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A Strategic Tanker/Transport Force for the ADF (Draft 1.21)

Carlo Kopp

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The Director
Air Power Studies Centre
RAAF Base
Fairbairn ACT 2600
Australia

Tel:	(02) 62876563	Intl: 61-2-62876563
Fax:	(02) 62876382	Intl: 61-2-62876382
Email:	apsc@dynamite.com.au	

ABOUT THE AUTHOR

Born in Perth, Western Australia, the author graduated with first class honours in Electrical Engineering in 1984, from the University of Western Australia. In 1996 he completed an MSc in Computer Science by research and more recently, submitted a PhD dissertation dealing with long range data links and mobile networks, both at Monash University in Melbourne. He has over 15 years of diverse industry experience, including the design of high speed communications equipment, computer hardware and embedded software. More recently, he has consulted to private industry and government organisations, and lectured in computing topics. The author has been actively publishing as a defence analyst in Canberra based Australian Aviation, since 1980, and more recently in Amberley based Air Power International, the UK based Janes Missiles & Rockets, and the US based Journal of Electronic Defense. His work has been published by the RAAF APSC since 1992, and USAF CADRE Air Chronicles since 1996. He is a member of the IEEE, AIAA and AOC.

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SYNOPSIS

The 1994 Defence White Paper, entitled "Defending Australia", articulates the need for a robust AAR capability and states the intent to "enhance the effectiveness" of the RAAF's F/A-18A fleet in part by "the availability of aerial refuelling aircraft". This paper explores the fundamental issues and alternatives available to fulfill this intended enhancement in capabilities. Technical and operational issues are discussed, performance and capability criteria defined in relation to AAR and airlift, and candidate airframes tested against these criteria. The essential conclusion is that a force size of the order of 12 B-747 sized tankers would address most of the ADF's strategic transport and AAR needs in the developing strategic environment.

AUTHOR'S NOTES

This paper was compiled wholly from open sources, detailed in the references.

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SQNLDR Murray Warfield (ret) of Qantas proposed the use of the 747 as a strategic tanker/transport for the ADF over a decade ago. His insights and comments were pivotal to this paper.

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Boeing 707-338C tanker/transports (RAAF).

A Boeing KC-747-100 strategic tanker/transport refuelling a USAF SR-71A during inflight refuelling trials. Note the nose down attitude of the tanker. (USAF).

A Strategic Tanker/Transport Force for the ADF

The 1994 Defence White Paper, entitled "Defending Australia", articulates the need for a robust AAR capability and states the intent to "enhance the effectiveness" of the RAAF's F/A-18A fleet in part by "the availability of aerial refuelling aircraft"[1]. This paper explores the fundamental issues and alternatives available to fulfill this intended enhancement in capabilities.

Introduction

The "Tyranny of Distance" is an unavoidable aspect of military operations conducted in the far north of Australia. It is all pervasive, insofar as it impacts the operations of all three services.

For the RAAF, extreme distances introduce a range of complexities in operations, especially of fast jet aircraft, since these by their very nature are voracious consumers of aviation kerosene.

As a result the operating radius of the F/A-18A, the F/RF-111C/G, and any future replacements, are constrained by the availability of runways and the limitations of the aircrafts' basic airframe designs. While some improvement can be achieved by carrying external tanks, these introduce a performance penalty through additional drag in the critical transonic cruise-climb regime, as well as displacing weapons from the aircrafts' stations. The impact of carrying large amounts of external fuel should not be underestimated, a smaller fighter such as an F/A-18A with two 480 USG external tanks will carry around 35% of its total fuel capacity at take-off in external tanks.

If fighter aircraft operate to their maximum combat radius using large amounts of external fuel, they will also incur a serious performance penalty in agility. This is a direct consequence of the much higher combat weight of the aircraft, burdened with additional fuel, but also the additional drag of the external tanks.

Providing that fighters are only employed as reactive interceptors, scrambled from runways and flown out on point intercepts against inbound threat aircraft at very modest distances, their range limitations without external tanks can be tolerated. Indeed, in geographical environments such as central Europe, or Israel, fighters are frequently flown with little or no external fuel. However, as we increase the distances to intercepts, we find that increasing amounts of fuel are required.

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[1] Section 5.38.

The "ground alert intercept" model of air defence operations is becoming increasingly less relevant with the proliferation of standoff weapons. Indeed, in the far north of Australia the distances between available runways[2] are such, that a timely response to engage a target on a track other than one passing close to the airfield in question is unlikely, unless exceptionally early warning is provided, and the intruding party is indeed sufficiently cooperative to position himself suitably for intercept !

Modern air defence operations rely extensively upon the idea of a Combat Air Patrol (CAP), whereby fighter aircraft are flown out to a station which is suitably chosen to allow the fighters to engage threat aircraft as early as possible. Directed by AEW&C aircraft and surface based air defence assets, such as microwave and OTH-B radars[3], CAP fighters can be positioned quickly to engage the threat before it can approach to a range at which a standoff weapon can be launched[4].

While the CAP model has been proven to be the most effective strategy for defensive counter-air operations, its flexibility comes with an inherent operational "price tag". The further the CAP station is from the fighters' operating runway, the shorter the CAP's on station endurance will be. Should we further budget for combat fuel burn at high power settings, the distance between a CAP station and runway can be very short indeed.

A publicly available figure for the F/A-18 aircraft underscores this[5]. With modest allowances for afterburner use, the on-station endurance for a CAP at 150 nautical miles (278 km) is around 1 hour and 45 minutes. The somewhat more fuel-efficent F-16C Block 40, with 1,040 USG of external fuel (approximately 3 tonnes), and four air-air

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[2]We consider operations from RAAF Learmonth, Curtin, Tindal, Darwin and Scherger. Refer FLIP/ERSA.

[3]Over The Horizon Backscatter radars operating in the shortwave bands, an example of which is the ADF's Jindalee Operational Radar Network (JORN).

[4]Even a relatively cheap and widely available anti-shipping missile such as the Exocet or Harpoon can be extremely effective if the intended target is an oil or gas production platform, or a coastal oil or gas production facility. Such targets have sizes, and thus radar signatures, significantly in excess of the naval vessels these missiles were designed to attack. Moreover, such civilian facilities are not protected by jammers and chaff dispensers and are unable to manoeuvre. Should we consider the scale of the facilities built over the last two decades in the Kimberley region, and the potential for significant future development in the Timor Sea area, there is no shortage of high value, immobile and highly combustible targets in the remoter parts of Australia's north.

[5]Lambert M., ed, Jane's All the World's Aircraft, 1991-1992, Jane's Information Group, Surrey, p439.

missiles, achieves a CAP on-station endurance of 2 hours and 10 minutes, at 200 nautical miles (371 km)[6]. These numbers are quoted from manufacturer's brochures, and therefore may be based upon slightly optimistic assumptions.

Let us consider a scenario where a CAP is required to protect the North Rankin A gas production platform, which is north west of Karratha. Sortiing from RAAF Learmonth, the CAP will need to cover about 185 nautical miles (circa 345 km) to reach the platform, and then position itself further out to such a distance to guarantee the interception of an aircraft launching a standoff missile. The on-station endurance of the CAP will be of the order of an hour, this assuming that a fuel efficient cruise profile can be flown. To provide continuous 24 hour defensive coverage, we require around 24 CAP sorties by the required number of aircraft. For a CAP comprising four fighters, this amounts to 96 sorties per 24 hrs of operations !

The availability of JORN to provide early warning of raids, whereby the CAP and supporting AEW&C platform are sortied only when a likely target approaches the area of interest, can result in significant economies of effort.

However, this is based upon the assumption that the attacker will be flying a long range aircraft to launch his weapons. A no less likely contingency is that the weapons could be launched from a submerged submarine, or a surface vessel. Soviet designed antishipping missiles with ranges of hundreds of kilometres have been widely marketed since the fall of the Soviet Union. If launched from such a distance, they will need to be intercepted much earlier than an aircraft with shorter ranging weapons, to provide an opportunity to reattack should the initial engagement against the missile not succeed. Since JORN will not provide early raid warning against a submerged attacker, this scenario would require that the full number of sorties be flown to provide reliable defensive coverage.

The only resolution to this problem is the provision of robust Air Air Refuelling (AAR). A tanker with sufficient fuel offload performance can be sortied with the CAP, and orbit at a safe distance to allow the fighters to refuel on demand, until the CAP is replaced with fresh aircraft, or all missiles are expended.

To provide for the reliable engagement of a multiple launch of cruise missiles in such a hypothetical scenario, the CAP station will need to be of the order of 500 nautical miles (cca 925 km) from Learmonth. Should we assume a six hour on station endurance, for a CAP (or multiple CAPs) comprising eight F/A-18 fighters, we incur an on

[6]Ibid. p404.

station fuel burn by these fighters of the order of 120 tonnes or more, even assuming that the fighters carry two 480 USG tanks of external fuel to cover the fuel burn incurred in transit to and from the CAP station. For a single tanker to support such a sortie will require that it be a genuine strategic tanker aircraft[7]. To provide such a supporting capability for the whole Tactical Fighter Group will require of the order of one dozen such tankers, making allowances for spare tankers.

Defensive Counter Air operations represent but one aspect of the defence of Australia's air-sea gap. The other vital aspect is anti-shipping strike against hostile surface vessels.

The operating radius requirements for maritime strike operations are more demanding than those for DCA CAP operations, especially if the ADF's intent is to protect sea lanes at extended distances.

Analysis performed by the author shows that an operating radius of about 2,000 NMI is required for the RAAF's combat aircraft, to guarantee reliable coverage of the most important sea lanes in Australia's nearer geographical vicinity. Given the need to sortie defensive fighter escort CAPs as well as anti-shipping missile "shooters", we must assume maritime strike packages of a substantial size.

For a such a number of aircraft to operate at radii of this magnitude, it will be necessary to opt for a genuine strategic tanker aircraft, with the range and offload performance to support a substantially sized package.

There is another strategic consideration. Should the difficulties experienced to date with the Collins SSKs persist, there is genuine potential for a lack of long range maritime interdiction capability in the coming decade. The deployment of a strategic tanker force of substantial size provides insurance against future problems with the class.

Considering that the aggregate Harpoon loadout for 82 WG is between 80 and 140 rounds, the latter assuming Harpoon capable F-111Gs, the aggregate maritime strike firepower is of a similar order to the 138 (23 x 6) Harpoons or torpedos carried by the Collins SSKs. However, the Collins has a combat radius of the order of 3,000 NMI or better. Therefore to offset the loss in capability which may result from future problems with the submarines, enough AAR capability must exist to support the F-111 to a similar combat radius, in adequate numbers.

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[7] Appendix A, Figure A.2.

Supporting a pair of F-111s to 3,000 NMI will require a large widebody tanker. Therefore to match the firepower of four Collins SSKs at 3,000 NMI, we require about twenty four F-111s and twelve large widebody tankers.

It is perhaps a convenient coincidence, that the sizing requirements for a tanker fleet to perform sustainable DCA operations, as well as ASUW operations is very similar in magnitude. It does however add robustness to the case, insofar as a strategic tanker fleet sized to either requirement can provide sufficient capability to address both needs[8].

An additional, and important benefit to be gained from a strategic tanker force of this magnitude is that it would provide the sustainability which is currently lacking in the RAAF's strategic deterrent capabilities.

The ADF will face other challenges in coming decades which will impose demands which cannot be met with current capabilities. Peacekeeping operations performed under UN auspices over the past two decades have frequently produced demands for airlift well in excess of what could be provided by the RAAF's C-130 and B-707 aircraft. Recent experience indicates that it is not prudent to assume that USAF Air Mobility Command airlifters will be made available at short notice to support such operations.

The participation of ADF personnel in future UN sponsored peacekeeping operations is highly probable, and likely to be in far flung parts of the world. We can thus expect a strong and ongoing demand for extended range airlift, especially of personnel and supplies.

Lifting refugees proved to be demanding during the Kosovo crisis, and similar contingencies are likely to arise again. The rapid delivery and distribution of humanitarian aid is another very likely contingency, again one where the ability to rapidly move bulk freight is of considerable value.

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[8] An interesting comparison is to consider the ratio of "equivalent strategic tankers" to fighters in the USAF inventory. If we count each pair of the USAF's 255 KC-135s as one "equivalent strategic tanker", and each of the 59 KC-10As also as one "equivalent strategic tanker", we get a ratio of strategic tankers to fighters of almost exactly 12.5%, against the total number of USAF fighters. RAF fleet numbers yield a similar ratio. If we consider the RAAF's fleet of 34 F-111s and 72 F/A-18s, applying the same 12.5% ratio yields just over 13 "equivalent strategic tankers", which closely matches more tedious fleet sizing estimates discussed earlier. See "World Military Aircraft Inventory", AW&ST, January 17, 2000, p269.

The evacuation of Australian nationals from foreign countries in crisis situations is another scenario where a rapid demand for passenger lift may arise at very short notice. Unless airlines are able to reschedule, this may be difficult to accommodate with available commercial capacity.

Other uses are also possible. One is the rapid deployment and resupply of RAAF fighter squadrons deployed to bare bases such as Curtin or Scherger. A single large widebody can easily carry several days supply of munitions for intensive operations, or enough fuel to sustain a small detachment of fighters for several days of flying from a bare base.

Another supporting application is the supply of aviation kerosene for Army helicopters deployed offshore on peacekeeping or peace enforcement missions. With the ability to carry tens of tonnes of fuel in bladders loaded on the main deck, the requirements for many days of operations by a substantial helicopter force can be accommodated in a single lift, into sites where the loss of infrastructure makes resupply over land or sea difficult and slow.

Addressing such needs using conventional heavyweight military airlifters incurs considerable difficulties. The first is that the ADF's choices in available aircraft types are very limited, indeed only the C-17 is currently in production in the West. The second problem arises from the high cost of what are essentially single purpose assets, which are of limited utility outside of their deisgn role.

Therefore careful consideration should be given to addressing these needs using derivatives of commercial transport aircraft.

While commercial transports modified as AAR tankers are mostly not well suited to carrying heavy equipment like armoured personnel carriers and tanks, required for combat operations, they are adequate for the transport of most of the equipment required for peacekeeping operations[9]. Situations where heavy equipment does need to be lifted into theatre will most likely arise in the context of a larger, coalition campaign, where access to USAF C-141, C-5 and C-17 aircraft will be available.

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[9] What proportion of the required total airlift payload requires dedicated military airlift assets depends quite critically on the contingency, and the required mix of land warfare assets. The items which require a specialised military airlifter are those which by height, width, length or weight are incompatible with the freight door size and floor strength of a commercial freighter aircraft. Items in this category are typically main battle tanks, large armoured personnel carriers or infantry fighting vehicles, mobile command posts built into large containers, heavy 6x6 or 8x8 trucks, area defence SAM systems and armoured recovery vehicles. Data compiled from USAF AMC sources would indicate that only 20% of material carried during the Desert Shield/Desert Storm airlift required specialised military airlift assets, and only 5% of material carried during the Somalia peacekeeping mission fell into this category. In general, light and highly mobile forces such as the Australian Army are much less dependent upon the availability of heavy military airlifters.

A single large widebody transport can lift between 300 and 500 troops, which means that a dozen such aircraft can move a brigade in the time to takes to load, cover the distance, unload, and return. When carrying equipment and supplies, each will lift between 75 and 110 tonnes. Therefore a dozen such aircraft can move between 900 and 1320 tonnes of equipment and supplies in the time to takes to load, cover the distance, unload and return[10].

Given this developing need for a airlift force of about a dozen or more large widebody transports, a useful opportunity exists to provide the RAAF with a substantial AAR tanker fleet. Equipping these aircraft with booms, hose/drum equipment and lower deck fuel cells, means that the ADF could exploit these airframes to plug a long extant gap in RAAF capabilities.

Therefore, by appropriate choice of aircraft type it is possible to address the developing needs for strategic AAR and strategic airlift with a single package of aircraft, which offers very significant economies across the board. It is reasonably safe to assume that the demand for the respective capabilities will not clash, since a scenario in which we are deploying and supporting UN peacekeepers is unlikely to overlap a situation in which we are conducting maritime strike or deterrence operations.

Because the performance requirements of a strategic tanker are more demanding than those for a widebody troop and freight transport, these must be the driving constraints in the choice of airframe. Therefore the following analysis focusses on meeting the needs of strategic AAR first and foremost.

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[10] The poor load bearing capacity and length of most runways in potential problem areas precludes the direct insertion of troops and supplies by any aircraft of substantial size, be it a heavy military transport or a widebody airliner. Therefore the only viable strategy is a two tier model, whereby the heavy lift aircraft deliver to the nearest airfield with a 747 rated runway, and C-130s are employed over shorter distances to deliver the payloads into the area of operations. Should a runway of suitable quality be available in the immediate vicinity of the problem area, the exposure of a high value asset such as a large transport to low calibre ground fire, shoulder launched SAMs or mortar attack on the ground must be questioned. Current US Army thinking is to restructure its assets so that everything can be lifted into a theatre by a C-17, and then moved inside the theatre by a C-130, which is entirely consistent with this two tier model. See Fulghum D.A., "Army Chief Stresses Agility, Firepower", AW&ST Oct 18, 1999, p36.

Aircraft Types for a Strategic Tanker/Transport Force

The choice of an airframe for a Strategic Tanker/Transport Force will necessarily involve some compromises in AAR capabilities and airlift capabilities. This is an inevitable reality where the only choice is the adaptation of existing airframe designs[11].

The capabilities required for an AAR tanker aircraft vary significantly with the intended mission profiles. Where combat air patrol endurance required is modest, at radii inside 500 NMI, the best choices are small or medium sized airframes. Under these circumstances, smaller amounts of fuel offload are required, and, within a given budget, larger numbers of such tankers can be procured giving much greater flexibility in operational planning. The benefits of this flexibility are immediately realised when supporting small reactive defensive combat air patrols, or defensive point intercepts beyond the range of the combat air patrol fighters[12]. A small to medium tanker also enjoys economies in operating costs[13]. By comparison, larger tankers not only incur higher costs for shorter range, small-offload missions, but they also require greater runway strength and length, the latter assuming similar generation powerplants. The higher unit cost of larger platforms also limits numbers with a concomitant loss of operational flexibility, although savings will be achieved through reduced crew numbers and reduced training costs. However, as we extend the required combat air patrol endurance to several hours, at combat air patrol station radii of the order of 500 NMI or more, or consider point intercepts to radii well in excess of 500 NMI, the fuel offload performance of the tanker aircraft becomes increasing important. These conditions decisively favour larger airframes.

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[11] It should be noted that the argument of "waiting around until a production tanker/transport which meets ADF needs is available" argument is unrealistic, if not naive. The only large sustained builds of tankers were the USAF orders for the KC-135 and the KC-10, decades ago. All other tanker builds involved the conversion of small batches of used commercial aircraft for this application.

[12] Whilst this approach may be attractive to some in the ADF who may favour a strictly reactive and thus defensive employment of air power, it does not represent the best application of our numerically modest fighter assets.

[13] This discussion will not consider small and medium sized tankers in detail, due to their very limited utility. Tanker conversions of most C-130 variants are not competitive for high offload missions. The USMC KC-130R/T variant offers only 1000 nautical mile (1,852 km) radius with 45,000 pounds of fuel (20,430 kilograms). While the KC/C-130J would improve on this, the gain would be incremental. Refer web page, Headquarters Marine Corps, Division of Public Affairs, (http://www.usmc.mil/).

It must be stressed that in the context of the public defence debate, proponents of small and medium sized tankers can correctly argue that big strategic tankers will cost more to operate per aircraft in training use, and they may find allies, as noted, in those individuals who insist upon the purely reactive application of the RAAF's fighter assets.

Figure 2. Boeing KC-135R Stratotanker. The upper picture shows tanker to tanker refuelling, the lower picture the use of wingtip mounted Mk.32B pods to refuel probe equipped USN F-14 fighters (USAF).

However in any wartime situation, small to medium sized tankers lack the offload performance to support large strike packages over substantial distances without the substantial use of tanker to tanker refuelling. The classical case study of what happens with small tankers when long range sorties are required is the 1982 Black Buck series of Vulcan strikes during the Falkland Islands war, where typically fifteen Victor tankers were required to support a single Vulcan bomber !

To robustly maintain a combat air patrol of respectable size for several hours at an on station radius of 500 NMI or more, and sustainably repeat this process as needed by operational circumstances, will require genuine strategic[14] tankers. This is a fundamental reality which cannot be escaped.

The issue of flexibility and training costs could be offset to a large degree by the adoption of a two tier model, in which a heavyweight large widebody airframe is employed for the operational strategic tanking role, and heavy airlift. A much smaller narrowbody aircraft with low offload performance and low fuel burn is then employed in small numbers for the reactive, low offload role, and for most of the training activity. The latter requirement could be fulfilled by re-engining the extant Boeing 707-338C with the highly fuel efficient CFM-56, and by fitting booms[15]. A costlier alternative in the short

[14] We use the term “Strategic Tanker” to describe a tanker delivering offload performance in the class of 75-110 tonnes, at a 2,000 NMI offload radius. The KC-10A is an example of such an aircraft. The offload performance for Boeing 707 and KC-135 variants is modest, in comparison. The former typically offloads about 25-55 tonnes at 1,000 NMI, depending on engine fit, runway length and the presence or absence of lower deck fuel cells. The KC-135 is also sensitive to engine fit, with offload at 2,000 NMI varying between 33 and 41 tonnes across variants. The performance of the RAAF's Boeing 707-338C tankers falls to the lower bound, due to the absence of lower deck fuel cells, and the use of sixties technology JT3D-3B powerplants. Compared to large widebody tankers in the KC-10A or 747 class, at least twice as many KC-135 class tankers are required to deliver equivalent offload.

[15] USAF estimates are that the retrofit of the KC-135 fleet into CFM-56 powered KC-135R configuration resulted in a 27% reduction in fuel burn, which across the fleet resulted in an estimated saving of 2.3 to 3.2 million barrels of fuel, annually. Boeing were contracted to provide 432 CFM-56 retrofit kits. Other major life extension programs included the reskinning of the lower wing, for 746 C/KC-135 aircraft, completed in 1988 after running for 13 years, and the Pacer CRAG glass cockpit retrofit. Refer USAF fact sheet for KC-135, (http://www.af.mil/).

term, which yields a better return in fuel burn costs in the longer term, is the acquisition of a newer narrowbody airframe equipped with a boom and a fuselage hose/drum/drogue unit. Two obvious candidates would be the KC-757 proposed by Boeing as a KC-767 supplement, or a variant of the Boeing 737, i.e. a KC-737. Both of these aircraft provide excellent operating costs, the 737 is widely used in Australia, the 757 offers common cockpit ratings to the 767, which is also widely used in Australia. Both would incur the expense of a new AAR conversion design and testing[16].

Type	C-130H	C-141B	C-5	C-17A
Manufacturer	Lockheed	Lockheed	Lockheed	Boeing
Payload Height [m]	2.81	2.77	4.11	3.76-4.11
Payload Width [m]	3.12	3.11	5.79	5.49
Payload Volume [m^3]	127.4	322.7	985.3	592.0
Maximum Payload [t]	~20.0	30-40	118.4	78.1

Sources: Boeing, Jane

Table 1.

The capabilities required for a strategic airlifter also vary with the intended mission profile. Where the transport of personnel and palletised supplies are the principal priority, and long runways of adequate strength are available, widebody passenger transports and freighter conversions of such types are the cheapest and most practical choice. However, if we wish to move heavier equipment items such as the ASLAV (LAV-25) armoured personnel carriers, artillery pieces, or even very large items such as Main Battle Tanks (MBT), the demands upon the aircraft in terms of cargo bay floor strength and loading door sizes increase significantly.

In practical terms this is reflected in established types of aircraft used for the AAR tanker and strategic airlift requirements. The KC-135 reflects optimisation for AAR operations, with a secondary personnel and freight carrying capability[17]. The KC-10A reflects a requirement which combined AAR support for fighters on long deployments, with the associated ground support equipment carried as freight, to reduce demands upon dedicated airlift assets. The C-141, C-5 and C-17 reflect

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16 The fuel burn of the 737 is of the order of 6,000-7,000 lb/hr (2.7-3.2 tonnes/hr), for the larger 757 fuel burn is of the order of 10,000 lb/hr (4.5 tonnes/hr).

17 The KC-135R is limited by floor strength to a mere six palletes, each at 2 tonnes gross weight.

optimisation for the strategic airlift requirement, with no secondary capability to provide AAR.

The dilemma for the ADF in selecting a type lies in finding a suitable compromise which provides sufficient capability in both AAR and airlift to be able to address the requirements of both roles adequately. Since the only production strategic airlifter at this time is the C-17 which is both too expensive, too capable, and lacks the payload-radius and thus offload performance for genuine strategic tanking, the only practical choice is an adaptation of a commercial widebody airliner airframe[18].

In a sense the ADF has little if any choice in this game, since the acquisition of a large number of medium sized tankers would not be competitive against a smaller number of heavyweight tankers, given the need to offload large amounts of fuel at long ranges. Deploying such a fleet in parallel with dedicated airlifters would clearly involve prohibitive expenditure.

A significant operational benefit to the use of a common type is that when performing the airlift role, the aircraft can refuel their own fighter escorts, thereby reducing the temptation an opponent may have to sortie a long range fighter such as the Su-27/30 to engage the airlift. In effect, a heavyweight strategic tanker/transport opens up the possibility of an "aerial convoy", whereby the transports are accompanied by their own escort fighter force.

The considerations which must be applied in the selection of an aircraft type may be summarised thus:

- The ability to support a refuelling boom, to tank the F-111, the F-16 (RNZAF, SAF, USAF), the F-15 (USAF) the Wedgetail AEW, USAF tankers and transports, and to avoid imposing constraints upon any fighter selected under AIR 6000.

- The ability to support one or more hose/drogue refuelling units, to tank the F-18 (RAAF, USN), the F-14 (USN), and to avoid imposing constraints upon any fighter selected under AIR 6000.

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[18] The future of the European FLA is rather unclear at this time, and the support of a Russian type such as the Il-76 or An-124 would be problematic, especially given the extant conflict of interest. There is also some speculation about a future KC-17A tanker/transport, but such an aircraft has yet to materialise even in glossy brochures. In terms of offload performance we could expect it to deliver much less than a KC-10A given its lesser payload-range performance.

- Sufficient offload performance to support strike packages operating to combat radii of 2,000 NMI or more, with a minimal number of airframes.

- The ability to support a receptacle to accept fuel from other boom equipped tankers, thereby improving operational flexibility.

- Best possible short field performance and minimal demands upon runway load carrying capability, and smallest possible span to maximise handling flexibility on the ground.

- Highest possible economic cruise speed and dash speed, to provide best possible flexibility and survivability.

- Four or three engines are preferable to two engines, for extended over water operations.

- Cabin volume for relief crews, and if possible for racks of supplementary communications relay equipment, such as satellite link or HF to UHF relays.

- Largest possible main deck internal volume, especially width and height, to accommodate bulky medium or low density freight.

- Sufficient lower deck volume to accommodate dedicated fuel cells and associated plumbing to provide a large, high flow rate AAR capability.

- Freight doors large enough to accommodate the ASLAV (LAV-25) and if possible, M-113 APCs. The ASLAV has a height of about 2.7 metres, a length of about 6.5 metres, and a width of about 2.62 metres. The M-113 has a height of about 2.4 metres, a width of about 2.7 metres, and a length of about 5.3 metres.

- Floor load bearing capability sufficient to accommodate the ASLAV (LAV-25) and if possible, M-113 APCs. The ASLAV weighs about 11 tonnes empty[19].

- Minimal requirements for additional maintenance support in Australia, thereby decisively favouring types already in service with local commercial operators.

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[19] The basic LAV-25/ASLAV weighs about 14 tonnes, fully loaded. A 2.44 x 6.05 metre pallete is limited to about 13.6 tonnes of weight.

- Minimal requirements for aircrew training infrastructure in Australia, thereby decisively favouring types already in service with local commercial operators[20].

- Minimal Non Recurring Expenses (NRE) to implement a freight handing conversion, involving floor strengthening, freight door installation and powered freight handling equipment installation. This will favour those types for which existing freighter and combi conversion programs are active.

- Minimal NRE to implement an AAR boom and AAR hose/drogue hardware installation. This will favour those types for which AAR tanker variant conversions have been performed, and are or have been flown operationally.

- Should used airframes be employed, these should have preferably been used for long haul operations to minimise the number of accrued landing and takeoff cycles.

These criteria may be employed for comparing types which are currently available as new or used airframes in the commercial marketplace.

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20 Should a type used by an Australian commercial operator be chosen, reservists can be drawn from these operators with a minimal demand for currency training. Other important benefits, discussed further, also accrue.

Type	KC-10A (DC-10-30CF)/ KDC-10-30CF	MD-11F	B767-300F/KC-767	A310-300/MRTT	B747-200F/ B747-300F/ (KC-25A)	B747SP	B747-400F
Role	Tanker/Transport	Freighter	Tanker/Transport	Tanker/Transport	Freighter	Airliner	Freighter
Manufacturer	Boeing	Boeing	Boeing	Airbus Industrie	Boeing	Boeing	Boeing
Empty Weight[kg]	109,328	118,160	85,275	114,000	169,690	151,454	180,622
MTOW[kg]	267,620	273,294	186,880	164,000	351,500	~317,515	362,880
Internal Fuel[L]	~200,000	146,170	91,535/128,000	97,300	198,390	190,625	204,330
Design Payload[kg]	76,843	92,200	54,885	34,000	90,000		129,210
Design Range[km]	7,032	6,770	6,055	7,400	8,426	11,340	8,060
Fuel Offload [kg/km@radius hr]	~85,000/3,540 (-)	~KC-10A	47,600/3,520	50,000/926 (2)	~95,000/3,520	~80,000/3,520	-
Main Deck[m^3]	~335	440	339.50	210.00	604.5	PAX Only	604.5
Lower Deck[m^3]	N/A	140.9	102.00	102.1	158.6	109.3	158.6
Total Volume[m^3]	~335	568.4-602.8	454.00	312.1	601.4	~580.0	777.8
Cargo Door	Side	Side	Side	Side	Nose, Side	None	Nose, Side
First Flight	1980, 1986 (1996)	1990	1986/TBD	1985/TBD	1972	1975	1988
Military Users	USAF, RNeAF	None	Proposed	Proposed	USAF, Iran	None	None

Sources: Boeing, Jane

Widebody Tanker/Transports

Table 2.

Table 2. summarises the salient characteristics of available commercial types for which boom equipped AAR tanker and freighter conversions exist, or have been proposed by vendors.

The *Boeing DC-10/MD-11* family of aircraft are the basis of the USAF KC-10A Extender, and the Dutch RNeAF KDC-10-30CF tanker transports. These aircraft provide suitable offload performance if equipped with lower deck fuel cells, and load carrying capability for both AAR, freight and personnel airlift roles.

Figure 3. Boeing KC-10A Extender (USAF).

Figure 4. RneAF Boeing KDC-10-30CF (Boeing).

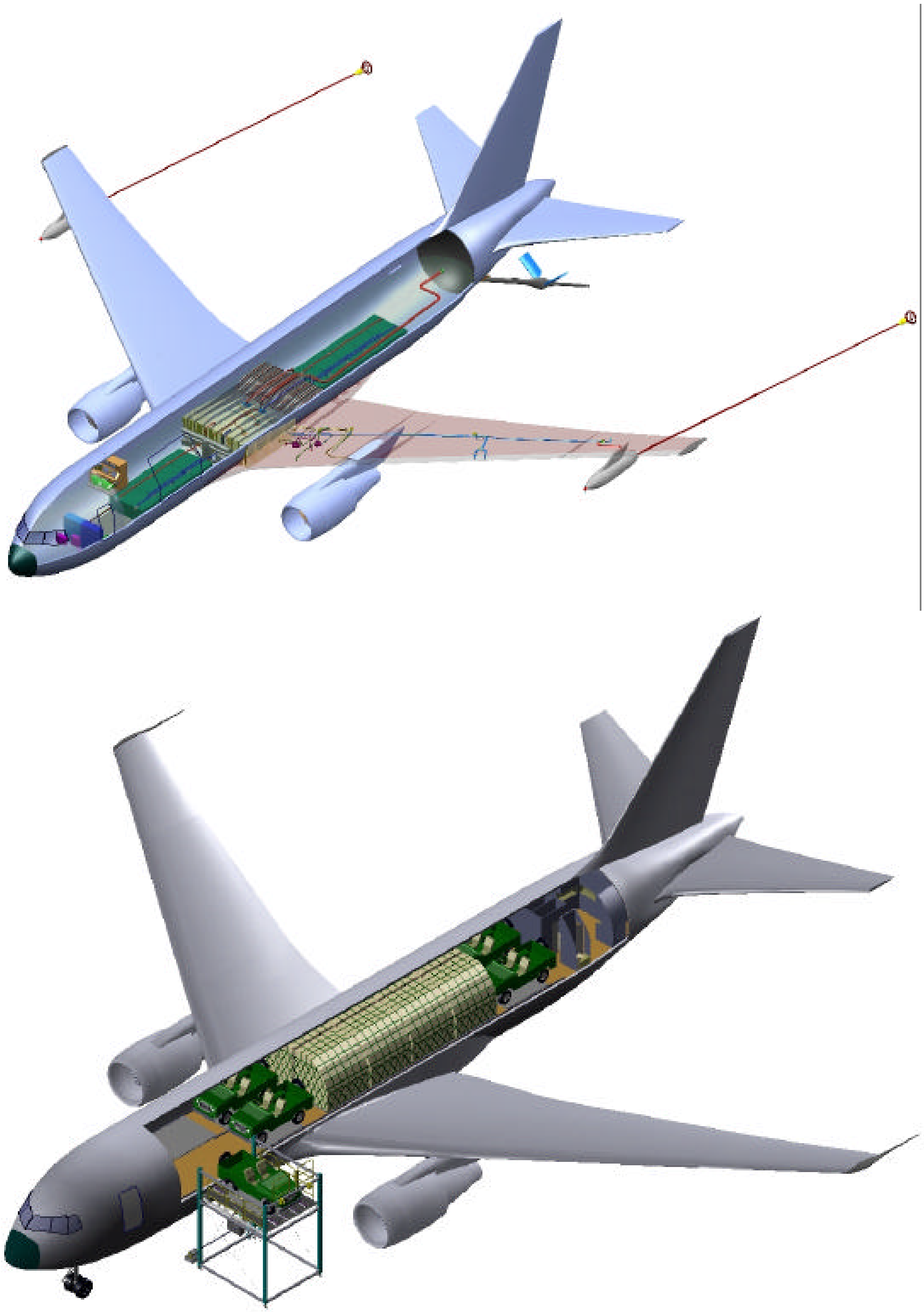

Figure 5. Boeing KC-767 Tanker/Transport (Boeing)

The USAF KC-10A has been flight tested with a pair of wing mounted Mk.32B refuelling pods, in addition to the internal Sargent Fletcher hose/drum/drogue unit and the AAR boom installation[21]. The current

[21] Boeing have modified to date only 20 KC-10As for Mk.32B pod installation.

build MD-11 and DC-10-30 and -40 can be readily adapted as freighters, as Boeing maintain an active conversion program. The available lower deck floor strength provides for about 42 tonnes of auxiliary fuel in the DC-10-30/40 models, and about 50 tonnes of auxiliary fuel in the MD-11 models.

Type	KC-10A/ DC-10-30CF/ KDC-10-30CF	MD-11F	B767-300F/KC-767	A310-300/MRTT	B747-200CF/ B747-300CF/ (KC-25A)	B747SP	B747-400F
Manufacturer	Boeing	Boeing	Boeing	Airbus Industrie	Boeing	Boeing	Boeing
MTOW[kg]	267,620	273,294	186,880	164,000	351,500	~317,515	362,880
Design Payload[kg]	76,843	92,200	54,885	34,000	90,000	38,000-45,000	129,210
Design Range[km]	7,032	6,770	6,055	7,400	8,426	11,340	8,060
Main Deck[m^3]	~335	440	339.50	210.00	604.5	~470.0	604.5
Lower Deck[m^3]	N/A	140.9	102.00	102.1	158.6	109.3	158.6
Total Volume[m^3]	~335	568.4-602.8	454.00	312.1	601.4	~580.0	777.8
Side Cargo Door [m]	2.59 x 3.56	2.59 x 3.56, 2.59 x 4.06	2.64 x 3.4	TBD	3.05 x 3.4	None	3.05 x 3.4
Nose Cargo Door [m]	None	None	None	None	2.49 x 2.64	None	2.49 x 2.64
ASLAV (LAV-25)	No (height)	No (height)	No (height, length)	No (height)	Side Door	N/A	Side Door
M113	Possibly (height)	Possibly (height)	No (length)	No (height)	Side Door	N/A	Side Door
Unimog 2450L 6x6	No (height)	No (height)	No (height, length)	No (height)	Possibly (length)	N/A	Possibly (length)
Unimog 4x4	No (height)	No (height)	No (height, length)	No (height)	Side Door	N/A	Side Door
Perentie 6x6	No (height)	No (height)	No (height, length)	No (height)	Side Door	N/A	Side Door
Perentie LRPV	Yes	Yes	No (length)	Yes	Both Doors	N/A	Both Doors
Perentie 4x4	Yes	Yes	Yes	Yes	Both Doors	N/A	Both Doors

Sources: Boeing, Jane

Notes: Paper fit checks only, require confirmation via load check, "possibly (dimension)" denotes a very tight fit on specified dimension.

Widebody Tanker/Transports - Freight Compatibility

Table 3.

However this family of aircraft is not operated in Australia, and thus there is no established base of aircrew nor any domestic support infrastructure. Moreover, the standard freight door is not of sufficient height to load Army APCs, thereby limiting the usefulness of the aircraft in airlift operations to personnel, freight and small vehicles.

For these reasons the DC-10/MD-11 family of aircraft are not a particularly suitable choice for this application.

The *Boeing 767* family of aircraft, specifically the –200C/F, -300C/F and –400C/F models, have been proposed by Boeing as a replacement for the KC-135 family of aircraft, and have been vigourously marketed by Boeing. However at this time no AAR tanker conversion exists, and significant NRE would be incurred. In terms of offload performance, the proposed Boeing KC-767 modestly outperforms the standard KC-135R.

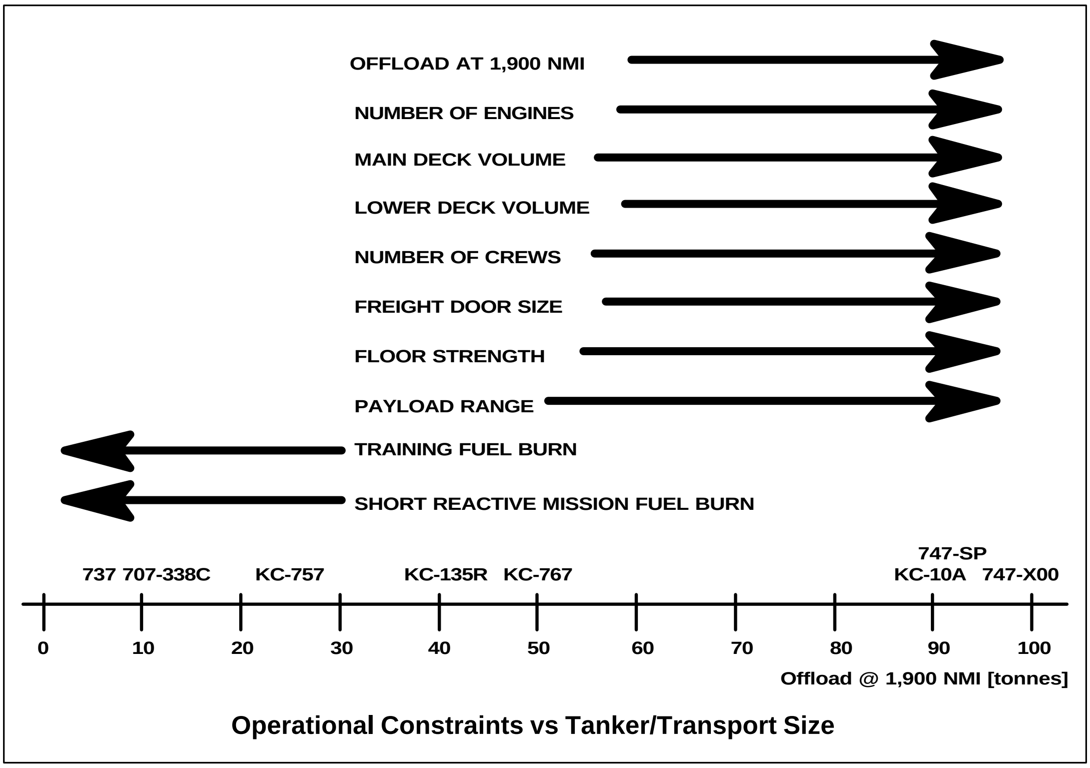

Figure 6.

Therefore, for a smaller fleet the KC-767 is inadequate for the outer radius envelope and thus not competitive with a larger widebody airframe such as a KC-10A. The other important limitation of the KC-767 is the limited freight door size and main deck width which preclude the loading of Army APCs. Current costs in the used aircraft market for the 767-300ER vary between USD 51M and 88M, depending on the age and condition of the aircraft[22]. In terms of speed its Mach 0.8 performance is modest, compared to the Mach 0.85 or better performance of the RAAF's Boeing 707 aircraft.

Therefore the KC-767 is not a good fit for the defined requirements.

The *Airbus Industrie MRTT (MultiRole Tanker Transport)* is a variant of the established Airbus A310-300 or -600 series airframe, which has been proposed and actively marketed as a European alternative to existing US AAR tankers. At this time no AAR conversion exists, and significant NRE would be incurred. This aircraft falls below the Boeing 767 in offload performance and would also be marginal in the airlift role.

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[22] Morton, Beyer & Agnew (MBA), "Future Aircraft Values", 1999 Edition, p 56.

The remaining large widebody type to consider is the *Boeing 747*.

The Boeing KC-25/KC-747 Strategic Tanker/Transport

The *Boeing 747* family of aircraft is used both by Qantas and Ansett in Australia, and Air New Zealand. The Boeing 747 design is a derivative of a sixties Boeing proposal for a military airlifter, which 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 program, losing out to the McDonnell Douglas proposal despite its superior performance.

Figure 7. Imperial Iranian Air Force (IIAF) Boeing KC-25/ KC-747-100 Strategic Tanker/Transport refuelling an IIAF 747-100 (Boeing).

Several AAR boom and receptacle equipped 747-100 tankers were supplied to Iran[23] during the mid to late seventies and a number of US military variants exist with AAR refuelling receptacles[24]. Against

[23] 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 the retrofit of the basic KC-135 boom to the 747 incurs minimal NRE. The Iranian aircraft employed an operator behind a rear fuselage window as per the KC-135 design. A cheaper alternative to produce, with some NRE involved, would be a 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 which is shown in Figure 8.

[24] US military 747-200B variants are designated C-25A, such as the VC-25A "Air Force One". The designation C-19A is reserved for 747-100 aircraft committed to

its nearest competitor, the DC-10/MD-11, it cruises faster at Mach 0.85, specific performance depending on the engine types fitted and conditions.

Figure 8. KC-135R Improved Refuelling Boom structural assembly. The "old" KC-135 boom structural tube (upper) has been replaced with a newer single piece extruded component (lower). Externally the appearance of the boom is unchanged (Boeing).

Therefore this aircraft is the only type which satisfies the requirement of an existing domestic operator base, the requirement for an established boom equipped AAR conversion, and delivers the long range AAR offload performance and volumetric requirements of the AAR and airlift roles, respectively.

Freighter conversions of the four basic versions are very widely used in the commercial air freight market, indeed the current industry trend is for older 747-100 and -200 airframes to be retrofitted into freighter configuration by the addition of a large aft fuselage Side Cargo Door (SCD), and installation of the freighter floor[25].

A simple measure of the Boeing 747 against other established tankers is that it delivers offload performance potentially superior and

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the CRAF scheme. Therefore a 747-200B tanker/transport variant could be designated a "KC-25A", with a different suffix applied for a different 747 variant, i.e. "KC-25B" for 747-SP or "KC-25C" for a 747-300 model.

[25] Morton, Beyer & Agnew (MBA), "Future Aircraft Values", 1999 Edition, p 56, 143-144. Freight conversions are performed by Boeing Wichita, GATX-Airlog, Pemco Aeroplex, Israel Aircraft Industries and HAECO with costs depending on the scope of the conversion package. Typical costs are between USD 12M and 20M per airframe.

payload-range superior to the KC-10A Extender, yet it is fast like the KC-135R or Boeing 707 tankers[26].

Figure 9. The IIAF KC-25/KC-747-100 boom installation under test. This is an unusually clean installation, with the operator's station recessed in the fuselage. Note the fuselage stiffeners (Boeing).

Five basic models of this aircraft exist, manufactured from about 1970. The 747-100 and -200 are the oldest models and given accrued airframe fatigue many airframes may not be a viable consideration for a large long term investment given the cost of airframe life extension[27]. The market value of 747-100 and older -200 aircraft

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26 The 747's Mach 0.84-0.85 cruise and typical step climb cruise profile between FL 310 and 390 is well matched to the F/A-18A and thus there is no requirement for the tanker to descend and slow down for AAR operations. For the F-111 a descent to FL 200 to 250 will be required, although the fuel burn penalty to do so will be reduced by the lower frequency of AAR operations required for the F-111.

27 Ibid, p137. Many late build 747-200 series aircraft will have acceptable fatigue life and the following analysis and conclusions for the 747-200/300 series would apply to these. The last -200F freighters were built during the early nineties. Typically the fatigue life of older 747s can be extended through Section 41 reworks, and Pylon and D checks, with the cost of such a work package reaching up to USD 10M per aircraft. Engine overhauls typically cost USD 1.5M each at intervals of 1,200 to 1,500 cycles.

varies between USD 4.6M and 7.7M, with later build 747-200 variants commanding between USD 13.8 and 26.2M apiece[28].

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. Of particular interest is the fact that at this time there is a glut of used 747-200B and -300 aircraft in the market, of which a good proportion are Combis, which 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[29]. Given the saturation of the market, it may be feasible to acquire aircraft at prices well below the actual value of the aircraft.

The extended upper deck on the 747-300 series aircraft 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 fore of the wing, thereby imposing some limits on the carriage of taller freight items. A 747-300 is thus more flexible in terms of its ability to mix freight and troop loads, but is less flexible in the mix of freight item sizes it can accommodate, in comparison with a 747-200 derivative.

The 747-400 is the current production model, introduced in the early nineties, 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 wingspan 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[30].

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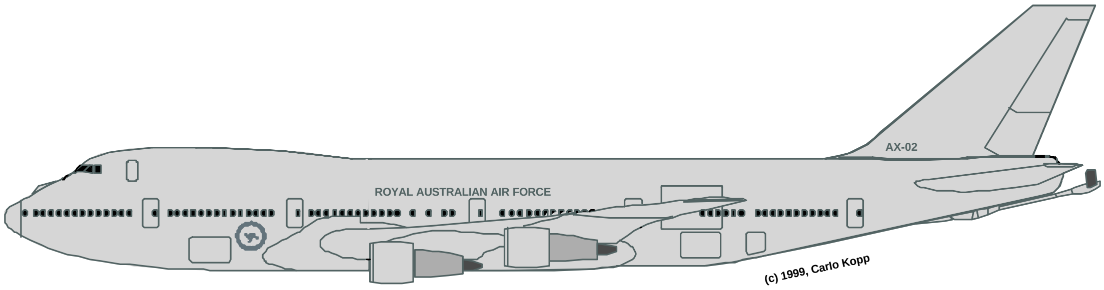
28 Ibid.

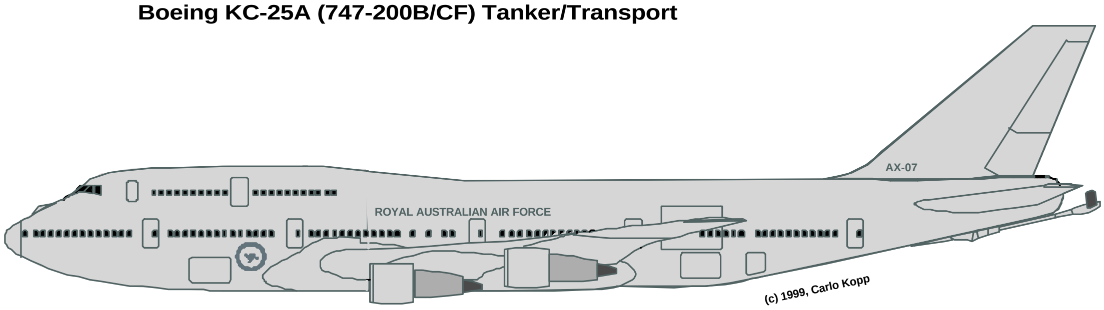
29 Ibid, also "Current Period Airliner Values", Australian Aviation, September, 1998, p8.

30 Ibid.

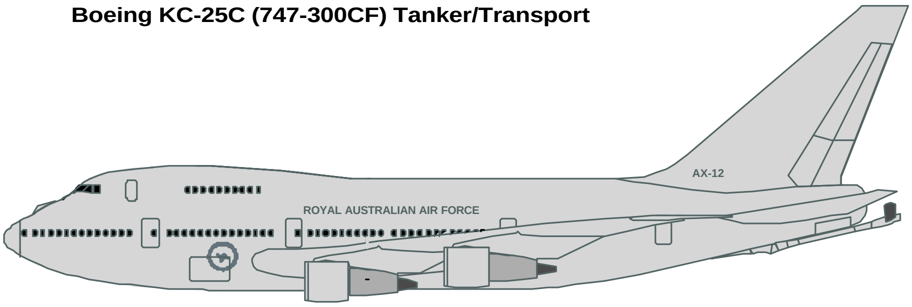
The lower deck volume of the -100/200/300 and -400 models available for container freight provides ample space for additional auxiliary fuel cells, which would be essential to extract the full offload potential of the aircraft as a tanker. Since intercontinental variants of the 747 carry a generous internal fuel load, at MTOW for most variants only about 20 to 40 tonnes would need to be carried in auxiliary lower deck fuel cells, with crossfeed from the main tank employed[31]. Offload performance at a 1,900 NMI radius would be about 95 tonnes of fuel or better, for a Combi or Freighter configuration with lower deck auxiliary fuel cells. Such performance is superior to the KC-10A.



Boeing KC-25A (747-200B/CF) Tanker/Transport



Boeing KC-25C (747-300CF) Tanker/Transport



Boeing KC-25B (747-SP) Tanker/Transport

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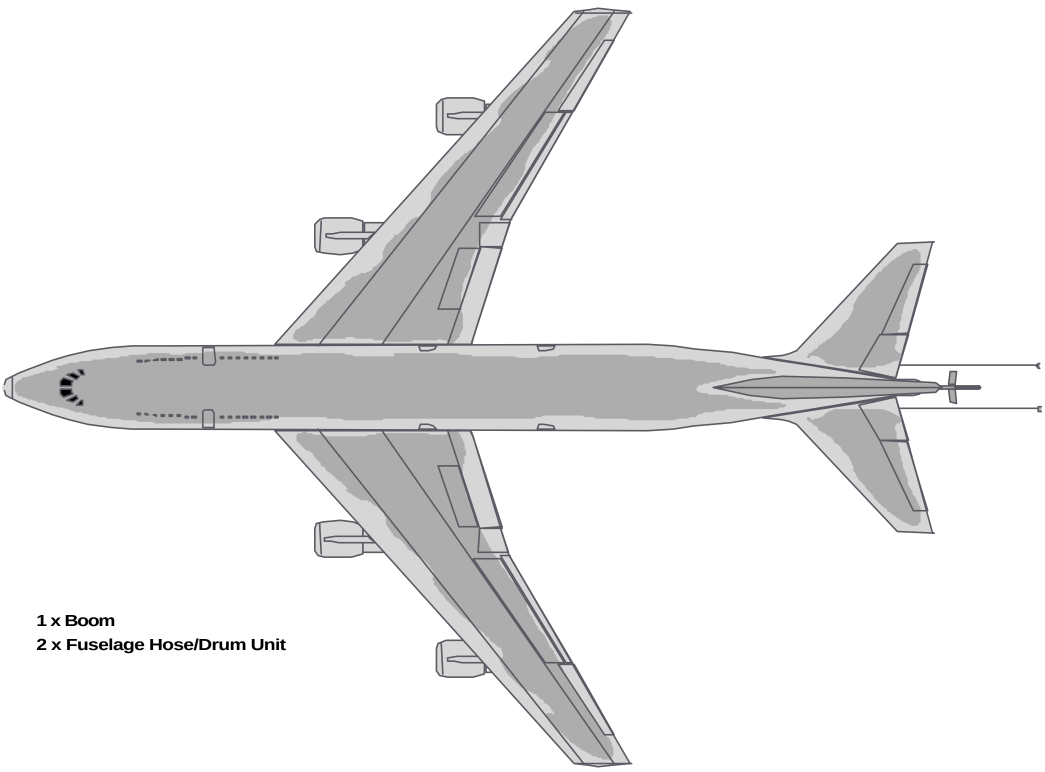
31 747 Airplane Characteristics, Boeing Commercial Airplane Company, Document D6-58326, 1984, Sections 2 and 3. A typical implementation for a lower deck fuel cell would resemble a reduced height LD2 type freight container. Without potentially expensive structural reinforcement of the lower lobe floor, the auxiliary fuel cells are weight rather than volume limited. The aggregate gross weight limit for fore and aft lower lobe compartments is 47.7 tonnes, assuming an evenly distributed load, which bounds the available capacity of lower deck tanks. The US FAA requires the tanks withstand loads of 9G. Typical contemporary implementation employs a rigid double walled tank design, rather than the older " fuel bladder inside a metal box" style.

Figure 10. Comparison of proposed Boeing KC-25/747 Variants (Author).

The Boeing 747SP is a high performance, lightweight, long range variant, manufactured between 1976 and the late eighties. Only 45 were 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.



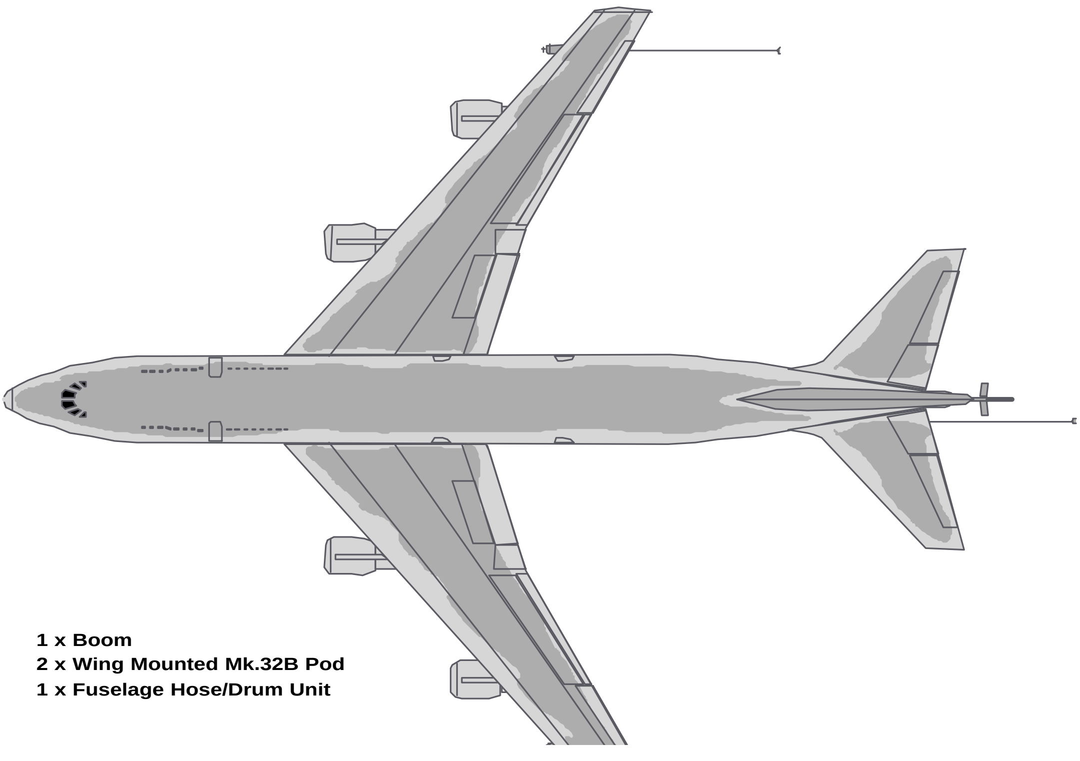


Figure 11. Boeing KC-25 (747-200/300CF) Tanker/Transport Refuelling Points (Author).

As the -400 has penetrated into the commercial market, the demand for the 747SP has fallen very strongly and as of July, 1999, seven were in storage and four dismantled for structural spares. Qantas continues to operate two examples. No less than fifteen 747SPs are currently on the market, including some VIP transports, with a unit cost cited between USD 5.3M and 7.7M apiece[32]. Because of the poor profitability of the 747SP on most routes, it is considered to be worth more as scrap than as an commercial asset. As the 747SP was almost exclusively used 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[33].

However, the general condition of many of the available aircraft is unclear, and considerable refurbishment, and corrosion repair effort may be required in addition to the required AAR hardware modifications. Providing that candidate airframes are adequately investigated prior to purchase, the risk can be managed reasonably precisely.

The 747SP has the best short field take off performance of any 747 variant. Most large widebodies require about 3,100 metres of runway, the 747SP requires 2,350 to 2,750 metres at MTOW[34], reflecting the lower MTOW and load carrying performance of this variant.

As a tanker the 747SP provides an internal fuel capacity of 148 to 153 tonnes, and lower lobe floor strength to accommodate about 30 tonnes of auxiliary fuel. Given existing MTOW limits on the aircraft this yields about 74-80 tonnes of offload at 1,900 NMI which is competitive performance against the KC-10A. Clearing the aircraft for a 4% increase in MTOW would bring offload closer to 85 tonnes under these conditions[35].

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[32] Morton, Beyer & Agnew, p56, also "Current Period Airliner Values", Australian Aviation, September, 1998, p8.

[33] Typically between 9,000 and 13,000 cycles on aircraft aged around 18 years, numbers more typical for 747 aircraft of 12-15 years of age.

[34] Refer 747 Airplane Characteristics, Boeing Commercial Airplane Company, Document D6-58326, 1984, Sections 2 and 3. Exact performance will depend on the engine types fitted, and the aggregate weight of any other modifications carried by the aircraft.

[35] Ibid. Exact offload performance will depend on the engine types fitted, and the aggregate weight of any other modifications and payload carried by the aircraft.

The limitation of the 747SP as a tanker/transport airframe is its low structural payload limit of 38 tonnes in the standard configuration, and the need to perform a Combi or Freighter conversion, neither of which were standard build options. A production option was an increased structural payload limit of 45 tonnes, and it may be feasible to further improve upon this. The issue is thus the NRE of such structural work, and the NRE associated with adapting the standard 747-200/300/400 freight floor and SCD installation. Given the low cost of basic airframes, such modifications are well worth exploring, especially since they are based upon standard components used in the 747-200B/CF/300CF freighter conversions.

In terms of initial acquisition costs and performance as a pure tanker, the most suitable 747 variant is the 747SP. With lower deck fuel cells its offload performance is competitive against the KC-10A, yet the cost of the basic airframe is 1/4 to 1/3 of current DC-10-30CF costs, and it offers superior short field performance and cruise speed. This competitive advantage must be balanced against its limited performance as a freighter, typically of the order of 40% to 50% of the structurally limited payload of a 747-200/300 series aircraft, and 50% to 60% of a KC-10A aircraft.

Biasing the requirement toward airlift, and factoring in availability and fatigue life, the most suitable 747 variants for a strategic tanker/transport role would be the 747-200B/CF/300CF, should examples with suitable maintenance histories be selected.

An issue for any Boeing 747 AAR tanker conversion will be the provision of hose/drogue refuelling hardware, as no current user (Iran) has had such fitted. The simplest alternative is the installation of one or two fuselage hose/drum unit, in a manner akin to the KC-10A or RAF Lockheed Tristar, preferably using the same hardware[36]. Refuelling of the C-130J and larger RAF assets imposes the constraint that such a fuselage installation be used.

The need for redundant hose/drogue systems to account for possible failures enroute indicates that the preferred configuration would employ either a pair of fuselage hose/drum units, or a three point arrangement with a single fuselage hose/drum unit and a pair of wing mounted Mk.32B pods as used on the RAAF's Boeing 707-338Cs. The latter would be more attractive operationally but a much more expensive choice since the overheads of design, wing modification to accommodate fuel lines, and flight testing would be incurred[37].

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[36] An alternative would be a Mk.32B pod mounted on an offset rear fuselage pylon, in a manner similar to pods on the Il-78 Midas.

[37] The Engineering, Manufacturing and Development contract for adding wing-mounted "hose and drogue" refueling pods to the KC-135R Stratotanker cost

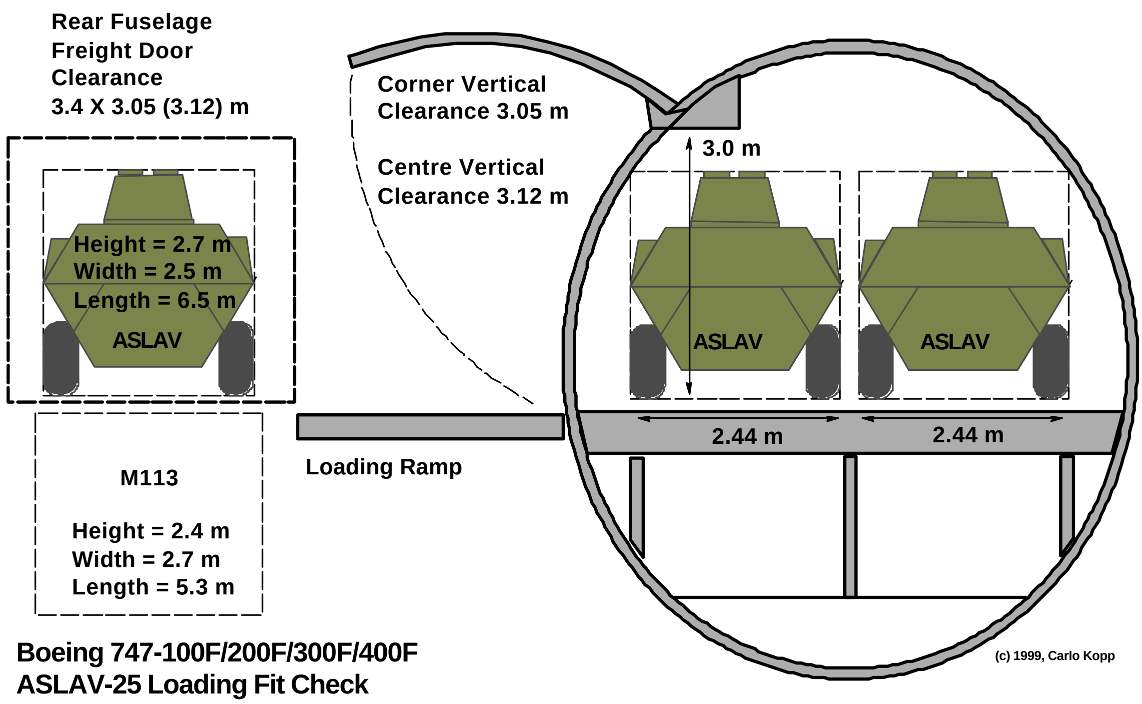

Figure 12. Boeing 747 Main Deck Geometry for ASLAV (Author).

A very attractive aspect of the standard Boeing 747-200CF/300CF and 400F Combi and Freighter conversions is the size of the standard rear fuselage SCD freight door. It provides a vertical clearance suitable for a 3 metre high load, and a horizontal clearance suitable for a 2.5 metre wide load[38]. The floor width is 6.13 metres, which means that on paper both the standard ASLAV and M-113 can be loaded, albeit with some care required during insertion. Clearances will need to be verified by a load check since the ASLAV is 18 cm wider and 45 cm longer than the standard 2.44 x 6.05 metre freight pallete. Specialised

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approximately USD 24.4M. Refer "Boeing Defense & Space Group Wins KC-135 Multi-point Refuelling System Contract", WICHITA, Kansas, Press Release, Oct. 10, 1995. The cost of conversion kits to fit Mk.32B pods to USAF KC-135R aircraft is about USD 2.55M per aircraft, excluding the cost of the pods. The cost for a KC-25/747 kit would be slightly higher due to the longer fuel lines required. Refer "Boeing Awarded $23 Million For KC-135 Refueling Pod Production Kits", Press Release, Boeing, WICHITA, Kan., Jan. 20, 1997. Given that Boeing have performed the adaptation of both the KC-135R and KC-10A for wing mounted Mk.32B pods for the USAF, it is reasonable to assume that much of the design work could be directly adapted to a KC-25/747 design, thereby reducing the magnitude of the NRE required. The all up cost of equipping a dozen KC-25/747 aircraft with pods would be thus of the order of USD 50M, excluding the cost of 24 pods and appropriate spare components.

38 The door is 3.4 metres wide, but some allowance must be made for swinging the load around as it is inserted. Refer Table 1. for comparsion with the C-130, C-141, C-5 and C-17.

variants of the ASLAV, such as the command vehicle and ambulance may not fit through the 747 freight door due to their bulkier and higher profile.

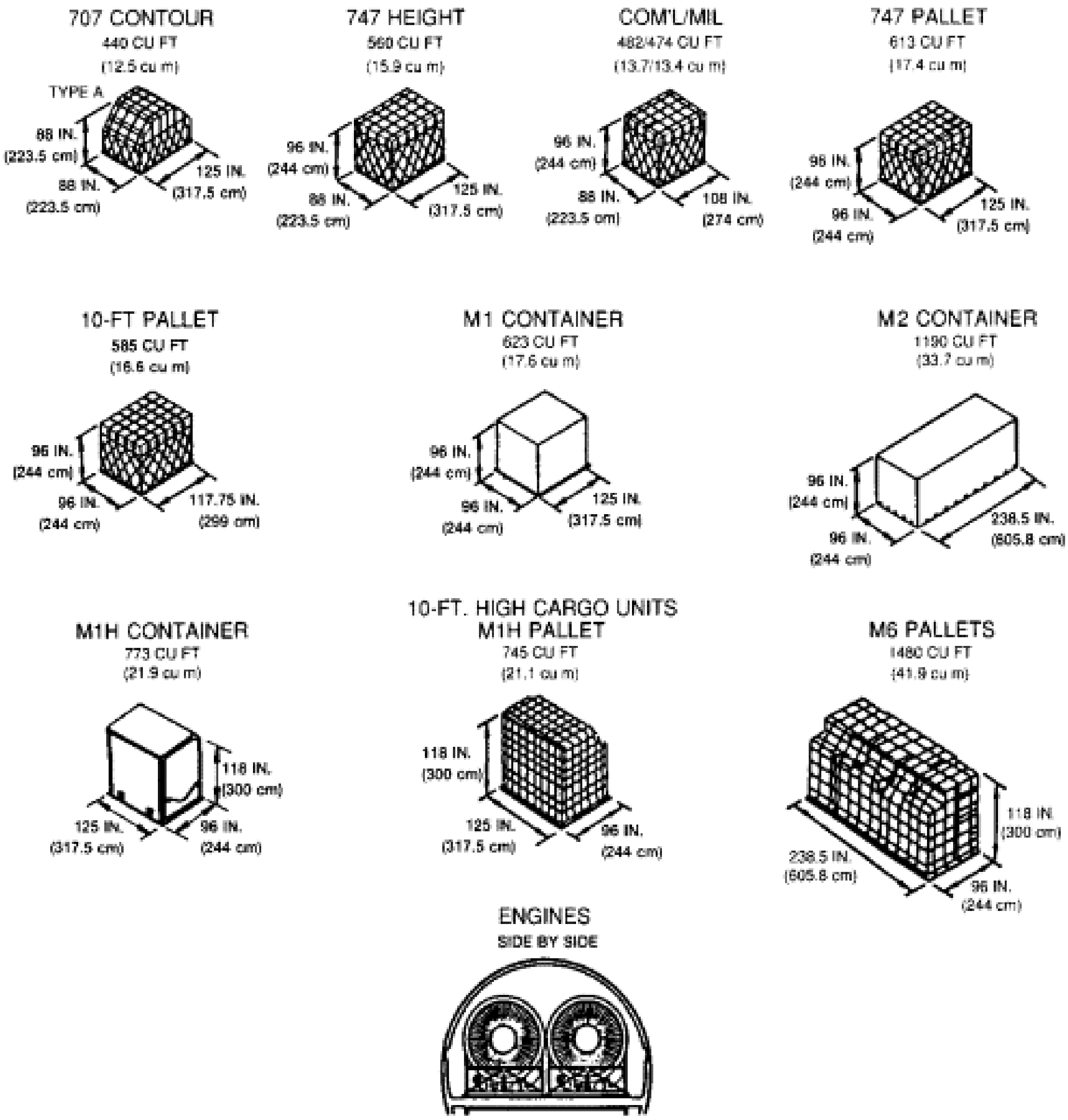
Unlike a conventional military airlifter allowing Roll-On / Roll-Off (RORO) loading, the Boeing 747 would require that the ASLAV be first tied on to a 6.05 metre pallete, and then handled and loaded into the aircraft as if it were an 11 tonne, 6.05 metre contoured freight container[39]. Since the vehicle is slightly longer than the standard pallete size, the locked down positions of the pallete would have to be slightly different to a standard load of 6.05 metre containers or palletes. On paper, this arrangement would allow four or more ASLAVs to be loaded, side by side, together with other freight[40].

Figure 13. KC-10A Freight Loaders (USAF).

[39] We envisage that a forklift would be used to load empty palletes on to the loader, for roll-on loading of the vehicle on to the pallete. Once the vehicle is secured to the pallete it may be loaded into the aircraft. For unloading, the "palletised" vehicle is released off the pallete and driven away, and a forklift is used to remove the empty pallete from the loader.

[40] This is a paper analysis and is not a substitute for lashing an ASLAV to a pallete and confirming that it can be loaded cleanly.

Unlike conventional military airlifters which have loading ramps and a very low floor height, the Boeing 747 requires specialised support equipment for loading and unloading. The height of the 747 main deck is between 4.67 and 5.33 metres, depending on the weight of the aircraft. Therefore, if the aircraft were to be operated into airfields which are not equipped to handle containerised freight, such equipment would need to be either prepositioned, carried in by the 747 strategic transport, or delivered by other aircraft prior to the arrival of the 747 strategic transports. Ground based loading equipment may be fully mobile container handling equipment, or much cheaper collapsible frame container and pallete elevators, like those employed by the USAF and depicted in Figure 13[41].



41 The USAF have recently deployed the Tunner 60,000 lb mobile loader, in addition to the collapsible frame loaders. The Tunner and much smaller 25K mobile loader are both described in Appendix C.

Figure 14.

New build Boeing 747-200CF/300CF/400F Freighters and many Combis have been delivered with a lifting Nose Door, similar in concept to that used on the C-5 Galaxy. This door has size limitations, primarily the vertical clearance limit of 2.49 metres imposed by the floor of the cockpit and upper deck section. This is inadequate for the ASLAV but may be sufficient for the M-113. It would however be convenient for roll-on/roll-off loading and unloading of 4WD vehicles and smaller trucks with heights under 2.45 metres, using a loader to lift them level with the aircraft main deck.

Figure 15. Boeing 747-200F Freighter Nose Door installation being used for container loading. Lufthansa were the lead customer for the 747-100F and remain a major user of the 747-400F (Lufthansa).

The Freighter/Combi Nose Door is however attractive insofar as it allows the aircraft, with minor modifications, to carry the Boeing On Board Loader device, which is stowed in the nose of the aircraft and deployed once on the ground to provide autonomous freight handling. This device takes 30 minutes to deploy or stow, weighs 6.6 tonnes and can handle payloads of up to 13.6 tonnes. When stowed it displaces two 2.44 x 6.05 metre containers or 6.7% of main deck capacity. The Boeing On Board Loader may be disconnected from the aircraft nose and used as a free standing loader. It is designed to load and unload 2.44 x 6.05 metre palletes or containers, using either the Nose Door or the Side Cargo Door. The loader is powered from the aircraft's electrical system at either door, or by a ground based generator[42].

This loader is not suitable in its basic configuration for the handling of the ASLAV and M-113 and will require some design changes for this purpose. A paper fit check indicates likely compatibility with a number of other Army vehicles. Modification of the loader design to increase its width and length will thus be required. Nominal time to load or unload an aircraft using this device is about one hour, assuming the device is already deployed.

An important limitation of the Nose Door is that the nose refuelling 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. Operational flexibility would be maximised should every aircraft be fitted with the Nose Door and a refuelling receptacle, and have appropriate modifications to carry the Boeing On Board Loader and operate it from both cargo doors.

The feasibility of retrofitting the Nose Door as part of the freight 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 Combis available in the marketplace. 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, whereby these are used to deploy one or more Boeing On Board Loaders into a site at the beginning of a lift. These loaders would be recovered at the end of the airlift. Other aircraft without Nose Doors would use the deployed loaders.

There may be some scope for faster reconfiguration time between the airlift and troop carrying configuration, by using dedicated 2.44 x 6.05 metre palletes fitted with fixed canvas troop seats, rather than commercial Combi airliner seating. This could be implemented in a manner which saves considerable weight, against commercial seating, thereby allowing more troops and freight to be loaded into the aircraft.

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[42] Refer Section 2, "747 Cargo Facility and Equipment Planning", Boeing Document D6-30108, August 1990. An interesting side note is that the design of the loader was paid for by the Iraqi national airline during the late eighties. They were the sole client for this piece of equipment. We can but speculate upon reasons for the Iraqis wanting to be able to load and unload large 13 tonne containers at unprepared sites. The loader is described in detail in Appendix C.

A simple measure of the Boeing 747-200CF/300CF/400F 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. 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.

An issue of some inconvenience is the absence of a door or hatch and internal ladder for crew and passenger access to the aircraft at sites without appropriately sized boarding facilities for airliners. The solution is to employ a modification used on the USAF's Boeing E-4 NEACP airborne command post and the VC-25A VIP aircraft. These aircraft carry a deployable set of airstairs stowed in the forward lower lobe cargo bay.

Figure 16. The VC-25A and E-4B both carry internal airstairs to provide crew and passenger access at sites without airliner boarding facilities.The airstairs deploy from the forward cargo door (USAF).

Installing deployable airstairs would remove at least one fuel cell in the forward bay. Given the load carrying capacity of the lower lobe lobe floor and MTOW limits in both the 747-200B/CF/300CF and 747SP models, this would not impair the potential offload performance, as a single cell amounts to 10% or less of the lower deck capacity.

Integration of the deployable airstairs will render some small portion of the main deck floor above the forward lower lobe cargo bay unusable for freight, so as to provide space for a hatch to access the airstairs. Since retractable stairs must be installed to provide access between the main deck and the upper deck, these should be located adjacent to the hatch to the airstairs to minimise the loss to main deck floor space.

The airstairs provide the ability to load and unload passengers, as well as providing access for the crew, regardless of site facilities and should be a serious consideration for all aircraft in the fleet. An E-4B with deployed stairs is depicted in Figure 16.

While a Boeing 747 based strategic tanker/transport is not the ideal solution for the strategic airlift requirement, it is an excellent basic platform for a strategic tanker, it is readily available via the modification of units from the large pool of used commercial airframes, and it is much more affordable than any new build alternative.

In terms of variants, it would appear that a mix of 747SP and 747-200B/CF/300CF models, given examples of suitable condition can be located, would be the most practical choice.

The 747-200B/CF/300CF is the better strategic tanker and transport by virtue of its higher MTOW, better offload performance and ability to carry heavy freight. The 747SP offers much lower initial acquisition costs, and slightly lower fuel burn[43]. It also offers better operational flexibility per total fleet offload performance and better short field performance, with the limitations of slightly lower unit offload performance, the inability to carry freight without modification and similar crewing and support requirements to the 747-200/300.

Therefore the 747-200/300 offers a better longer term return on investment, with a much greater initial acquisition cost. The proportions of any mixed fleet would therefore have to be based upon a careful analysis of the point in the fleet lifecycle where the difference in initial acquisition cost favouring the 747SP is balanced by the lower return in airlift capability given similar crewing and support costs.

Determining the number of aircraft to provide the capability will require some detailed modelling of AAR performance for the ranges in question, and some analysis of the airlift requirement. A first order estimate indicates that between 12 and 14 747-200/300 aircraft would be required, depending on the offload performance achievable for a given configuration, runway capabilities available and aircraft empty weight after the installation of AAR hardware and freight

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[43] A reasonable comparison of fuel burn costs between the 747 and established tankers can be made by comparing the typical cruise burn for the RAAF's 707-338C at 15,000 lb/hr (6.8 t/hr) with the 747 at 18,000 to 22,000 lb/hr (8.15 to 10 t/hr), allowing for a range of 747 engine fits and gross weights. Therefore the 747 burns about 20% to 47% more fuel per hour, yet delivers many times the offload performance of the 707-338C. Refer NATO ATP-56A (Annex 10A), 10A-1 and 747 Airplane Characteristics, Boeing Commercial Airplane Company, Document D6-58326, 1984, Section 3.

modifications. For the same fleet offload performance, 12 to 16 747SP aircraft would be required. Some spares would be required.

Learmonth would require a modest 10% runway extension to support the 747-200/300 at MTOW. The runway strength at Curtin is not adequate for high gross weight operations[44], and its remoteness makes the resupply of large quantities of fuel to support tanker deployment difficult. Darwin would provide a better runway than Tindal for 747-200/300 operations.

The 747-200/300 could be, according to Boeing-Wichita information, modified into a freight configuration with a lead time of only several months. Providing that the engineering effort to adapt existing AAR hardware is appropriately synchronised in time with the freight conversion, it should be feasible to cycle airframes through both modifications consecutively, to achieve the earliest possible Initial Operational Capability.

Conversion for this dual role capability would require the following modifications:

1. Installation of an AAR boom and operators' station.
2. Installation of two fuselage hose/drum/drogue units, or a single fuselage hose/drum/drogue unit and a pair of wing mounted Mk.32B pods.
3. Installation of AAR fuel pumps, valves, manifolds, plumbing and operator controls.
4. Installation of lower deck auxiliary fuel cells.
5. Installation of AAR receptacle for tanker-to-tanker refuelling.
6. Installation of single point ground refuelling receptacle for lower deck auxiliary fuel cells.
7. Installation of the forward lower deck internally stowed airstairs and retractable upper deck stairs.
8. Installation of at least two observers' bubble windows, replacing aft upper deck windows.
9. Installation of dual TACAN beacons and formation lighting.
10. Installation of military UHF communications equipment, preferably with crypto capability, IFF and JTIDS equipment.
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[45].

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[44] FLIP/ERSA.

[45] Radar Warning Receiver, Defensive Electronic Counter Measures, Infra-Red Counter Measures.

15.Installation of the Side Cargo Door if not already fitted.
16.Strengthening of the main deck floor to freighter standard and installation of freight handling hardware.
17.For aircraft with extant 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 airstairs, Nose and Side Cargo Doors, the Boeing On Board Loader, and refuelling receptacles.

C/N	Engines
23026	JT9-D7R
23029	JT9-D7R
23409	JT9-D7R
23769	JT9-D7R
23221	RB211-542C2
23392	RB211-542C2
23534	RB211-542C2
23709	RB211-542C2
23920	RB211-542C2
24215	RB211-542C2
23600	JT9D-7R4G2
22489	JT9D-7R
24194	JT9D-7R
23409	JT9D-7R
23769	JT9D-7R
23033	JT9D-7R
23243	JT9D-7R
23244	JT9D-7R
23245	JT9D-7R
24837	CF6-50E2
23028	JT9D-7R4G2

This table is based on Boeing data, 22/9/99

Availability Status of Boeing 747-300 Aircraft, 1999.

Table 4.

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 preferable.

C/N	Prior/Current Operators or Owners	Accidents	Current Status	Availability	Engines	
20998	Iran Air (EP-IAA)		In Service			1976
20999	Iran Air (EP-IAB)		In Service			
21022	Pan Am (N530PA) / United (N140UA)		Dismantled			
21023	Pan Am (N531PA) / United (N141UA)	G/C Right Wing (1987)	Dismantled at ADM			
21024	Pan Am (N532PA) / United (N142UA)		Dismantled at ADM			
21025	Pan Am (N533PA) / United (N143UA)		WFU at ADM -Ardmore, OK.			
21026	Pan Am (N534PA) / United (N144UA)		Dismantled at ADM -Ardmore, OK.			
21093	Iran Air (EP-IAC)		In Service			
21132	SAA/Luxair/SAA/Air Mauritius/SAA/Alliance (ZS-SPA)		In Service			
21133	SAA/Air Malawi/SAA/Luxair/Trek Airways/SAA/Air Namibia/South African (ZS-SPB)		In Service			
21134	SAA/Air Mauritius/SAA/Avia/SAA/Air Namibia/SAA/Air Namibia (ZS-SPC)		In Service			
21174	Syrianair (YK-AHA)		In Service			
21175	Syrianair (YK-AHB)	G/C Engine Cowl (1996)	In Service			
21253	SAA/Royal Air Maroc/Corsair (F-GTOM)	G/C -Wing (1997)	In Service			
21254	SAA/Air Mauritius/SAA/Air namibia/SAA (ZS-SPE)		In Service			
21263	SAA/Luxair/SAA/Air Mauritius/SAA/UTA/SAA/Namib Air/Air Namibia/L.A.M.	Engine Fires (1998)	W/O After incident.			
21300	China Airlines/Mandarin Airlines		In Service	Yes	JT9-D7	1977
21441	Pan Am (N536PA) / United (N145UA) / NASA (N145UA)		In Service			
21547	Pan Am (N537PA) / United (N146UA)	CAT (1988)	Stored at MZJ			
21548	Pan Am (N538PA) / United (N147UA)		Stored at MZJ			

Table 5. Availability Status of Boeing 747SP Aircraft, Late 1999[46].

[46] Based on T. Mogren's 747 SP Website index, amended using other sources. URL http://www.vikingslides.com/SP/, 22/09/1999.

21648	Pan Am (N539PA) / United (N148UA) / Qatar (VR-BAT) /Qatar (VP-BAT)	Engine Fail (1991)	In Service			
21649	Pan Am (N540PA) / United (N149UA) / Tajik Air (N149UA) / Brunei Gvmt (V8-AC1)		In Service			
21652	Saudi Arabian Gvmt		In Service			
21758	Iran Air		In Service			
21785	Braniff Airways/Oman Gvmt VIP Transport		In Service	Yes	JT9-D7J	1979
21786	Braniff Airways/Aerolineas Argentina/Air Mauritius/Qatar Airways		In Service			
21932	CAAC/Air China	G/C Left Wing (1996)	In Service	Yes	JT9-D7	1980
21933	CAAC/Air China		In Service	Yes	JT7-D7	1980
21934	CAAC/Air China	G/C Engine Cowl (1998)	In Service	Yes	JT9-D7	1980
21961	TWA/United Arab Emirates		In Service			
21962	TWA/American Airlines/Kazakhstan Airlines/Brunei Gvmt/Air Atlanta Icelandic/Star Air/Jaguar/V.I.P.		In Service			
21963	TWA/American Airlines/United Arab Emirates		In Service			
21992	Braniff Airways/Pan Am/United/Oman Gvmt	G/C Engine Cowl (1996)	In Service			
22298	China Airlines/Mandarin Airlines	R/W Overrun (1999)	Major Damage	Yes		
22302	CAAC/Air China		In Service	Yes	JT9-D7	1980
22483	Korean Air Lines/Korean Air/Boeing		Stored MZJ	Yes	JT9-D7A	1980
22484	Korean Air Lines/Korean Air/Boeing		Stored MZJ	Yes	JT9-D7A	1980
22495	Qantas/Australia Asia/Qantas		In Service	Yes	RB211	1981
22503	Saudia		In Service			
22547	China Airlines (B-1882) / Mandarin Airlines / (N4508H)		STD LAS.	Yes	JT9-D7A	1981
22672	Qantas/Australia Asia/Qantas		In Service	Yes	RB211	1981
22750	Saudia/Saudia Royal Flight		In Service			
22805	China Airlines/Mandarin Airlines	CAT - VNE (1985)	Stored LAS	Yes	JT9-D7A	1982
22858	Iraqi		Stored in Tozeur, Tunisia			
23610	United Arab Emirates		In Service			1987

Available Airframes

This would also provide the opportunity to standardise the inertial navigation and communications equipment fit across the fleet[47].

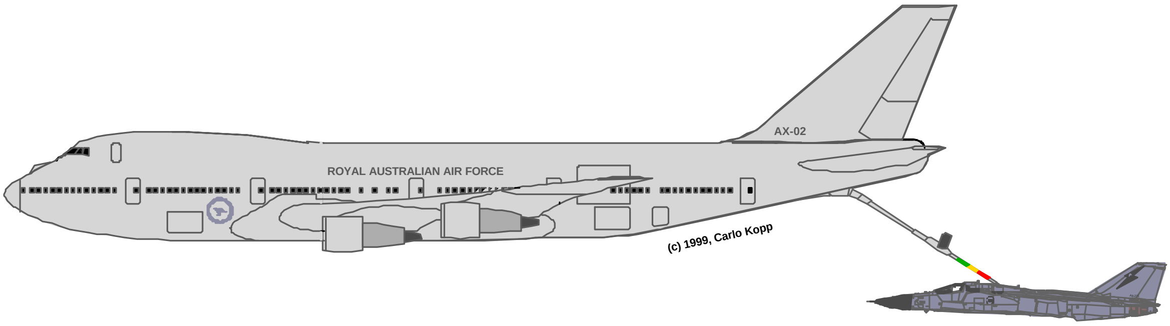

Figure 15. Comparison of Boeing KC-25 (747-200CF/300CF) and GD F/RF-111C/G sizes (Author).

There may be some merit in retrofitting all aircraft to a common engine type, should airframes of suitable quality not be fitted with such. Local commercial operators of the 747 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 .

The commercial aspect of such an acquisition is of modest complexity, since with the exception of the AAR conversion, multiple sources exist for freight conversions, airframe life extension and engine overhaul or retrofit. The only extant and flight tested AAR conversion was performed by Boeing. While other vendors may be competent to engineer an AAR conversion, they will incur the full engineering overheads and development risks of a new design.

The cost of such an acquisition to the taxpayer could be offset considerably, by performing substantial portions of the structural work and modifications to the raw airframes in Australia. Structural overhauls and engine overhauls of 747 aircraft have been performed in Australia, and suitable hangar facilities and experience both exist within this country.

Whether the best strategy is to release an RFP for the supply of fully modified 747 aircraft to a specified configuration, and place responsibility for the choice of airframes upon the vendor, or to acquire the aircraft directly off the commercial suppliers, and then release an RFP for the modifications remains to be determined. We

47 A good case can be made for a fully FANS compliant package to attain full commonality with local commercial operators, and USAF AMC assets.

could expect that shifting the burden on to the vendors will have some impact on the price tag as they would want to cover any risks they might incur. The availability of suitable airframes and pricing in the market will vary and this should be a consideration, since the pool of available aircraft and prices will fluctuate as older airframes are absorbed into the freighter market.

The total expense for the acquisition phase of the program would comprise the cost of the used airframes, the cost of any re-engining, zero-timing and corrosion repair, the total cost of the required AAR, and where applicable, freighter modifications as detailed above[48]. Since the program would involve a reasonable number of aircraft, some economies of scale in the production phase could be achieved.

Crewing the aircraft will be a major issue. If we assume a fleet size of twelve aircraft, with a glass cockpit and two person flight crew, and assume two sets of crews for the fleet, we end up with a requirement for 48 pilots, of which half are qualified as aircraft commanders. Maintaining currency, given the hourly operating costs of such aircraft, would be by any measure expensive. Simulators, no matter how good, are not a substitute for time in a real cockpit.

Therefore it will be necessary to explore other alternatives. One possibility worth exploring is that of hiring out the aircrew to the airlines, at such a rate where the offer is attractive to commercial operators. The contractual arrangement would be such that these pilots would fly regular operations for the airline in the same manner as the aircrew employed by the airline, however they could be recalled by the RAAF at very short notice to crew the strategic tanker/transport fleet.

Such a strategy has several attractions. The first is that it is an unbeatable attraction in the recruiting game, for those applicants with long term aspirations of a airline career. The second is that the crews get to maintain a high level of currency on the basic aircraft, and long haul overseas flight experience in the process. For the airlines, there is the advantage of simplified recruiting of junior pilots, who will have acquired their ab initio, early flight training and some multi-engine time in the very rigourous RAAF training regime. Contractual arrangements would need to be such, that the airline can recoup the training investment in such aircrew after they complete their service

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48 Whether the cost of any required runway extension, modification or construction work should be budgeted into the program is open to debate, insofar as such modifications are not constrained in use to the 747 strategic tanker/transport fleet. Hangar construction is only justified for aircraft servicing, and the Avalon and Mascot facilities may suffice as is for this purpose.

in the RAAF. The arrangement would have to be such to make "poaching" of such aircrew impossible before their contracted service periods run out. The aircrew would periodically fly the RAAF aircraft to maintain proficiency in AAR flight operations, but would gather most of their hours on commercial aircraft.

Other than pilots, each aircraft will require a loadmaster / boom operator qualified also to handle hose/drogue equipment operation, and several loaders. Training the loadmaster / boom operator category may require a simulator, and a ground based training facility will be required for training in rapid uploading, offloading and handling of freight. The latter could be accomplished by acquiring a 747-100F freighter which is about to be retired, and stripping it down to a fuselage with a working electrical system and APU to power the freight handling hardware.

Basing the aircraft will be an interesting issue, since few RAAF bases have adequate runways for 747 operations, especially at high gross weights. Another issue will be fuel supply, since at full MTOW these aircraft carry of the order of 170 tonnes or more of Avtur each. To sortie half a dozen at once could impose unreasonable demands upon the fuel reserves of many smaller bases.

Amberley would appear to be the best prospect, with some gross weight limits imposed, for a squadron home base capable of supporting training flights only.

From a practical perspective, the full MTOW capabity will be required only for long range or long endurance AAR operations, or for heavy lift transport operations. The former category of operations is geographically confined primarily to Learmonth and Darwin, both of which have adequate runways. The latter category would be confined mostly to Darwin and Townsville. Therefore Townsville will require an additional parallel runway of a suitable rating.

Domestic and Foreign Policy Considerations

The investment of about one billion dollars or more of ADF funds into the establishment of a strategic tanker/transport force is a major defence expenditure, but also one which is easily justified from a strategic and operational perspective. Indeed the existing AIR 5402 ADF Air Refuelling Capability program to upgrade or replace the Boeing 707 tankers, and the AIR 5414 airlift programs deal with specifically these issues.

In presenting such a program to the Australian community, a number of valid points can be stressed:

- The aircraft will be employed for the purpose of deploying and sustaining ADF personnel performing peace enforcement and peacekeeping operations under UN auspices.

- The aircraft can be used for aid distribution and refugee movement in international crises, as well as disaster relief in domestic and regional situations.

- The aircraft can be used for the rapid evacuation of Australian nationals from crisis spots, globally.

- The aircraft provide insurance against further problems with the Collins class, by extending the reach of the F-111 to a similar radius.

- The aircraft can refuel RNZAF, SAF F-16s and Malaysian F/A-18s thereby contributing to regional cooperation. Since they can refuel USAF, USN and RAF assets, they also contribute to the coalition operations with the US and the UK.

- Performing substantial proportions of the modification effort domestically will offset the cost to the taxpayer, and yield longer term dividends in strengthening the extant in country 747 overhaul and support base.

The aircraft would provide a substantial and unprecedented improvement in the RAAF's ability to perform strategic land and maritime strike operations, and this can be shown as a decisive commitment by the government to deal with the longer term strategic changes in the wider region.

In the context of foreign policy, a commitment to a strategic tanker/transport force will be viewed very favourably in the Western community, especially the US, since it reduce demands by the ADF upon its allies and adds to the collective pool of tanker/transport assets.

Within the region, a strategic tanker/transport force will unambiguously indicate that Australia will be much less dependent upon its regional neighbours for basing facilities, much less dependent upon overcommitted US resources, and will be able to respond rapidly to any regional hot spot. This will considerably strengthen Australia's political negotiating position in any scenario akin to the early phases of the East Timor crisis, where Australia stood alone.

The image of a dozen or more 747 transports lined up on a tarmac, painted in low visibility grey and wearing RAAF roundels, will be visually impressive and an item which will reassure the media and the public of the government's commitment to strengthen the ADF in the deteriorating strategic context of the coming decade.

Conclusions

This paper argues the case for the acquisition and deployment of a substantial strategic tanker/transport force for the ADF, comprising a fleet of modified variants of the Boeing 747 transport.

Such a strategic tanker/transport force will address the serious inadequacies extant in the RAAF's current tanker/transport fleet, providing the capability to engage land and maritime targets at combat radii substantially in excess of those achievable with extant assets. In the strategic airlift role, such a strategic tanker/transport force will provide the ability to rapidly deploy and then robustly sustain a brigade sized ground force element anywhere in the wider region thereby significantly reducing dependency upon USAF airlift assets.

There is an overwhelming case to employ the Boeing 747 airframe as the basis for this capability. The type offers these advantages over other alternatives:

- Refuelling boom and receptacle installations have been performed and used operationally, thereby minimising NRE expenditure, risk and lead time.

- The aircraft is large enough to easily accommodate a fuselage hose/drum/drogue unit and wing mounted Mk.32B pods, if desired.

- The size of the 747-200B/CF/300CF aircraft offers the potential for superior offload performance to the KC-10A, KDC-10-30CF and Tristar tankers, thereby fulfilling the RAAF's future strategic tanking needs with as few as a dozen airframes.

- The 747SP offers much lower initial acquisition costs and superior short field performance to all other alternatives, the 747-200B/CF/300CF is competitive against the KC-10A, KDC-10-30CF and Tristar.

- The cruise speed of the aircraft is competitive against the KC-135R and Boeing 707, yet the offload performance of the 747-200B/CF/300CF is potentially superior to the KC-10A, KDC-10-30CF and Tristar tankers.

- With four engines, the aircraft is better suited for extended range over water operations, against three engined and twin engined alternatives.

- The upper deck can be used to provide berthing for relief crews, loaders and provides additional volume for racks of C3 equipment, if required.

- The main deck volume of the 747-200B/CF/300CF is superior to all other widebody alternatives, thereby providing a better ability to lift low and medium density payloads, and the clearance to carry ASLAV armoured personnel carriers, side by side.

- The rear main deck freight door of the 747-200B/CF/300CF is large enough to fit ASLAV armoured personnel carriers[49].

- The standard freight modification floor strength of the 747-200B/CF/300CF is sufficient to carry palletes loaded with ASLAV armoured personnel carriers.

- The lower deck volume of the 747-200B/CF/300CF is superior to all other widebody alternatives, thereby providing generous volume for additional AAR fuel cells.

- The aircraft is operated by Qantas, Ansett and Air New Zealand, therefore a large support infrastructure already exists in Australia and New Zealand.

- Aircrew training and long term term career path considerations are much simplified by the large extant base of domestic operators.

- The use of the 747 can be exploited very effectively as a means of aircrew recruitment, and recruit motivation.

- The extant passenger to freighter conversion program for the 747-200B/CF/300CF means that used airframes can be converted to an airlift configuration very quickly, with no additional NRE.

- There is an abundance of used 747SP and 747-200B/CF/300CF airframes available in the market at this time, thereby allowing considerable choice in the quality of used airframes to be acquired. This in turn significantly reduces potential risk in acquiring used airframes.

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

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49 Pending confirmation of paper fit checks with a trial loading.

The limitations of the Boeing 747 in the strategic/tanker transport role may be summarised thus:

- Hourly operating expenses are higher than those for smaller tanker/transports, thereby increasing training costs, and penalising operations where a reactive deployment with small offload requirements is typical.

- The freight door size and floor strengths of the 747-200B/CF/300CF impose limits on the size and weight of airlifted armoured equipment and other military supplies.

- dedicated ground loader equipment will be required for the 747-200B/CF/300CF, and must be prepositioned via other means for operation into sites without existing capability of this type.

- The airlift and offload performance of the 747SP is inferior to the 747-200B/CF/300CF, while incurring similar costs to crew and support. There may also be issues with freight conversion as the aircraft has numerous structural differences.

- The age of the 747SP fleet will require judicious choice of candidate airframes for AAR conversion, and it is likely that some structural zero-timing and corrosion repair will be required.

- It may be necessary to retrofit some airframes to a common engine engine configuration, to minimise longer term support costs for a fleet.

To provide a general measure of capability, one dozen 747-200B/C/300CF derivative KC-25 strategic tanker/transports provide the cruise speed and offload performance equivalent to around thirty KC-135R tankers, and can lift the payloads of a dozen C-17A airlifters over about a 60% greater distance, all at about 1/3 of the total acquisition cost of the combined packages of KC-135R and C-17A aircraft. A mixed fleet including some 747SP derivatives yields similar offload performance and lesser airlift performance, with even lower acquisition costs.

In summary it is fair to say that the strengths of the 747-200B/CF/300CF 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.

We can thus argue there is a compelling case to explore this implementation of a strategic tanker/transport force in much more detail, and seriously consider acquisition in the very near term. The need for this capability is certain to grow, and the proposed implementation yields by far the best "bang-per-buck" of any available alternative.

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"767 Airplane Characteristics", Boeing Commercial Airplane Company, D6-58328-1,
April 1999, covering 767-400.

"DC-10 Airplane Characteristics", Boeing Commercial Airplane Company (McDonnell
Douglas Corporation - Douglas Aircraft Company), DAC-67803A, January 1991.

"MD-11 Airplane Characteristics", Boeing Commercial Airplane Company, MDC K0388
Rev.E, October 1990.

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SAE Aerospace Standard 1825

http://www.boeing.com/ - Boeing Commercial Airplane Company webpages
http://www.boeing.com/ - Boeing Commercial Airplane Company webpages
http://www.qantas./ - Qantas Airways Ltd
http://www.af.mil/ - United States Air Force
http://www.ual.com/ - United Airlines, Inc
http://www.sofcom.com.au/ - Sofcom Motoring
http://www.seistl.com/ - Systems & Electronics, Inc

Appendix A

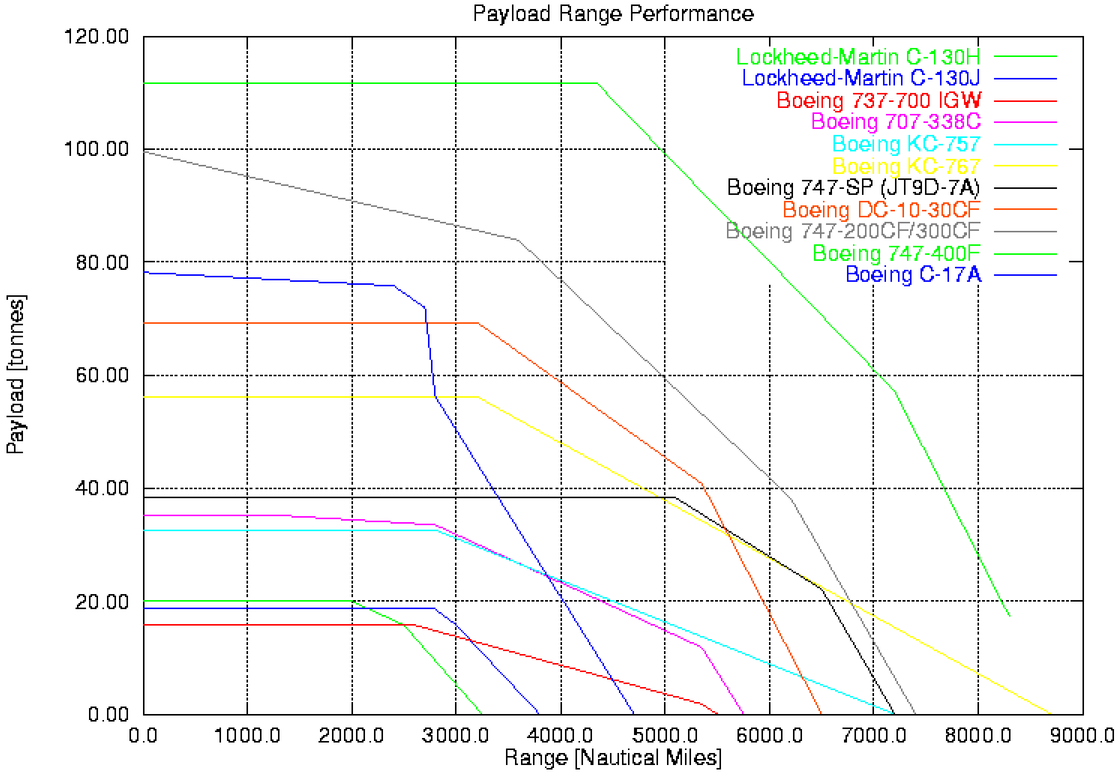

Figure A.1 Payload Range Comparisons of Tankers and Transports. This plot has been compiled from various sources and should be used as a guide only, since the accuracy of many of the performance points depends upon unspecified or differing initial assumptions (Author).

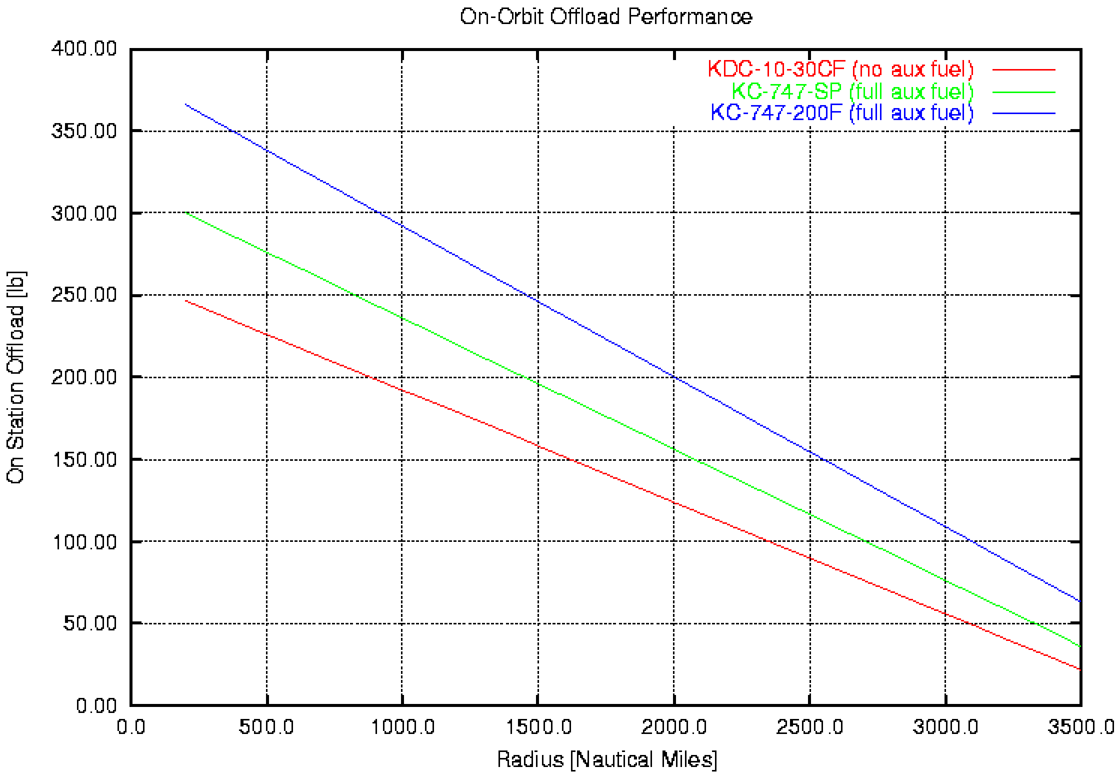

Figure A.2 Offload performance comparisons between large widebody tankers. The tanker will transit to station at the specified radius and then offload fuel until only enough remains for the return flight (Author).

Appendix B

KC-25/KC-747 Diagrams and Photographs.

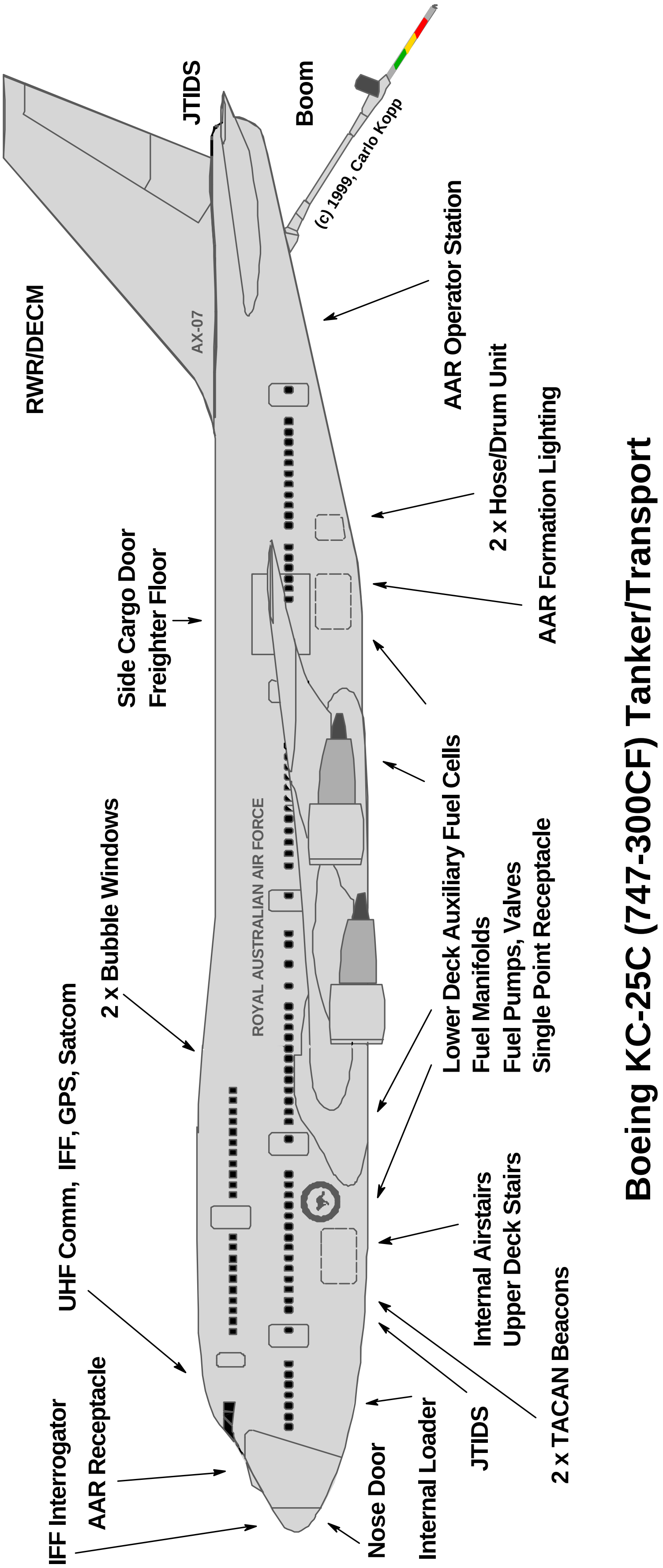

Figure B.1 Summary of KC-25 Modifications to 747-200/300 (Author).

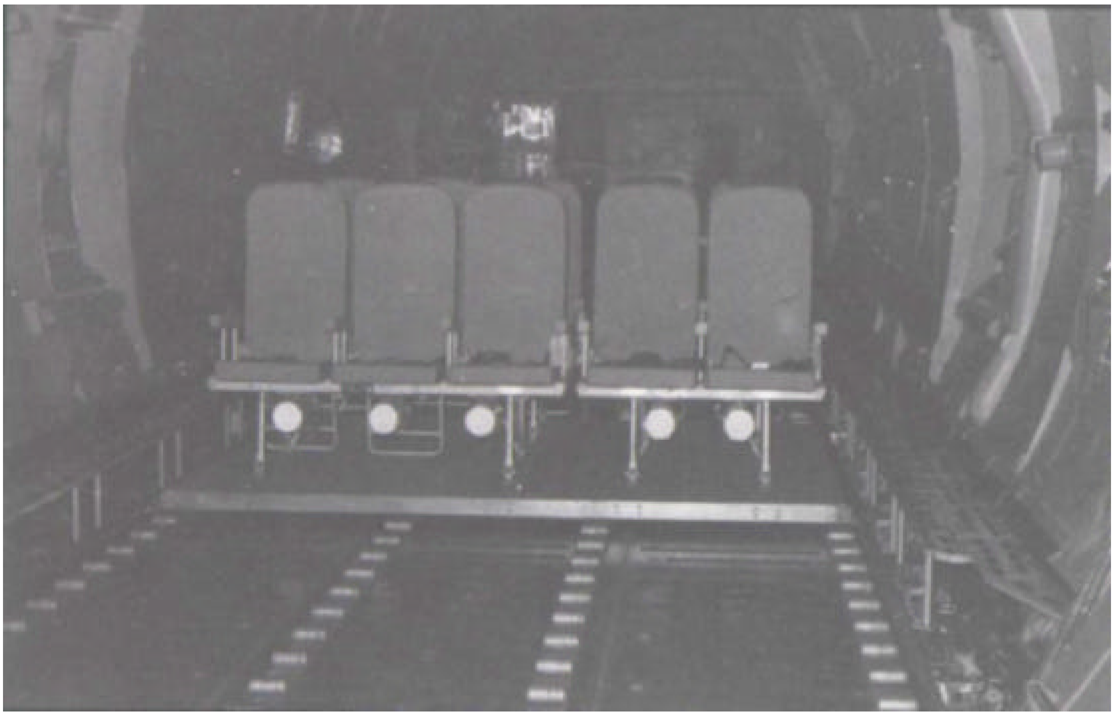

Figure B.2 Palletised passenger seats used for the rapid conversion of the C-141 Starlifter. These are manufactured by AAR Corp (USAF).

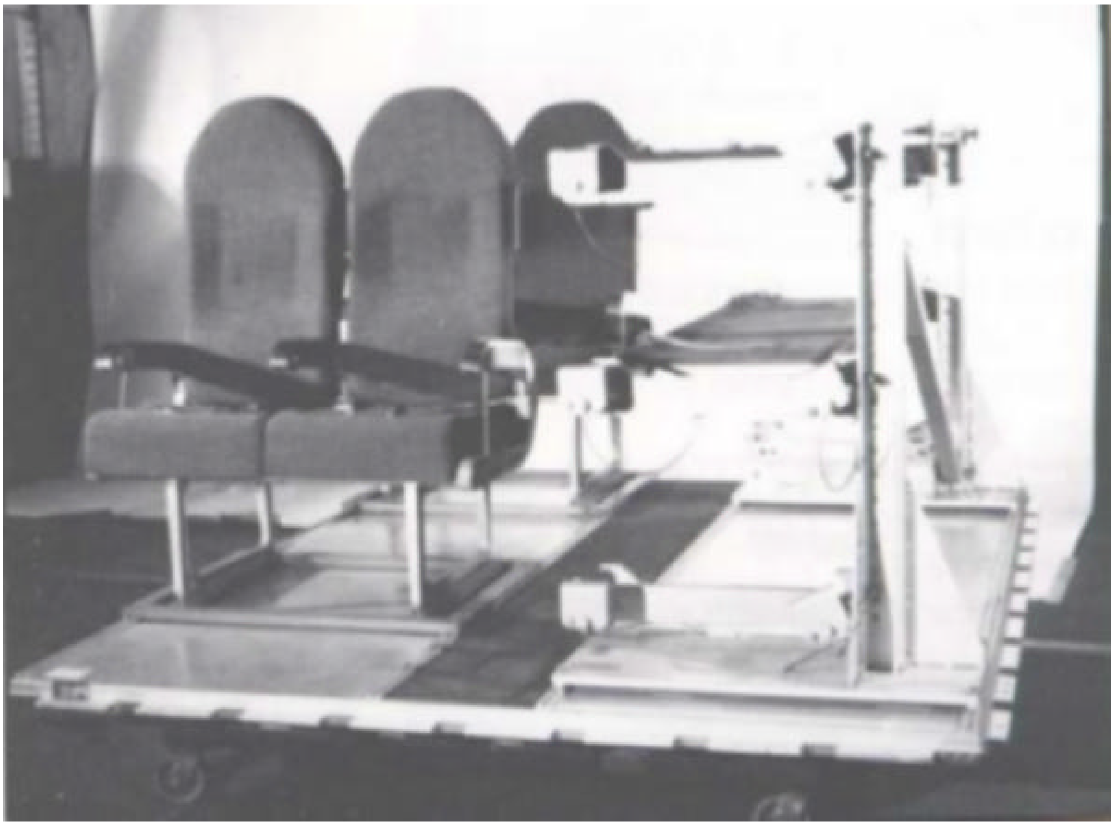

Figure B.3 Universal seat and stretcher pallete used for USAF/CRAF Medevac Boeing 767 aircraft. These are manufactured by AAR Corp (Boeing).

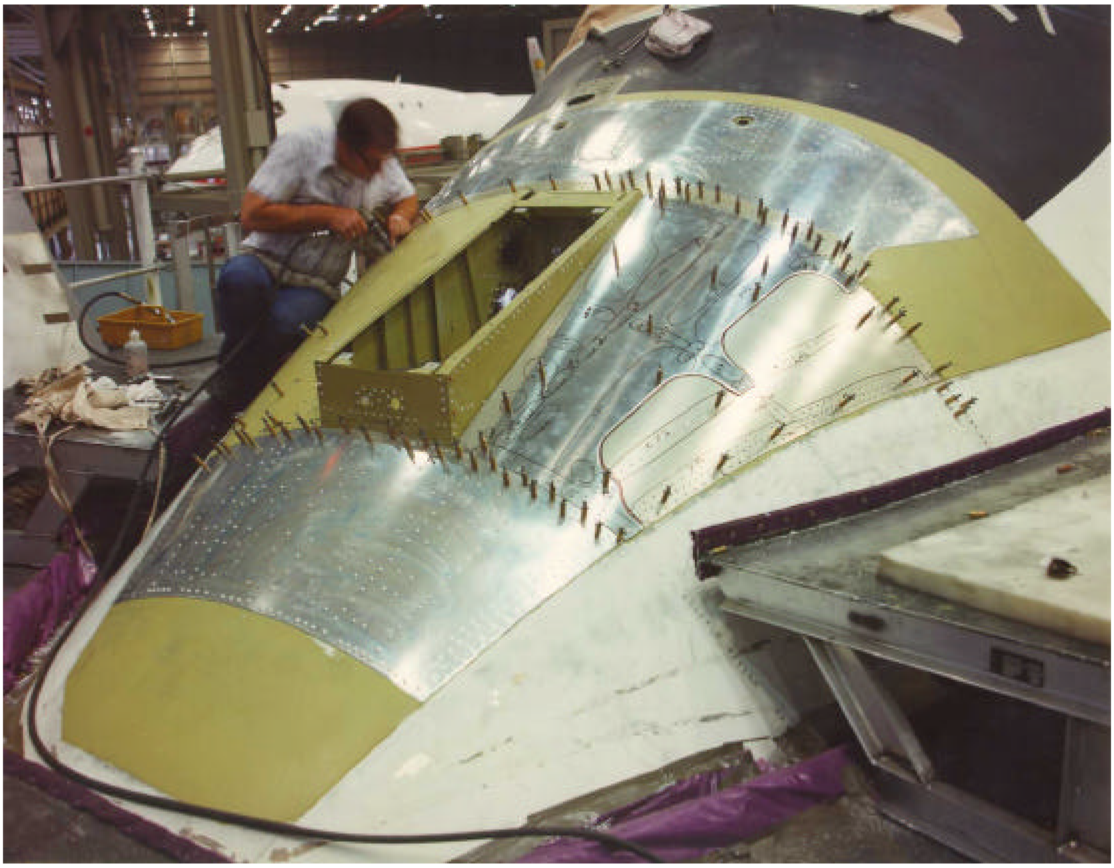

Figure B.4 Installation of nose AAR receptacle on IIAF Boeing KC-747-100. The same receptacle design is used on the USAF VC-25A and E-4B NEACP (Boeing).

Figure B.5 Installation of a lower deck auxiliary fuel tank in the IIAF Boeing KC-747-100 aircraft. This style of tank design has been superceded by lighter and more maintainable double walled fuel tanks, which have a similar shape and size to the LD2 lower deck luggage container (Boeing).

Figure B.6 Aft quarter view of the IIAF Boeing KC-747-100 Strategic Tanker/Transport (Boeing).

Figure B.7 IIAF KC-747-100 Strategic Tanker/Transport "boomer" station and high speed boom installation (Boeing).

Appendix C

Boeing On Board Loader

The *Boeing On Board Loader* was manufactured by Boeing for the Iraqi national airline during the nineteen eighties. This device is designed to be stowed in the nose of a Boeing 747-200C/F Combi or Freighter. The nominal time to load or unload the full capacity in pallete or container freight for a 747-200C/F is about 1 hour.

- Loader Weight: 6.6 tonnes
- Deployment Time: 30 minutes
- Stow Time: 30 minutes
- Power Supply: 747 electrical system or 115V/400 Hz ground generator
- Maximum Payload Mass: 13.6 tonnes
- Maximum Payload Size: 2.44 x 6.05 metre pallete or container

Minor modifications are required to the Nose Door area to accommodate attachments for loader deployment and stowing.

The existing loader design can be used for standard pallete and container freight, and vehicles with width and length inside a 2.44 x 6.05 metre envelope. Modifications to the width and length of the loader will be required to accommodate the ASLAV/LAV-25 and M113.

All photographs courtesy of Boeing Commercial Aircraft Company.

Figure C.1 Boeing On Board Loader, Nose Door loading of truck .

Figure C.2 Boeing On Board Loader, Nose Door loading of palletes .

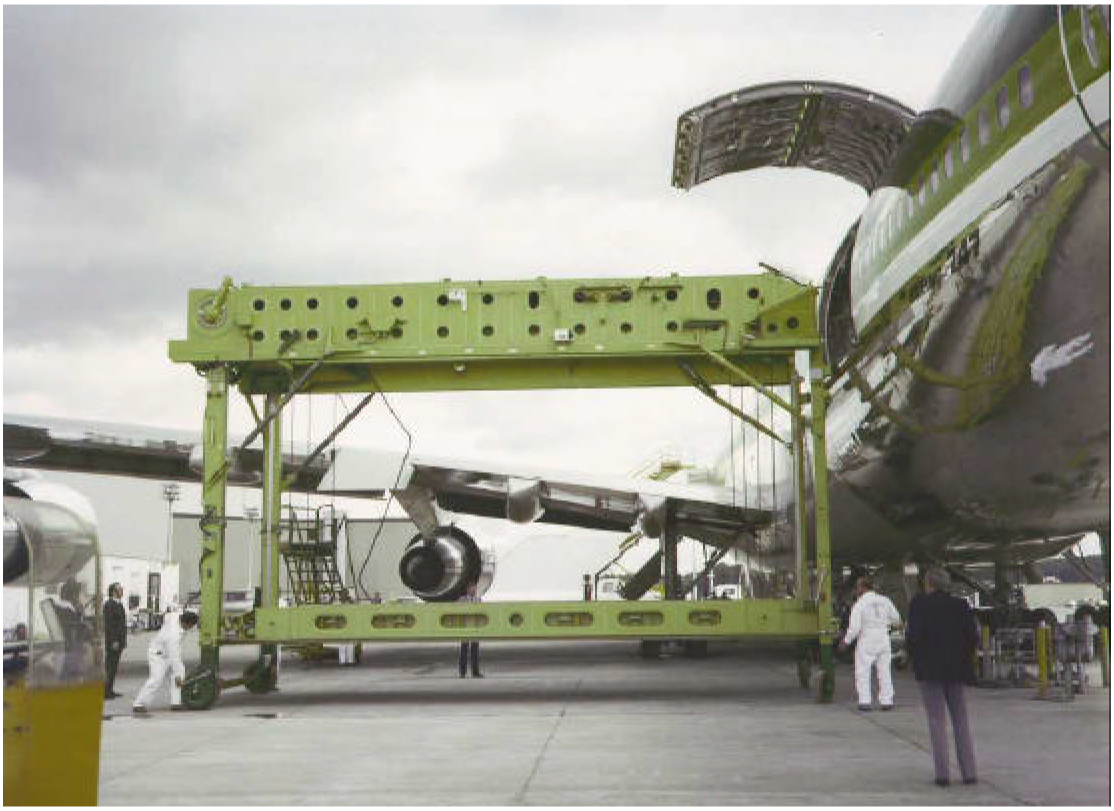

Figure C.3 Boeing On Board Loader, Side Cargo Door position .

Figure C.4 Boeing On Board Loader, Side Cargo Door pallete loading .

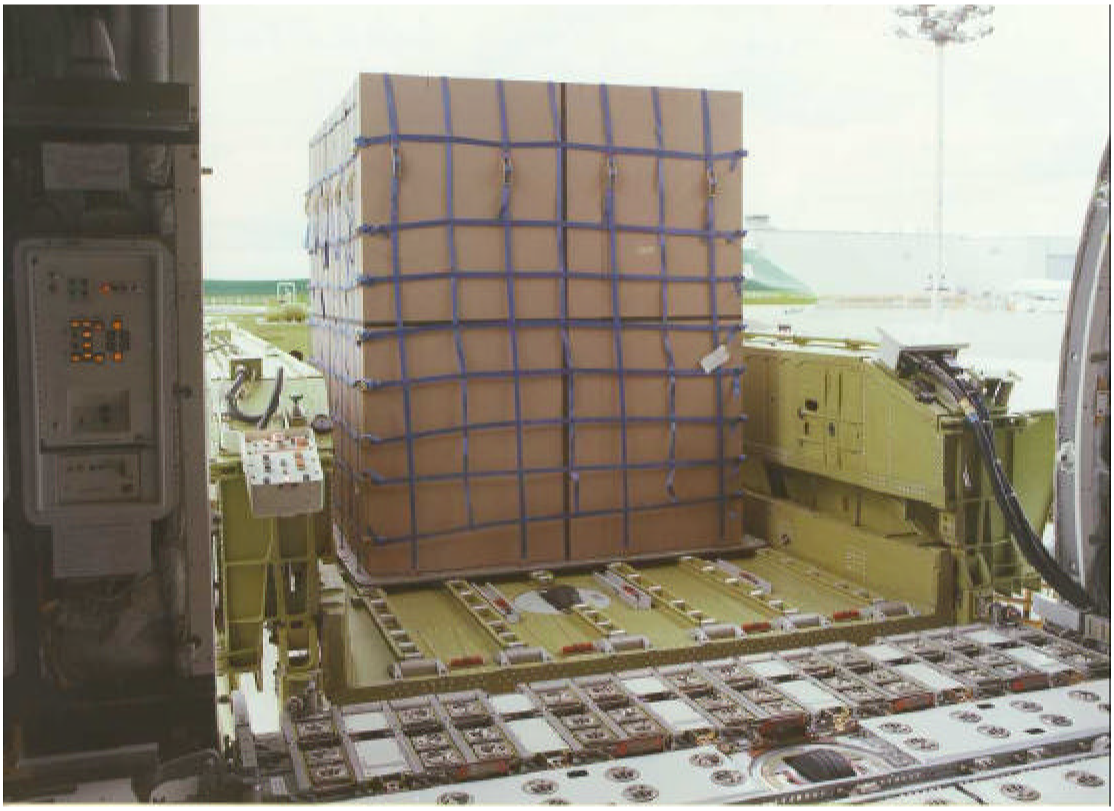

Figure C.5 Boeing On Board Loader, internal view of Side Cargo Door pallete loading operation. Note the generous clearance on eitther side of the 2.235 metre freight pallete.

Figure C.6 Boeing On Board Loader, deployment sequence step 1 .

Figure C.7 Boeing On Board Loader, deployment sequence step 2 .

Figure C.8 Boeing On Board Loader, deployment sequence step 3 .

Figure C.9 Boeing On Board Loader, deployment sequence step 4 .

Figure C.10 Boeing On Board Loader, deployment sequence step 5 .

Figure C.11 Boeing On Board Loader, deployment sequence step 6 .

Figure C.12 Boeing On Board Loader, deployment sequence step 7 .

SEI 60K Tunner Loader

The 60K Tunner Loader Loader was designed by Systems & Electronics, Inc for the USAF AMC during the nineties, to replace a range of older loader designs. The Tunner achieved IOC in 1997. This device is designed to be deployed by C-5, C-17 and C-141. It has the capability to load and unload the C-130, C-141, C-5 and C-17, as well as the commercial DC-10, L-1011 and B-747 freighter and combi variants.

Loader Weight: 29.5 tonnes
Deployment Time: minutes
Stow Time: minutes
Power Supply: Turbocharged V-6 Diesel, 350 HP, hydrostatic drive
Maximum Payload Mass: 27.2 tonnes
Deck Width (Deployed): 4.3 metres
Deck Height (Deployed): 0.9-5.6 metres

The Tunner can be transported in a stowed configuration, with the deck folded and wheels rotated by 180 degrees, or in a deployed configuration for RO/RO unloading, using a C-5. The design is intended to provide the USAF with a rapidly deployable loader capable of loading and unloading all widely used military airlifters and commercial freighters, as well as transferring loads between the C-130 and larger transports. The deck can be adjusted in pitch, roll, yaw and translation to accommodate various freight loading door configurations. A powered roller system is employed.

The design is too heavy to airlift by any C-130 variant.

Figure C.13 SEI Tunner Loader, general configuration (USAF).

Figure C.14 SEI Tunner Loader, 747-200F loading (USAF).

Figure C.15 SEI Tunner Loader, RO/RO deployment in C-5 (USAF).

Figure C.16 SEI Tunner Loader, stowed configuration (USAF).

SEI 25K Loader

The 25K Loader was designed by Systems & Electronics, Inc. This device is built to be deployed by C-5, C-17, C-141 and importantly, C-130. It has the capability to load and unload the C-130, C-141, C-5 and C-17, as well as the commercial DC-8, DC-10, L-1011, B-707 and B-747 freighter and combi variants. The latter are accessed by fitting structural components to raise the height of the tray. The need to mechanically reconfigure this loader to required aircraft floor heights is its principal operational limitation.

Maximum Payload Mass: 11.3 tonnes
Deck Height (Deployed "Standard" Configuration): 0.99-3.96 metres
Deck Height (Deployed "High Reach" Configuration): 3.96-5.64 metres

The 25K Loader is transported in a stowed configuration. The design is intended to provide a rapidly deployable loader capable of loading and unloading all widely used military airlifters and commercial freighters. The deck can be adjusted in pitch, roll, yaw and translation to accommodate various freight loading door configurations.

Figure C.17 SEI 25K Loader, front tilt test (SEI).

Figure C.18 SEI 25K Loader, rear tilt test (SEI).

Figure C.19 SEI 25K Loader, up, down and shipping configuration (SEI).

Figure C.20 SEI 25K Loader, maximum height extension (SEI).

Appendix D

Boeing 747 Technical Data and Performance

This appendix contains the most relevant portions of these documents.

747 Airplane Characteristics, Boeing Commercial Airplane Company, D6-58326, May 1984

1.3 Family Comparison
2.1 though 2.2 Aircraft Weights and Dimensions
2.4 Interior Arrangements
3. Performance Charts

747-400 Airplane Characteristics, Boeing Commercial Airplane Company, D6-58326-1, October 1994

2.1 though 2.2 Aircraft Weights and Dimensions
2.4 Interior Arrangements
3. Performance Charts

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