Part 1 of this special report explored the evolving strategic context in South East Asia and identified the developing need for Australia’s air force to acquire a substantial strategic tanker transport force. Since publication of Part 1, the December 2000 White Paper was released reflecting a similar viewpoint held by Australia’s defence planners. Indeed, the White Paper extends established ADF doctrine to now encompass the use of tanker-supported F-111s for long range strikes against any military targets, maritime or land based that could represent a threat to Australia or its strategic interests. Another important feature of the White Paper is that it asserts the critical importance of maintaining air superiority over Australian territory and its maritime and air approaches. Ambitious capability goals are defined in this respect, in particular the capability to conduct sustained long range strike campaigns by the F-111 force, using aerial refueling. Whether we consider the White Paper capability goals in counter-air operations or strike operations, it is clearly evident that the RAAF will need to field a substantial aerial refueling force to meet these objectives. The White Paper commits five new technology tankers to replace the Boeing 707-338C fleet, which is suffering from fatigue and corrosion problems that would be prohibitively expensive to rectify. Analysis based on strike, defensive combat air patrol and comparative fleet ratios indicates that about 12 to 16 large widebody tankers or 24 to 32 medium tankers would provide appropriate fleet sizing for deterrence operations, long range maritime strike, air support of regional peacekeeping deployments, and air defence of the air sea gap and the ‘deep north’. Should ‘heavy widebodies’ be employed, then airlift and ongoing resupply of a brigade-size ground force element would also be feasible. For all practical purposes the budgetary commitment in the White Paper addresses at best 40 per cent and, at worst, 20 per cent of the actual refueling capacity needs the RAAF will face. Pressures in crewing and fuel offload performance per airframe will drive tanker needs in the direction of large widebodies, whereas pressures in training fuel burn and low intensity operations will favour medium widebodies. It is likely that the immediate pressures of 707 training capability replacement will thus see medium widebodies adopted by the RAAF in the near term. In addressing the needs of high intensity operations, the most economical choice is then to further expand the tanker fleet by the use of large widebodies, thus producing a ‘two tier’ tanker fleet. While a medium tanker requirement can be readily addressed using either Boeing 767 or Airbus 310/330 derivatives, neither have the offload performance to meet a heavy tanker requirement. Boeing DC-10/MD-11 and Lockheed Tristar derivatives will be difficult to support in Australia, more so beyond 2010 when commercial fleets begin to downsize, and this is despite the adequate performance of these types as tankers. Indeed the USAF KC-10A will be orphaned post 2015, an issue of some concern in the US. The only remaining type in the required size and performance class is the Boeing 747, and this aircraft is the subject of this final part of the series.

**Boeing 747 Derivatives**

The Boeing 747 family of aircraft is used both by Qantas and Ansett in Australia, and Air New Zealand. Qantas flies the 747 in passenger and freighter variants. Its design is a derivative of a 1960s Boeing proposal for a military airlifter that lost out to the Lockheed C-5A Galaxy. The aircraft was later evaluated against the DC-10 as part of the USAF Advanced Tanker / Cargo Aircraft (ACTA) program, losing out to the McDonnell Douglas KC-10A, despite its superior performance. Photographs exist of the 747 refueling even the SR-71A during these trials. Several AAR boom and receptacle equipped 747-100B tankers were supplied to Iran during the mid to late 1970s, including aircraft with lower-deck fuel tanks, and two US military variants exist with AAR receptacles. The conversion package for Iran was performed with the expectation that other clients would be found, and a full production standard documentation package was generated as a result. Therefore, a current retrofit of the basic KC-135 boom to the 747 incurs minimal Non Recurring Expenditure (NRE).
Boeing 747 derivatives

The Iranian aircraft employed an operator with direct view as per the KC-135 design, but located behind a recessed rear fuselage window in the aft pressure bulkhead, rather than in a protruding faired as used by the KC-135. A cheaper alternative to produce, at the expense of some NRE, would be the remotely operated boom as used on the KDC-10/30CF. The classic KC-135 boom was recently re-engineered in a number of areas to employ current production techniques such as extrusion rather than riveting. Booms supplied on recently delivered KC-135R conversions have been based on this newer implementation that would be used in any new-build 747 retrofit. The lower deck volume of the -100 and -200 models available for contractor's freight provides ample space for additional auxiliary fuel cells and this would be essential to extract the full offload potential of the aircraft as a tanker. Since intercompany, low lobe fuel cell configuration, and there are no 400 models available for airframe, and another version being a KC-235 for a KC-235B, and a 747SF model or a KC-235C for a 747-300 model. A simple measure of the Boeing 747-400 against other established tankers is that it delivers offload performance potentially superior and payload-range superior to the KC-10A Extender. Extension length was fast like the KC-135 and Boeing 707 tankers, cruising at 0.84-0.85 Mach. This is a very important attribute for strike and offensive counter-air refueling operations, since the tanker must keep up with a fighter package, and must be capable of operating at the boundaries of contested airspace.

Therefore, this aircraft is the only type which satisfies the requirement of an existing domestic operator base, an equipment supported to extend the technology of the AAR mission, and the volume limitation of a high performance, lightweight, long range, variant. The 747-400, manufactured between 1976 and the late 1980s, can be used specifically designed for very long range, low load factor routes as a replacement for the long range variants of the Boeing 707. It employs a shortened fuselage, lighter structure and enlarged tail surfaces. Until the advent of the 747-400 variants and the -200B it was the 747 variant with the best range performance. As the -400 has penetrated into the commercial market, the demand for the 747SP has fallen strongly. As at July 1999, seven were in storage and four dismantled for structural spares. Qantas continues to operate two examples. Less than fifteen 747SPs are currently on the market, including some VIP transports, with a unit cost of between USD 5.3M and 7.7M apiece. Because of the poor profitability of the 747SP on most routes, it is considered to be worth more as scrap than as a commercial asset. The 747SP was almost exclusively designed for long haul operations, the number of cycles on the airframes will mostly be excellent, in relation to the age and accrued flight hours of the aircraft. The 747SP is capable of using a new wing design and fuselage stretch, will be available by 2005 and will deliver significantly better payload radius performance than the 747-400 series.

Boeing 747-300

The 747-300 is the extended upper deck variant of the late build -200B airframe, manufactured between the early eighties and nineties. With the advent of the extended range -400 model, the demand for this model in the commercial market has declined and it is readily available, while accrued fatigue life will be modest for examples flown mostly on long haul routes. At present, there is a glut of used 747, 200B/C, and -300B/CF aircraft in the market; a good proportion of these are Combis that are already fitted with the large SCD freight door and would thus incur lower costs to convert to a tanker/transport configuration. Typical unit costs fall between USD 39.4 and 50.8M, but will vary with the age, condition and fit of the aircraft. Given the saturation of the market, it may thus be feasible to acquire aircraft at prices well below the actual value of the aircraft. The extended upper deck on the 747-300 series provides the means of carrying up to 85 economy class passenger seats in addition to main deck freight, but does so at the expense of reducing the ceiling height of the main deck floor of the wing, thereby imposing some limits on the capacity of tailor freight items. Special Freighter conversions, however, may have a modified upper deck floor to extend main deck internal clearances, at the expense of the upper roof floor.

A 747-300 can thus be more flexible in terms of its ability to mix freight and troop loads, but at the expense of the mix of freight items sizes it can accommodate, in comparison with a 747-200 derivative.

Boeing 747-400

The 747-400 is the current production model, introduced in the early 1990s, available in passenger, Combi and Freighter versions. It features the extended upper deck of the -300, and a new extended wing fitted with winglets. Since it is available either new-build or with a service life under 10 years, fatigue life is not an issue for the 747-400 at this time. The 747-400 offers the best load carrying performance of any 747 variant, but its larger MTOW imposes the need for better runways, and due to its large wing area, ground handling can be an issue on some sites. It is also expensive in the used aircraft market, as it remains strongly in demand, with typical used aircraft worth between USD 92.5M and 158.5M. The Longer Range 747-400 incorporates additional lower deck fuel and improved engines. The 747X, with a new wing design and fuselage stretch, will be available by 2005 and will deliver significantly better payload radius performance than the 747-400 series.

Boeing 747SP

The Boeing 747SP is a high performance, lightweight, long range variant, manufactured between 1976 and the late 1980s, with only 45 built. The aircraft was specifically designed for very long range, low load factor routes as a replacement for the long range variants of the Boeing 707. It employs a shortened fuselage, lighter structure and enlarged tail surfaces. Until the advent of the extended range -200B variants and the –400 it was the 747 variant with the best range performance. As the -400 has penetrated into the commercial market, the demand for the 747SP has fallen strongly. As at July 1999, seven were in storage and four dismantled for structural spares. Qantas continues to operate two examples. Less than fifteen 747SPs are currently on the market, including some VIP transports, with a unit cost of between USD 5.3M and 7.7M apiece. Because of the poor profitability of the 747SP on most routes, it is considered to be worth more as scrap than as a commercial asset. The 747SP was almost exclusively designed for long haul operations, the number of cycles on the airframes will mostly be excellent, in relation to the age and accrued flight hours of the aircraft. The 747SP is capable of using a new wing design and fuselage stretch, will be available by 2005 and will deliver significantly better payload radius performance than the 747-400 series.
As a tanker, the 747SP provides an internal fuel capacity of 148 to 153 tonnes, and lower lobe floor strength to accommodate a maximum of 30 tonnes. In these aircraft, the existing MTOW limits on the aircraft, this yields about 75-80 tonnes of offload at 1,900 NMI, which is consistent with design, wing modification to accommodate fuel lines, and flight testing would be incurred.

The Engineering, Manufacturing, and Development contract for adding wing-mounted hose and drogue pods to the KC-135R Stratotanker cost approximately USD 24.4M. The cost of conversion kits to fit Boeing 747–400s is about USD 2.55M per aircraft, excluding the cost of the pods. The cost for a KC-25/274 kit would be slightly higher due to the longer fuel lines required. Given that Boeing did not adapt the design of the KC-135R and KC-10A for wing mounted Mk.32B pods for the USAF, it is reasonable to assume that a normal service life of the design could be directly adapted to a KC-25/747 design, thereby reducing the maintenance of the NRE required. The full cost of equipping a dozen KC-25/747 aircraft with pods would be the order of USD 50M, excluding the cost of 24 pods and appropriate spare components.

The 747 as an Airlifter

A very attractive aspect of the standard Boeing 747-200CF/300CF and 400F Combi and Freighter conversions is the size of the aircraft and its ability to load and unload. Since the vehicle is slightly longer than the standard pallet size, the locked down positions of the pallet would have to be slightly different to a standard load of 6.05 metre containers or pallets. On the 747-200CF, the arrangement would allow four or more ASLAVs to be loaded, side by side, together with other freight.

Unlike conventional military airlifters that have loading ramps and a very low floor height, the Boeing 747 requires specialized support equipment for loading and unloading. The height of the 747 main deck is 1.63 metres, and a forklift is used to remove the empty pallet from the loader. Since the vehicle is slightly longer than the

Boeing airlifters

As a freighter, allowing Roll-On/Roll-Off (RO/RO) loading, the Boeing 747 would require that the ASLAV be first tied on to a 6.05 metre pallet, then handled and loaded onto the aircraft as if it were an 11 tonne, 6.05 metre specialised freight container. A forklift would be used to load empty pallets onto the loader, for roll-on loading of the vehicle onto the pallet. Once the vehicle is secured to the pallet it may be loaded into the aircraft. For unloading, the palletised vehicle is released off the pallet and driven away, and a forklift would remove the empty pallet from the loader. Since the vehicle is slightly longer than the

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The Engineering, Manufacturing, and Development contract for adding wing-mounted hose and drogue pods to the KC-135R Stratotanker cost approximately USD 24.4M. The cost of conversion kits to fit Boeing 747–400s is about USD 2.55M per aircraft, excluding the cost of the pods. The cost for a KC-25/274 kit would be slightly higher due to the longer fuel lines required. Given that Boeing did not adapt the design of the KC-135R and KC-10A for wing mounted Mk.32B pods for the USAF, it is reasonable to assume that a normal service life of the design could be directly adapted to a KC-25/747 design, thereby reducing the maintenance of the NRE required. The full cost of equipping a dozen KC-25/747 aircraft with pods would be the order of USD 50M, excluding the cost of 24 pods and appropriate spare components.

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An important limitation of the Nose Door is that the nose refueling receptacle design would need to be adapted to use a flexible or articulated connection to the fixed fuel lines in the forward fuselage, or shifted above the cockpit, thereby incurring some additional NRE. The feasibility of retrofitting the Nose Door as part of the fuel modification needs to be further investigated, as this would provide more flexibility in the choice of airframes which otherwise must be selected from the limited pool of Nose Door equipped aircraft available to the RAAF. Another alternative is to rework the design of the Boeing On Board Loader to allow it to be deployed from the SCD rather than the Nose Door. The final option is a mixed fleet with only some aircraft fitted with the Nose Door.

11. Installation of military GPS navigation equipment.
12. Installation of IFF interrogator.
13. Installation of a suitable intercom system.
14. Installation of Echidna RWR and DECM package, possibly also IRCM on engine pylons.
15. Installation of the Side Cargo Door if not already fitted.
16. Strengthening of the main deck floor to prevent damage by aircraft undercarriage.
17. For aircraft without a Nose Door, installations, modification to support the Boeing On Board Loader, and supply of these devices, modified as required.

Serious consideration should be given to the use of a standard configuration, if possible, whereby all aircraft are fitted with the air-stairs, Nose and Side Cargo Doors, the Boeing On Board Loader, and refueling receptacles. Whether to retrofit the aircraft cockpits to a current standard ‘glass cockpit’ arrangement is open to debate. While this would increase the unit conversion cost, it offers the longer-term economy of a two-person flight crew, against a three-person flight crew, assuming a dedicated AAR operator. Given that most commercial models now have glass cockpits, maintenance of currency for reservists flying commercial models would indicate that a glass cockpit would be preferred. This would also provide the opportunity to standardise the inertial navigation and communications equipment fit across the fleet. A FANS compatible system would be desirable. There may be some merit in retrofitting all aircraft to a common engine type, should airframes of suitable quality not be fitted with such. Quanta will be well equipped to advise on the performance and idiosyncrasies in supporting specific engine types. Overhauled used engines of suitable quality may be acceptable, since the aircraft in RAAF service would not be operated at the tempo of a commercial operator outside periods of war or other contingencies.

There may be some scope for faster reconfiguration time between the airlift and troop carrying configurations: by using dedicated 2.44 x 6.05 metre pallets fitted with fixed canvas troop seats, rather than commercially Combi aircraft seating. This could be implemented in a manner that would save considerable weight, compared with conventional seating, thereby allowing more troops and freight to be loaded into the aircraft. A simple measure of the Boeing 747-200CF/300CF/400CF as an airlifter is that it provides payload range performance in the class of a C-5 Galaxy, but its freight loading door limits payload items to sizes similar to those carried by a C-130 Hercules or C-141 Starlifter. With the exception of length, the Boeing 747 SCD can handle items slightly larger than either the C-130 or C-141 Starlifter. With a length of 18.7 metres, the Boeing 747 SCD can handle items slightly larger than either the C-130 or C-141 Starlifter. Therefore any Army assets air-portable by C-130 will almost certainly be portable by 747, thereby taking a significant load off the RAAF C-130 fleet.

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Conclusions

This report argues the case for the acquisition and deployment of a substantial strategic tanker/transport force for Australia, comprising a fleet with a large proportion of modified variants of the Boeing 747 transport.

Such a force would wholly address the capability gap between the government’s stated five-tanker fleet, and actual operational needs for a credible force.

The Boeing 747 makes an excellent strategic tanker, but not an ideal airlifter. However it is the only aircraft type that will allow Australia to deploy a large strategic tanker/transport force with a modest initial expenditure, while exploiting the established training and support base.

To provide a general measure of capability, one dozen 747-200/300/400CF/SF derivative KC-25 strategic tanker/transporters provide the cruise speed and payload performance equivalent to seven of the KC-135R tankers, or 26 767-200 tankers, and can lift the payloads of a dozen C-17 airlifters over about a 60% greater distance, all at about one-third of the total acquisition cost of the combined packages of KC-135R and C-5A aircraft. A mixed KC-25 fleet, including some 747SP derivatives, yields similar payload performance and lesser airlift performance, with even lower acquisition costs. A mixed fleet of C-17 and KC-25 yields inferior payload performance, but would provide a superior airlift capability, with a penalty in acquisition costs.

In summary, it is fair to say that the strengths of the 747-200B/300/400CF/SF and 747SP as a strategic tanker/transport outweigh its limitations, especially in comparison with other alternatives derived from commercial airframes. While its weaknesses are most prominent in the airlift role, it performs this role far better than other commercial types.

At this time the composition of the RAAF’s future tanker force is yet to be determined. What is abundantly clear at this time is that a force which is robustly sized to meet the capability goals in the new White Paper will have to contain a substantial fraction of heavy strategic tankers. Should the 747 be used as the basic heavy tanker platform, the economics will be well within Australia’s reach.

Footnote

This report is based primarily on RAAF Aerospace Centre Working Paper 82, published March 2000. The author gratefully acknowledges the assistance of Squadron Leader Murray Warfield (ret) of Qantas, who originated the idea, the RAAF School of Air Navigation at Sale, Captain Kurt Todorov, USAF (ret), Captain Perry Beer, Army Reserve, and Boeing Australia for their advice and assistance with this project. The paper is available at http://www.defence.gov.au/aerospacecentre/publish/paper82.htm