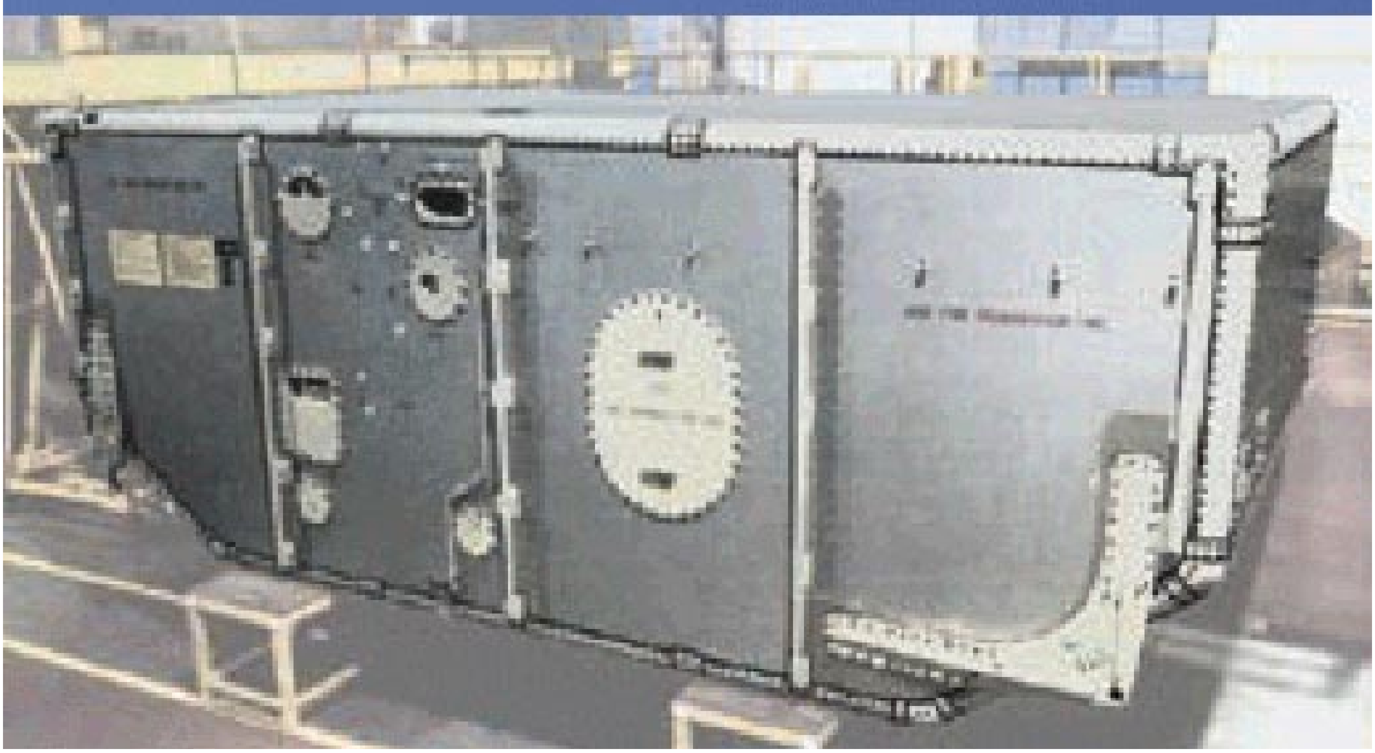
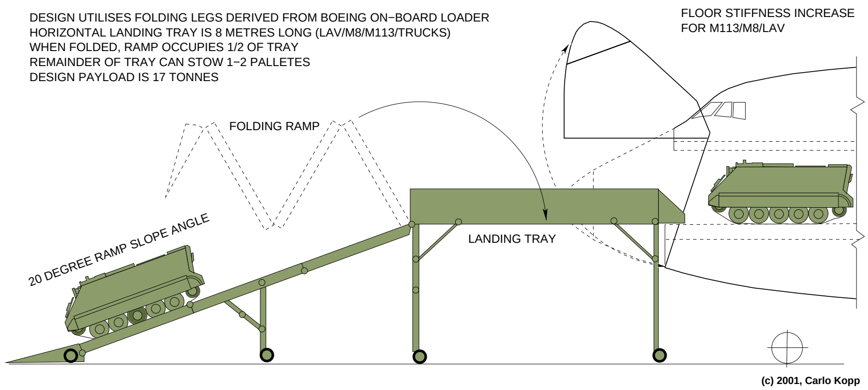


worth. Moreover, if committed to refuelling they are unavailable for airlift, and vice versa.

To place this in perspective, a C-130 Hercules airlifter equipped as a tanker delivers about 1/3 the offload performance of a medium tanker like a 707 or KC-135. Other than niche roles such as refuelling helicopters or close air-support fighters, the C-130 is not very useful as a tanker.

It follows that the RAAF would have to commit its whole airlift fleet to aerial refuelling operations to achieve the effect of a small number of genuine tankers, thus imposing much greater demands in aircrew and airframe time per tonne of fuel offloaded.



KC−33A (KC−747−400F) RO−RO Nose Door Ramp CONOPS Proposal

The other side of this argument is that a robust fleet of RAAF tanker/transports can address much of the strategic airlift needs, thus freeing up the C-130 fleet almost wholly for tactical Army support work.

Electronic Warfare Self Protection Suites

Presently USAF tankers do not carry either Radar Warning Receivers (RWR) or Defensive Electronic Counter-Measures (DECM)/Expendables. Therefore these aircraft are wholly dependent upon defence by fighters and supporting AWACS.

This remains a very contentious issue in the US. In every air war since the 1960s, tankers have had to perform emergency refuelling penetrations of contested airspace to rescue fighters with empty tanks, most recently during Allied Force. Without RWR/DECM, these aircraft are sitting ducks for mobile SAMs or fighters which may penetrate the defensive CAPs. Some years ago the author discussed this issue with a USAF ANG tanker captain who flew in Desert Storm. Their operational practice was to carry extra crew to maintain a lookout using binoculars!

In this day and age of 80nm (150km) range ramjet BVR missiles such as the R-77M RVV-PD (ramjet AA-12 Adder), the safety margins for forward operating tankers have been significantly eroded. US operational experience clearly shows that fuel management by fighter pilots in the heat of combat will always be a problem issue, so tankers will always be confronted with the need to either skirt or penetrate into dangerous airspace.

The inevitable conclusion is that a prudent operator will install some defensive EW capability.

What represents the best EW package is an excellent question. An RWR is a must, preferably one with decent detection range performance against a 10-20kW class air intercept radar. A towed decoy package would be an excellent defensive measure against long range radar guided AAMs and SAMs. Whether expendables are justified is open to debate, insofar as a fighter getting close enough to use a heatseeking AAM might just as well use his gun. At the speeds, altitudes and ranges tankers will be operating at, the primary threats will remain long range SAMs like the SA-10/12/20 and BVR missile shots by fighters.

(left) The only choices in heavy tankers will be the KC-25/747 and the KDC-10/KMD-11. Of these candidates, the 747 is the type which is more economical to support in Australia, and in addition offers superlative airlift capability. The USAF evaluated the 747 in the ATCA program during the late seventies, but selected the smaller KC-10A instead. Against the KDC-10 and A340, the 747 offers better offload performance and is faster. Depicted are the 747-300SF freighter conversion (top), a new build 747-400F (middle) and the LR 747-400 auxiliary fuel tank design (lower) which would be adapted for a tanker conversion. (Boeing)

If the tanker has a secondary role as an airlifter, then shoulder launched SAMs do become an issue and a flare dispenser or infrared jammer is justified.

Equipping a tanker with a robust defensive package is a large cost overhead, which could fall into the $US5-20m cost range, depending upon how elaborate the package needs to be. Should the RAAF consider equipping its future tanker fleet with a defensive package, there would be much merit in using as much common hardware as is possible against the F-111 and F/A-18. Should the domestic ALR-2000 series be used, this would at least introduce some economies of scale into the equation. Given the airframe size of a tanker, antenna and towed decoy placement is not an issue.

Funding Tanker Fleet Expansion

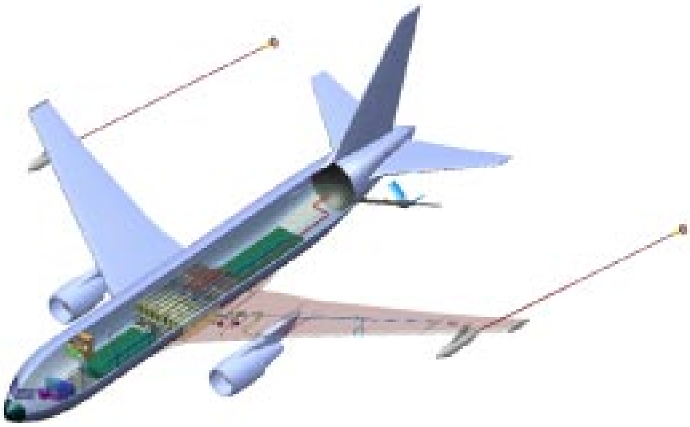
As always, funding expansion of an existing capability will result inevitably in arguments over money. The basic cost of a robustly sized tanker fleet would vary significantly with the mix of aircraft chosen and level of capability per aircraft.

For instance in heavy tankers, provision of full freight capability can add $US12m-20m per aircraft. While plumbing and wiring for wing pods costs around $US2.5m-3m per aircraft, an all up tanking package including a boom, manifold and pump system, auxiliary tanks, AAR receptacle/probe and single point ground refuelling falls into the $US30m-35m range. Additional avionics such as JTIDS/MIDS terminals, secure military comms, military GPS and a minimal RWR would run into millions per aircraft. Depending on the type and age of the airframe chosen, between $US30m and 90m could be spent.

Therefore a medium or heavy tanker could cost between $US75m and 145m, medium tankers not necessarily being cheaper to buy than heavies. With fleet numbers between 12 and 28 the total package cost could vary between $US700m and 4bn, depending on choices made. Therefore doing a proper tanker fleet expansion would be a large project, albeit much smaller than Air 6000 and at most similar to Air 5077 in costs.

There are numerous ways in which this could be implemented. The ‘classical’ model would be to order the aircraft to be delivered over a 3-5 year period, and expend around $US500m annually over that period. Alternately, the buy could be spread over a 10 year period, halving the annual cost to about $US250m and also providing plenty of time to build up aircrew and training systems.

Another strategy is private financing (PFI), where the Commonwealth would contract a supplier such as an airline to provide the aircraft and crews on demand, either for the whole tanker fleet or a portion of it. Numerous alternatives exist in PFI schemes, ranging from a dedicated RAAF use only tanker fleet, to ‘dual use’ aircraft which are swapped between military tanking and commercial transport work.



A KC-767-200ER/300ER is a credible replacement for the KC-135R, offering better offload and airlift capabilities, but it is slower, using a medium haul optimised wing, making it less convenient in situations where dash speed and long range fighter support are needed. At the moment the aircraft is expensive as the costs of engineering and testing the tanker conversion need to be covered, and used airframes cost at least $US50m. (Boeing)

In a 'dual use' PFI arrangement, the aircraft would be owned by the contractor, and flown as commercial freighters or airliners, with pods, military comms and EW equipment removed, but retaining the tanker plumbing, wiring, pylons and boom. The performance hit resulting from the extra weight/drag would be offset in the cost of the contract. Regular training, large exercises and crisis situations would see some or all of the 'dual use' PFI aircraft withdrawn from commercial use and reconfigured for RAAF operations.

The PFI model is attractive to our political leadership since it spreads the cost of the fleet over time, and does not incur the large budgetary 'hit' of a single large purchase. Whether it would be cheaper overall than doing it the 'classical' way remains to be determined. Indeed, some very complex contractual arrangements may be required to keep both parties happy, especially with a 'dual use' PFI model. The risk is that poor choices either by the contractor or the Commonwealth could land either with a large long term contract which doesn't work for them in the intended manner, resulting in litigation and profit destroying disputes.

Crewing a 'dual use' PFI fleet raises other issues. While commercial pilots may be viable for training operations, crisis or wartime use would demand reservists.

Other complexities may also arise with 'dual use' PFI schemes, such as aircraft in commercial use overseas being impounded by allies of an opponent should a dispute arise. The withdrawal of the aircraft from commercial service for mobilisation would be a dead giveaway of military intent, and the time and cost overhead of reconfiguring them for military use would make any fleet mobilisation an expensive proposition.

Most of these complexities vanish with a dedicated military PFI fleet, which in effect becomes a form of a wet lease arrangement. Such arrangements are potentially much simpler, but do not offer the political attractions of commercial work to offset costs.

While a PFI fleet may have the potential to ease or remove the funding crunch of an upfront buy, it does introduce numerous complexities which need to carefully considered. As always, there are no free lunches.

Conclusions

Tankers are the backbone of a modern air force, and by this measure the RAAF is at this time in a very weak position. More tankers are essential to put genuine credibility into the RAAF's force structure, and meet the stated capability goals in the new White Paper.

Without a robustly sized tanker fleet, the RAAF would be unable to perform medium and high intensity air defence operations in the 'cruise missile launch belt' northeast of the Pilbara and Timor Sea, and would be hard pressed to effectively escort the F-111 to the outer bounds of its combat radius. Indeed, genuine independent air operations over the air sea gap are contingent upon having a proper number of tankers. The order of magnitude in tanker numbers is at least 12.5 heavy tankers, 25 medium tankers, or some High/Low mix of either.

In terms of medium tanker choices, cheap options do not exist in the foreseeable future. Many longer term alternatives are in some respects inferior performers to established tankers such as the KC-135R and 707-338C, both of which would need over the longer term very expensive rejuvenation. In heavy tankers, the 747 remains the most practical and cheapest choice, with the MD-11 a viable alternative. Capital acquisition unit costs to a government or a private contractor would be of the order of $US2bn for a 50/50 medium/heavy mix and comprehensive equipment fit.

The biggest issue for the RAAF in tanker fleet expansion will be crewing, even with the most aircrew efficient choice of heavy tankers. Another issue will be the provision of adequate fuel replenishment to northern bases. A 747 rated runway close to Karratha and its planned synthetic fuel plant could prove to be a very useful asset in this respect.

None of these problems are insurmountable, nor unreasonably expensive should the government make judicious long term choices. Nevertheless, they will present challenges within a Canberra political culture which has a very poor literacy level in these issues and is very nervous about short term expenditure.