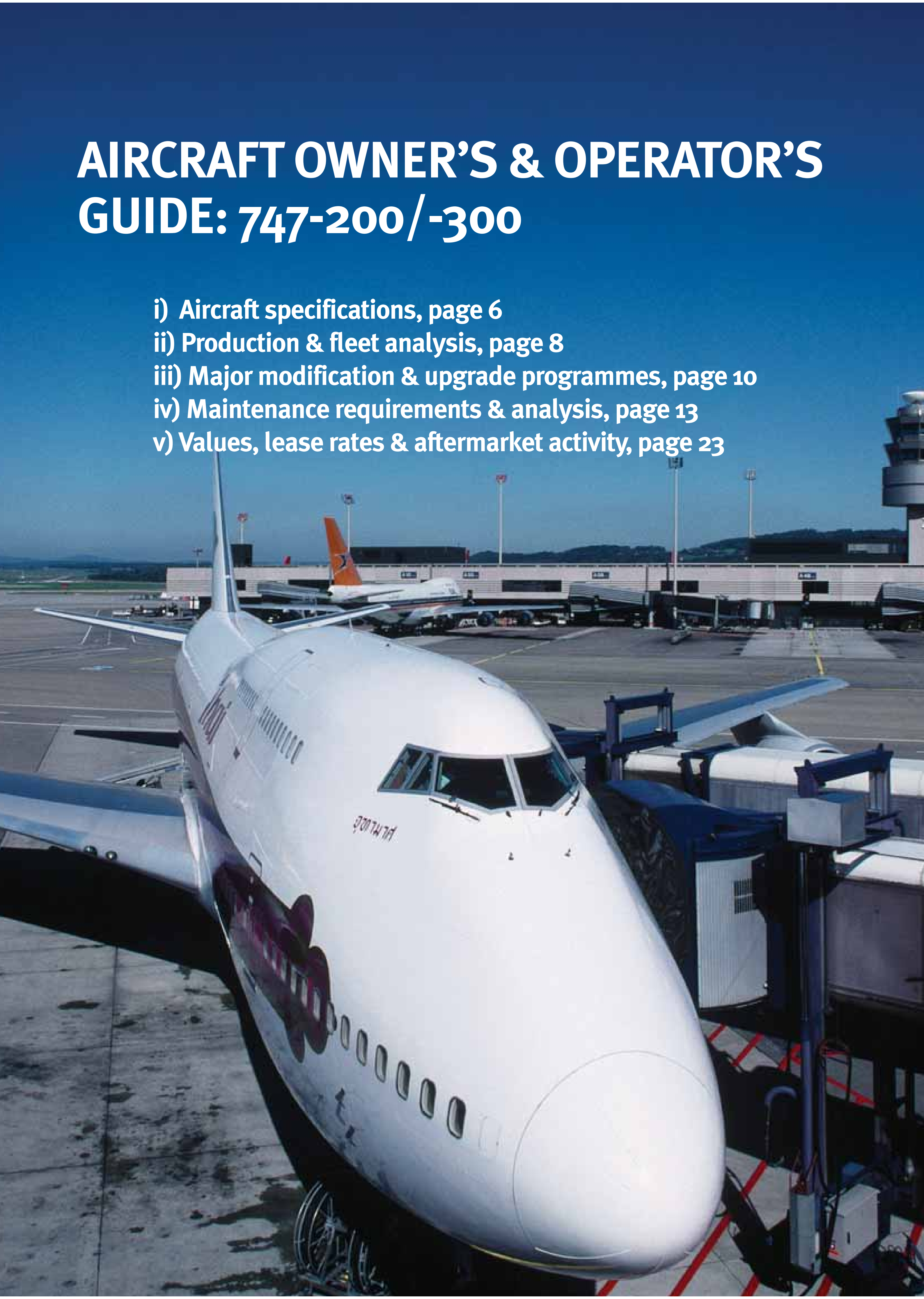
AIRCRAFT OWNER'S & OPERATOR'S GUIDE: 747-200/-300



747-200/-300 specifications

There are several 747-200/-300 variants with different MTOW & engine combinations, as well as different MTOW limits for Stage 3 compliance.

The 747-200 and -300 followed almost instantly on the heels of the initial -100 series aircraft. The various combinations of gross weight, engines, permissible weight at Stage 3, and range are analysed here.

A total of 476 -200s and -300s were manufactured between August 1970 and October 1991. Of these, 395 were the -200 and 81 were the -300 with the 23ft 4in extended upper deck that added 40 economy seats.

The first -200 to roll off the production line was line number 88 in August 1970 for Northwest Orient Airlines, although KLM was first in service with the -200B in February 1971. The last aircraft was line number 886 delivered on 19th November 1991, a -200F for Nippon Cargo Airlines. The first -300 series aircraft was line number 570 delivered in March 1983. The last -300 was line number 810 completed in August 1990.

-200B & -300 development

Even before the first flight of the -100, Boeing announced a higher gross weight variant with a choice of engines from Pratt & Whitney (PW), General Electric (GE) and Rolls-Royce (RR). The -200 was the first 747 to be configured as a freighter, a combination passenger-freighter and a convertible.

Several developments have been made to the -200 that allow more power, increased weight and range, and a variety of seating combinations. Several specialist versions were produced, including the hinge-nosed -200F freighter, -200C Convertible, the -200 Combi with side cargo (SCD) door, and the -200SUD (stretched upperdeck).

The first 747-300, with an extended upper deck compared to the -200, was built in September 1982 (line number 570) and entered commercial service in March 1983 with Swissair as a Combi. The extended upper deck increased seat capacity by about 10%. The -300 also had improved engines with a reduced fuel burn of 25% per passenger. Passenger capacity was also increased by 10% by the extended upper deck. Boeing delivered 81 747-300s in passenger, Combi and short-range configurations, the last being line number 810 in August 1990 for Sabena.

The -200 and -300 production line was closed on November 19th 1991, the last aircraft being a -200F.

Technical description

The technical capability of the 747-200B and -300 series is determined by a combination of its installed engines, MTOW permitted by the installed engines, fuel volume and Stage 3 compliant MTOW.

The earlier built 747-200B has a structure and landing gear to permit a MTOW of up to 775,000lbs. Further structural changes were made from line number 409 to permit an MTOW up to 833,000lbs.

The -200 fleet has a choice of Pratt & Whitney (PW) JT9D-3A, -7A, -7F, -7J, -7Q, and -7R4G2 engines. These are rated at 45,000lbs to 54,000lbs thrust. General Electric supplied the CF6-50E/-50E1/-50E2 variants rated at 52,500lbs thrust. The Rolls-Royce options are the RB211-524C2 and -524D4 rated at 51,500lbs and 53,100lbs thrust.

On the larger -300, engine options are the JT9D-7R4G2 rated at 54,000lbs thrust, CF6-50E2 and newer CF6-80C2B1 rated at 56,700lbs thrust, and the RB211-524D4 rated at 53,100lbs thrust.

The different MTOWs that are possible for each engine type are shown *(see first table, page 7)*, together with fuel volume in US Gallons (USG).

Aircraft with the JT9D-7A installed had an original certified MTOW of 775,000lbs and 785,000lbs *(see first table, page 7)*.

The later -7F/-7FW/-7J all allowed the aircraft to operate up to a MTOW of 800,000lbs. These three variants were also used on aircraft which originally had MTOWs certified at 775,000lbs and 785,000lbs *(see first table, page 7)*.

Aircraft with the JT9D-70A had MTOWs of up to 820,000lbs.

The later JT9D-7Q and -7R4G2 variants, the CF6-50 and the RB211-524 engines all permitted a MTOW of up to 833,000lbs *(see first table, page 7)*.

Stage 3 compliance

These MTOWs are the original take-off weight limits, and some engine-MTOW combinations are not Stage 3 compliant. The non-Stage 3 compliant combinations have had a limit imposed on their MTOW. This has the effect of reducing engine throttle setting, and so reducing noise emissions.

The Stage 3 MTOW limits for the JT9D-7Q, JT9D-7R4G2, CF6-50 and RB211-524C2/D4 are unchanged from the original MTOWs *(see second table, page 7)*. This gives the passenger-configured aircraft a range of 5,900-6,100nm, depending on engine installed.

Aircraft with the JT9D-7A are limited to a MTOW of 734,000lbs for Stage 3 compliance *(see second table, page 7)*. Range for this aircraft is 4,250nm.

The JT9D-7F limits the MTOW to 750,000lbs, and the corresponding range is 4,650nm. Aircraft with the JT9D-7J are limited to a MTOW of 770,000lbs and a range of 5,000nm *(see second table, page 7)*.

Payload capacity

In a passenger configuration, the -200B has a tri-class seat capacity of 360-420 seats. The 747-300's tri-class capacity is typically about 20-30 seats more.

All -200 and -300 models have significant belly cargo space of about 5,250 cubic feet with containerised cargo in 30 LD-1 containers. They can also take palletised cargo.

–200M Combi

The -200M or 'Combi' has a maindeck that has a SCD at the left rear of the fuselage. This allows freight to be carried in the rear section of the maindeck, while the front section is configured to carry passengers. The Combi became popular in the late 1970s and early 1980s. Six 10-feet high pallets can be carried at the rear of the main deck in Zone E. Each of these has a volume of 773 cubic feet, thus providing 4,638 cubic feet of cargo volume. The passenger accommodation is reduced by up to 238 passengers in three-class layout, depending on configuration.

The -200B Combi has the same range characteristics as the -200B in all-passenger configuration.

–200C Convertible

The -200C was made available at the same time as the -200F. The -200C is similar in appearance to the -200B except that it has the upward-opening nose door and strengthened floor of the -200F. The interior can be configured in either a passenger or freighter role.

The conversion of the aircraft from one role to another allows operators to take account of seasonal fluctuations in passenger and freight traffic. The -200C did not prove particularly popular, and only 13 were produced.

–200F Freighter

The -200F, with a MTOW of 775,000lbs, had a larger payload-range capability than the -100F. The -200F has the upward hinging nose door. This is the fundamental difference between the -200F and the subsequently modified -200SF. The nose door is standard, with the main deck SCD an option.

The nose door only permits eight-feet high maindeck freight containers, which have an internal volume of 623 cubic feet. The maindeck can accommodate 29 of these, and so has a total freight volume of 18,270 cubic feet *(see third table, this page)*.

The SCD allows 21 10-feet high containers to be carried in the mid and aft sections of the maindeck, while eight eight-feet high containers have to be carried in forward section. The 10-feet high containers have an internal volume of 773 cubic feet, and overall aircraft with a SCD have a maindeck freight volume of 20,685 cubic feet *(see third table, this page)*.

Combined with the 5,250 cubic feet provided by the 30 LD-1 containers in the belly, total freight volume is 23,520 cubic feet for the -200F with only the nose door, and 25,935 cubic feet for aircraft with the SCD.

The -200F has a maximum zero fuel weight of 590,000lbs. Operating empty weight, including tare weight of containers, varies between 342,000lbs and 351,000lbs, depending on MTOW variant and installed engine. This allows an available structural payload of 239,000-248,000lbs *(see third table, this page)*.

-200 SUD

When Boeing announced the 747-300 programme in June 1980, Boeing and the press referred to it as the -200 SUD. The new aircraft was later re-designated as the -300. A modification was available to operators of -200Bs, however, to stretch the upper deck to the same capacity as the -300. KLM ordered the modification of its 10 -200Bs to -200 SUD.

-300 series

The -300 programme was announced by Boeing on June 12th 1980, originally as a modification to the existing models. Typical seating is 405 in a three-class configuration. The -300's weights and engine options are described *(see first table, this page)*.

The Combi is identical to the standard -300, except for a 120 x 134 in main deck cargo door aft of the wing. Zones D and E have a strengthened floor with cargo handling equipment. A typical Combi configuration is 289 passengers in three classes and seven 10-feet high pallets aft. The weights and engine options are described *(see table, this page)*.

-300 SR

In 1987 Boeing offered the -300 in an SR version for high-density traffic volumes to Japan Airlines. In a two-class, high-density configuration, the -300SR can seat 563 passengers. In single-class configuration it can carry 624 passengers. The -300SR is offered at MTOWs of 520,000lbs and 600,000 lbs with fuel capacities of 48,000USG and 48,500USG. Only four were built for JAL. AC

747-200/-300 SERIES GROSS WEIGHT & ENGINE CONFIGURATIONS

Variant	-200	-200	-200	-200/-300
MTOW lbs	775,000	785,000	800,000	833,000
Fuel volume USG	52,410	52,035	52,410	52,410
Engine options¶	JT9D-7AW JT9D-7FW JT9D-7JW	JT9D-7AW JT9D-7FW JT9D-7JW	JT9D-7FW JT9D-7JW	JT9D-7Q JT9D-7R4G2 CF6-50E2 RB211-524C2 RB211-524D4

747-200/-300 MTOW & MLW LIMITS FOR STAGE 3 COMPLIANCE

Variant & engine	-200 JT9D-7A	-200 JT9D-7F	-200 JT9D-7J	-200/-300 JT9D-7Q
MTOW lbs	734,000	750,000	770,000	833,000
MLW lbs	630,000	630,000	630,000	666,000
Range nm (Pax aircraft)	4,250	4,650	5,000	5,900

Variant & engine	-200/-300 JT9D-7R4G2	-200/-300 CF6-50E2	-200/-300 RB211-524C4 RB211-524D4
MTOW lbs	833,000	833,000	833,000
MLW lbs	666,000	666,000	666,000
Range nm (Pax aircraft)	6,100	5,900	6,050

747-200F FREIGHT SPECIFICATIONS

Aircraft model	-200F Nose door only	-200F Nose door & SCD
Type maindeck containers:	96" X 125" X 96"	96" X 125" X 96"
Number of containers:	29	8
Type of maindeck containers:		96" X 125" X 118"
Number of containers:		21
Maindeck container volume cu ft:	18,270	20,685
Belly containers	30	30
Belly container volume cu ft:	5,250	5,250
Total container volume cu ft:	23,520	25,935
MZFW lbs	590,000	590,000
OEW lbs	342,000-351,000	342,000-351,000
Structural payload lbs	239,000-248,000	239,000-248,000

747-200/-300 fleet analysis

While the 747-200/-300 have an image of being old aircraft, there are several low-time, high specification aircraft that can provide start-up airlines with high capacity at a low acquisition cost.

Of the 476 747-200 and -300s built, 280 are still in service, mostly with tier-one operators like Japan Airlines (JAL) and Northwest Airlines, and major cargo carriers.

The most desirable -200Bs are those with JT9D-7Q, JT9D-7R4G2 and CF6-50E2 engines which allow the aircraft to operate at the highest MTOW of 833,000lbs. Aircraft that have accumulated fewer than a total of 80,000 flight hours (FH) and 15,000 flight cycles (FC) are also the most desirable. This makes it possible to operate the aircraft for at least another 4,000FC before Section 41 termination modification would be required. This is equal to between six and eight years' operation at typical rates of utilisation. Airlines are likely to retire aircraft at this stage, since the cost of completing Section 41 would not be economically attractive.

Airlines and potential purchasers and operators also have to consider the timing and requirements of other modifications and heavy maintenance. Many may not want to perform a D5 check, and so will retire the aircraft just prior to reaching this point. This will be due at about a total time of about 100,000FH, while a D4 check will occur at about 80,000-82,000FH total time and a D3 check due at about 60,000-65,000FH.

All -300s have the highest MTOW of 833,000lbs, but the most desirable are those equipped with CF6-50E2/-80C2 and JT9D-7R4G2 engines.

Of the 395 -200Bs built, 212 remain operational. Of the 81 and -300s built 69 remain operational. The remaining aircraft have been retired, destroyed or stored.

-200B

The early years of the passenger -200B saw a significant number of deliveries followed by another peak in 1979-1981. By 1982 190 aircraft were delivered, most of which are now subject to Section 41 termination *(see 747-200/-300 modification programmes, page 10)* assuming 1,000 cycles a year. Increasingly, however, termination of Section 41 is considered normal, rather than the exception.

Of 57 the-200Bs that remain operational, the majority are powered by engines that permit the highest MTOW of 833,000lbs. The most numerous of this group are 22 JT9D-7Q-powered aircraft. Many of these are high-time aircraft, with only two that have accumulated about 15,000FC or less, but these two have in excess of 80,000FH.

There are only five aircraft with JT9D-7R4G2 engines, and four are operated by Northwest and the fifth by Japan Airlines. All five have 9,700-12,100FC.

There are just four civilian aircraft with CF6-50E2 engines which were built in the mid-1980s. There are 11 RB211-524-powered aircraft. Many are low-time aircraft, but are generally less desirable because of their high empty weight.

A few other aircraft are powered by the JT9D-7A/-7AW/-7J. These have limited gross weights are high-time aircraft.

-200SCD

About 75 aircraft with side cargo doors (SCD) are in operation. These are a mixture of Combi aircraft and Combi and passenger aircraft that have been modified to freighter. The largest number, 37, are equipped with CF6-50E2 engines, and have been the most desirable with freight operators. Only 11 of these aircraft have accumulated less than 15,000FC and so could operate for at least another four or five years before coming due for a D5 check.

Another 22 are powered by JT9D-7Q and -7R4G2 engines. These are operated by Northwest, Japan Airlines, Air China, UPS, Kalitta Air, and Tradewinds. Most of the -7R4G2-equipped aircraft have accumulated less than 15,000FC and are desirable, while many of the -7Q-powered aircraft are high-time aircraft.

-200F

Just over 60 -200Fs are in operation. This includes 10 high-time aircraft equipped with JT9D-7A/-7F/-70A engines. Of the more desirable types, there are also 17 aircraft with -7Q engines. These are mainly high-time aircraft operated by JAL, Northwest, El Al, and MK Airlines.

There are also eight aircraft with -7R4G2 engines. These are relatively low time, with between 9,000FC and 15,000FC. Some of these are operated by JAL and Northwest, as well as by Air China, Dragonair and Korean Air.

The largest group is the 24 aircraft equipped with CF6-50E2 engines. Fifteen of these have accumulated less than 15,000FC and 80,000FH, making them some of the most desirable 747-200s still in operation. Many of these aircraft are operated by Nippon Cargo, Lufthansa Cargo and Air France.

Only four -200Fs are powered by the RB211-524, and these are operated by Cathay Pacific and Saudia.

Only five Convertibles remain in operation, and four are powered by the CF6-50E2.

-300 & -300 Combi

Most -300s were delivered from 1985 to 1987. Of the 81 built, 56 were standard -300s and 21 were Combis, including the first -300 built for Swissair which is now retired. Only four of the -300s have been converted to freighters, most by TAECO.

The -300 fleet is dominated by the JT9D-7R4G2, which powers 27 of the 53 aircraft that remain operational. Most of these are low-time aircraft which have accumulated 11,000-13,000FC and 55,000-85,000FH. This fleet is dominated by aircraft operated by JAL and Corsair. Smaller numbers are operated by Air Atlanta Icelandic, Phuket Airlines and Korean Air.

The other large fleet of -300 passenger aircraft are the 21 powered by the RB211-524. These are operated by either Qantas or Saudia, and have accumulated 13,000-17,000FC and 55,000-75,000FH.

A few -300s are powered by the CF6-80C2B1, the engine's first application on the 747 family. Five aircraft with these engines operate with Thai Airways and Iberia.

Another 14 -300s are the Combi variant. This is split between six aircraft with JT9D-7R4G2 engines and eight with CF6-50E2 engines. These are all low-time aircraft, and operators include Dragonair, Korean Air, Air France and Surinam Airways. There are also two low-time CF6-80C1B12-powered -300 Combis operated by Air India.

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747-200/-300 modification programmes

The major modification and upgrade programme include mandatory avionic installations, gross weight upgrades, structural modifications and freighter conversions.

There are four main categories of modifications applicable to the 747-200/-300. These include: flightdeck and avionic modifications; engine and weight upgrades; safety-related modifications; and passenger-to-freighter conversion programmes; available to enhance the 747-200/-300's productive life.

Most other upgrade packages and heavy modifications issued for the aircraft have either been carried out or are economically unattractive to operators. A modification is also available to upgrade the JT9D-7J engine to increase the Stage 3-compliant MTOW.

Avionic upgrades

One of the main improvements over the 747-200/-300 was the use of a two-man flightdeck on the 747-400. This features advanced on-board computing power coupled with advanced glass displays, which make the third member of the crew, the flight engineer, redundant, and bring significant cost advantages. In conjunction with this, there have been a series of regulations affecting all aircraft that require improvements to navigation and communications on-board aircraft to enhance safety and deal with ever more congested airspace.

One of the pioneers of flightdeck avionic upgrades was KLM Engineering & Maintenance in the Netherlands. Marijan Jozic, modification programme manager at KLM Engineering & Maintenance, and winner of the 2004 Volare Award for Aircraft Maintenance awarded by the AAI, has a wealth of experience on the classic jumbo. "Until 1987 engineering activity was restricted to replacing old cinema projectors with video projectors in the cabin. Then came TCAS," begins Jozic. "KLM Engineering & Maintenance expanded its activities to become a systems integrator and installation service provider. The wave ended after the traffic collision avoidance system (TCAS) 1989 deadline. Then we had SATCOM installation led by our marketing department. This was followed by reduced vertical separation minima (RVSM) requirements, and then the channel spacing modifications on radio communications. We combined the frequency spacing requirements with FM immunity modifications.

"One of the most important new developments we embarked on for the 747 Classics was pioneering avionic and flightdeck upgrades," continues Jozic. "Our original classics had DELCO inertial navigation systems (INS) which had poor reliability. We looked at various control panels and display options, but at the same time also wanted to provide a 747-400-like environment for these classic aircraft, and add FANS-1 capability. The introduction of basic area navigation (B-RNAV) in Europe was also a big driver. So our cockpit modification grew, adding a Canadian-Marconi (now BAe Systems Canada) flight management system (FMS) and a display from Smiths for the attitude direction indicator (ADI) and horizontal situation indicator (HSI). We wanted to add replacement engine instrument displays, but there were some challenges with interfacing to the existing systems remaining on the aircraft, and so the displays were dropped. What we were left with accommodated precision area navigation (P-RNAV) requirements, and a data link functionality for future and conventional ADS. The triple redundant GPS/FMS/INS configuration would permit dispatch into RNP-4 airspace with a single point failure."

The programme was certified on September 10th 2001, which could not have been worse timing. Although KLM Engineering & Maintenance completely modified all its own aircraft, Martinair was the only other airline that had the full modification. "The new modification package completed for Martinair during 2003/2004 is actually an improved upgrade," comments Jozic. "We have made it easier to install, with new wiring routing and displays from Astronautics. One benefit of the upgrade is that pilots can take advantage of special arrival and departure procedures (SID/STAR) with this retrofitted configuration. This will assist in avoiding fines at a noise sensitive airport like Amsterdam Schipol, and in enhancing operating costs."

ARINC in fact went the furthest, developing a two-man flightdeck modification for the 747 Classic, but this was shelved after September 11th 2001. There were other smaller flightdeck modifications available, including one from Spirent Systems (now Teledyne Controls) called AvVance. Not only does it replace old, unreliable mechanical instruments, but it also provides real-time data and exceedance recording capabilities. This allows maintenance crews to download and analyse engine performance data after each flight, reducing the reliance on pilot reporting, and extending service life. It can save maintenance costs.

Of most recent interest is a project that Jozic has just completed for start-up airline Focus Air Cargo. Operating two 747-200Fs and one 747-300F, Focus wanted to upgrade all the avionics, but it was looking for a lower cost alternative to the standard KLM package. "We came up with a very interesting package that is ideal for 747 Classics coming out of storage," says Jozic. "We combined a Litton92 INS with a standalone GPS from Northrop Grumman, and added a Honeywell Enhanced Ground Proximity Warning System (EGPWS). We also did an enhanced transponder modification, which is mandated by 2007. The end result is an extraordinary package that should be very attractive to 747 Classic operators. In all, there are three supplemental type certificates (STCs) with the package, one with Northrop Grumman and two with a company called ECS, based in Wisconsin, USA."

Mandatory avionics

In Europe, it is mandatory for all aircraft to have two sets of VHF communication transceivers installed and operational with 8.33kHz frequency spacing above FL245.

Additional proposed new communications rules are being considered covering 8.33kHZ, extending it to cover above FL195. Two sets of VHF communication transceivers with 25kHz frequency spacing are mandated below FL245, and elsewhere not covered by 8.33kHz requirements.

TCAS has already been mandated. There is also EGPWS, but this

Major structural modifications include Section 41 inspection termination. This has to be to completed by a total time of 20,000FC, and is estimated to have a total cost of up to $2.0 million. There are many aircraft in operation with a total time of less than 16,000FC, and these are more likely to be retired when reaching the 20,000FC threshold than bear the cost of the modification.

requirement is expected to expand as technology moves on. RVSM is currently only mandatory in Europe and the Atlantic ocean areas to support higher traffic densities. The B-RNAV is mandatory in Europe. P-RNAV is optional for now, but will be required to fly into major airports in the near future with preferential slots. Mode-S transponders are also mandatory, with the elementary and enhanced surveillance becoming mandatory in 2007. Strengthened flightdeck doors are mandated.

Requirements differ in North America. As with Europe, 8.33kHz frequency spacing and 25kHz frequency spacing are mandated. TCAS mandatory effectivity was extended to January 2005 and EGPWS also became mandatory in 2005. Mode-S transponders are mandatory as in Europe. As with all aircraft, strengthened flightdeck doors are mandated in North America.

Engine and weight upgrades

Aircraft from line number 260 incorporated an option to increase fuel capacity to 53,986US Gallons, which is available if the engines have sufficient thrust. Engine type is an important consideration when assessing a 747 Classic aircraft.

Upgrades are also available for Rolls-Royce engines, increasing their reliability and providing higher thrust ratings. Most upgrades involved high pressure turbine (HPT) blade modifications and fitting newer technology elements from the Trent 700 and 800 back into the RB211-524.

For aircraft from line 409 and beyond, upgrading the maximum take-off weight (MTOW) to the maximum 833,000lbs is possible, provided engines with sufficient take-off thrust are installed.

Paper change upgrades to increase MTOW that merely change charts and manuals are available, but most MTOW increases require modifications to the crown section, wing spar and monocoque or a stronger standard of landing gear. Most weight upgrades are usually incorporated as part of a freighter conversion programme.

Structural modifications

In the 1990s, two total loss accidents involving -200F aircraft operated by El Al and China Airlines, were caused by engine separation in flight. The four point attachment of the original engine pylon was meant to protect the fuel tanks in the wing by allowing pylon separation.

Boeing announced an upgrade programme to the Classic fleet based on the 747-400's pylon design which strengthened the fixing and introduced corrosion-resistant fuse pins. The modification required about 25,000 man hours (MH) and about 40 days downtime. Service bulletin (SB) 747-54A2159 is the overall and major terminating action for this modification. All affected aircraft have been modified.

Ageing aircraft considerations for the 747 Classic have been well defined and mandated. Section 41 remains the most well known modification to the 747-200/-300. Section 41 is the forward section of the fuselage, including the flightdeck and upper deck areas. In 1986 cracks were found in the fuselage rings in this area, mainly because the fuselage had a cross-section in the shape of a pear. All aircraft built up to line number 685, which was built in August 1987, are affected by AD86-23-06 (which superseded AD 86-03-51) which requires regular structural inspections of the area.

Inspections start at a total accumulated time of 8,000 flight cycles (FC) and continue until 19,000FC. After 19,000FC the inspections must be performed more frequently. Section 41 is, however, divided into nine zones so that an operator can opt to terminate certain zones and keep on inspecting others.

The extensive downtime involved in performing these inspections, and the cost of MH, means that most operators seek to terminate the AD and associated inspections with structural modifications. Terminating the inspection requires the virtual replacement of the nose section. Boeing provides kits free of charge, but all other costs have to be borne by the operator. About 32,000MH may be required to terminate all nine zones of Section 41. The total cost can easily amount to $2 million. Because of the extensive work involved in Section 41, operators tend to undertake the task at the same time as a D check. SB53-2272 covers this termination action.

The loss of TWA Flight 800 is still a mystery. However operators of the 747 already have to comply with new operating standards to minimise the risk of an in-flight explosion of the fuel tank. This is accomplished by ensuring that relevant tanks are full and in checking wiring for chafing. There are also more severe modifications being considered, including the use of inert gas to contain dangerous fuel vapour in tanks that are not full.

Noise compliance

Many 747-200s and -300s do not meet the FAR Part 36 Stage 3 noise requirements, without incurring weight penalties and/or landing flap settings.

Details of compliance for aircraft with different engine types and MTOWs are in Boeing document D6-13703 Section 1.2. Only Pratt & Whitney JT9D-7Q, JT9D-7R4G2, and General Electric CF6-50E series, and Rolls-Royce RB211-524D4 engines allow the aircraft to operate at the highest MTOW of 833,000lbs. A 820,000lbs MTOW certification is permitted for aircraft equipped with the JT9D-70A.

There are four different freighter conversion programmes for the 747-200/-300. Few -300s were converted, and some of the most popular types for freighter modification were the CF6-50E2-powered 747-200 Combis. Modification to freighter provides up to 25,500 cubic feet of cargo capacity and 234,000lbs of payload.

For the JT9D-7J, there is a paper modification that improves performance of the -200B when operating under Stage 3 restrictions. The upgrade is achieved by moving the centre of gravity, combined with a change in the aircraft trim. This allows a lower thrust setting to be used, resulting in lower noise levels at higher MTOW, increasing MTOW from 770,000lbs to 791,000lbs and increasing cargo capability for the -200B by an estimated 10 tons.

Freighter conversions

Over the past 20 years, the fleet of factory-built 747 freighters has been augmented by conversion of about 100 passenger 747s, mostly the -200 model. Boeing's launch of a passenger-to-freighter conversion for the 747-400 will start to affect the market for 747-200/-300 conversions. Many new start-up airlines, like US-based Focus Air Cargo and Cargo 360, turn to the 747-200/-300 for low-cost freighter assets.

During conversion, sidewall freighter panels are installed, primary and secondary control cables relocated, and a smoke detection system installed. The air-conditioning system will also be modified for a 747 freighter system. A side cargo door and freighter floor beams are installed. The body frames are reinforced to accommodate the heavier loads. Main deck floor panels are replaced with freighter floor panels. Combi aircraft are cheaper to convert, with four organisations able to undertake freighter conversions on the 747 Classics.

The cost of freighter conversion and accompanying freight handling system installation costs up to $16 million for a passenger aircraft, and up to $11 million for a Combi. This cost is excessive in relation to the 747-200's/-300's remaining life, especially when other costs of Section 41 and other modifications may also have to completed. Moreover, the market value, lower cash operating costs, higher payload capacity, and remaining life of the 747-400 make it more attractive for freighter conversion.

Boeing

Boeing Wichita has undertaken many such conversions on both the -200 and -300, but tends to be more expensive than its competitors. The downtime for Boeing ranges from 67-80 days. The cost of converting a -200B to a special freighter varies with specification. Converting a Combi to a freighter is about half the price of converting a passenger aircraft. There are various changes to the MTOW, maximum landing weight (MLW) and maximum zero fuel weight (MZFW), each adding to the base cost.

On the -300, the floor of the extended upper deck drops down on the main deck cargo bay, making it less attractive as a freighter. The Boeing reconfiguration of the -300 requires reinforcement of the forward section of the cabin floor and removal of the cabin facilities.

Bedek Aviation

Israel Aircraft Industries (Bedek Aviation) has become well known for 747 conversions, and is the largest conversion centre outside the US. Bedek has performed more than 36 747 Classic conversions.

Bedek's pricing for conversion of -200 passenger and combi aircraft is lower than Boeing's.

GATX/Airlog

GATX/Airlog also held an STC for the conversion of 747s, but the Federal Aviation Administration (FAA), admitted that this was granted in error. GATX/Airlog does not have the ability to undertake conversions itself, but relies on other modification centres. Two ADs were issued affecting 10 aircraft that were converted using the GATX modification (nine 100s and one 200). AD 96-01-03 makes it necessary to restrict the payload of the aircraft to only 120,710lbs, compared to its full 220,195lbs capability, making the aircraft uneconomic to operate. The 13 aircraft that have been converted using the GATX/Airlog modification from Combi or CRAF units are not affected by the restrictions of the AD.

HAECO/TAECO

HAECO is the fourth conversion centre. During 1995, it completed the first -200SF conversion for South African Airways. However the Hong Kong-based company has preferred to focus on conversions for Combis. HAECO won a large order from Atlas Air for Combi conversions.

TAECO's Combi to freighter -200 conversion is cheaper than the Boeing conversion.

747-200SF payload

Each conversion has an optional maximum zero fuel weights (MZFW) of 545,000lbs, 560,000lbs and 590,000lbs. The higher MZFW option is achieved by additional structural modifications during conversion, and commands a higher price. The OEW of converted aircraft, including tare weight of containers is about 356,000lbs. This gives the aircraft a structural payload of up to 234,000lbs.

With the side cargo door installed, the 747-200SF can accommodate eight 96-inch high containers and 21 118-inch high containers. These provide about 20,245 cubic feet. In addition, the aircraft can carry 30 LD-1 belly containers which provide a total volume of 5,250 cubic feet. Total volume in this configuration is 25,495 cubic feet, which allows a maximum packing density of 7.4-9.1lbs per cubic foot. Other configurations, that include pallets, provide less volume. AC

747-200/-300 maintenance analysis & budget

The 747-200/-300 has high maintenance costs, although operators can minimise these as aircraft approach retirement.

The 747-200/-300s that remain in service are between 15 and 34 years old *(see 747-200/-300 fleet analysis, page 8)*. This means that virtually all aircraft in operation have had three D checks, while the oldest will have been through five. Many 747-200s and -300s operate as freighters or converted freighters, while no more passenger-configured aircraft are being modified to freighter. Most aircraft will continue in operation until they reach their fifth D check or up to a maximum age of 30 years.

Most aircraft now accumulate about 3,500 flight hours (FH) per year and have an average flight cycle (FC) time of 5.0FH, thereby generating about 700FC annually.

Maintenance programme

The 747-200/-300's line maintenance programme is standard for most types. The aircraft has transit and pre-flight checks prior to each flight, and daily checks. While daily checks on short-haul aircraft are performed at night when the aircraft are grounded, 747 operators still have to do daily checks when the aircraft return to home base, or occasionally at outstations. Many operators are permitted interval extensions of 48 hours for daily checks. Ameco Beijing, which manages the maintenance for Air China's 747-200F fleet, has a system with an AF check every 24 to 48 hours, as well as a daily check performed every five elapsed days of operation.

There are five A check multiples: the 1A, 2A, 3A, 4A and 6A items. The A check cycle will therefore be completed at the A12 check when all task groups are in phase. The basic interval for 1A items varies. Ameco Beijing has an interval of 300FH. "The A check cycle has an interval of 3,600FH, which coincides with our basic C check interval," says Michael Keller, manager of production engineering & planning department at Ameco Beijing.

Maintenance schedules for A checks are similar for most airlines, although some operators choose to equalise the A check packages. Air New Zealand had a block check system, but had a basic 1A interval of 450FH which was later escalated to 550FH.

El Al operates a unique ramp and A check system. "Until now we have used a system of transit checks prior to each flight, a daily check every 24 hours performed at Tel Aviv, and E800 and L800 checks to deal with engine-related and lubrication items from the A check instead of having a full A check. These two have an interval of 800FH," explains Moti Sonsino, director of aircraft overhaul and logistics at El Al Engineering. "We then have a larger B check every 1,600FH. Our fleet of five aircraft is now between 24 and 27 years old, and we are going to change to a system of having an A check every 400FH to replace the E800, L800 and B checks. This is because the number of defects is gradually increasing and more frequent line checks are needed to manage it."

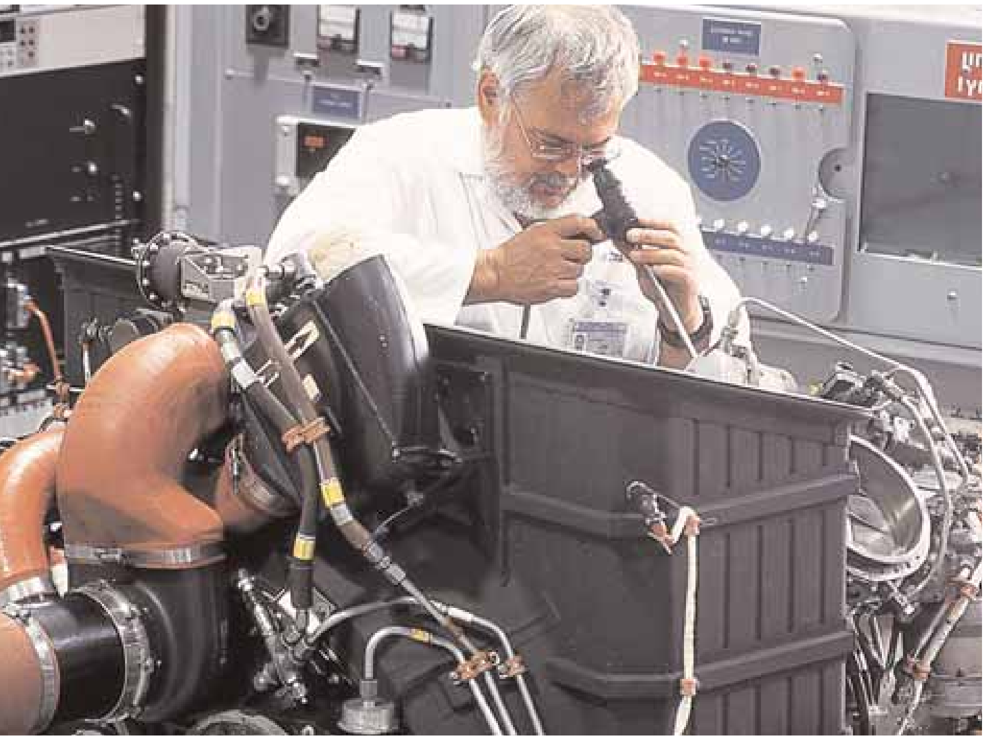
The 747-200/-300 originally had an MSG-2 maintenance programme. Most operators have remained with it.

The 747-200-300 has a block C check programme, with five multiples. "The basic C check interval is 3,600FH and 15 months, whichever comes first," explains Keller. "The five multiples are 1C, 2C, 3C, 4C and 6C groups of tasks. These can be equalised, but we group multiples accordingly to perform block checks, with the C4 check having the 1C, 2C and 4C items. The C6 check has the 1C, 2C and 3C items. This has an interval of 21,600FH, and the C7 check has an interval of 25,000FH. There are also a few items at 20,000FH, which are de-escalated to the C5 check.

"The D check is independent of the C check, and the D check interval varies according to which one has been performed," continues Keller. "The D1 has an interval of 25,000FH, the D2 an interval of 22,000FH, and the D3, D4 and D5 all have a 20,000FH interval. This 20,000FH interval coincides with the probable timing of the C6 check, at which point the C check cycle is terminated."

Other operators have longer C check intervals. "We had an interval of 5,000FH, and then escalated this to 6,000FH and 15 months," says Graham Wallace, project leader engineering services at Air New Zealand Engineering Services (ANZES). "Our D check interval was 25,000FH and was then extended to

The 747-200's/-300's ageing aircraft programme adds a large number of MH to base checks. Full workpackages for D checks can be 90,000-100,000MH for aircraft at their D4 or D5 checks.



Rotables can be paid for via a flight hour agreement. The implosion of the 747-200/-300 fleet, however, means many airlines can reduce their cost of rotables by acquiring items at low rates on the used market.

30,000FH. We originally phased our maintenance programme by performing 1/8 of 1C items, 1/16 of 2C items, and 1/32 of 4C items in each check, which was performed about every eight weeks. We then changed to a block system, with a C check about every 13 months."

El Al equalises its D check over six C checks. The C check has a basic interval of 4,800FH and 24 months, whichever comes first," explains Sonsino. "We use about 90% of the full cycle interval of 28,800FH, and so complete it at about 24,000FH."

Ageing programme

In addition to base maintenance checks in the MSG-2 maintenance programme, operators have to consider additional maintenance requirements connected to the aircraft's ageing aircraft programme. "There are four main parts to the 747-200/-300's ageing aircraft programme," explains Sven Pawliska, team leader system engineering at Lufthansa Technik. "The first of these is the corrosion prevention and control programme (CPCP). This is a set of about 30 inspection tasks to check for corrosion, which have initial thresholds of between four and 30 years. These also have repeat inspection intervals. These inspection intervals are not in the same phase as the C and D checks in the MSG-2 maintenance schedule. The addition of the CPCP to the C and D checks means they vary in workscope content and MH requirement.

"The second main part of the ageing aircraft programme is the supplemental structural inspection document (SSID). This is sometimes referred to as the SSIP," continues Pawliska. "This is independent of the MSG-2 maintenance programme, and the SSID should not be confused with the significant structural items (SSI), which is a part of the MSG-2 maintenance programme related to the aircraft structure. The SSID is also a set of structural inspections which add to the workscope of the C and D checks.

"The other two parts of the ageing aircraft programme are the repair assessment programme (RAP) and widespread fatigue damage (WFD) programme. The RAP requires an inspection of a structural repair 15,000FC after it has been performed, while the WFD requires inspections if fatigue damage is found in several places on an aircraft or on several aircraft in a fleet," explains Pawliska.

Boeing made an MSG-3 analysis for the 747-200/-300 and issued the maintenance programme in 2002. A few operators have converted their aircraft from an MSG-2 to an MSG-3 programme, although it is only considered to be beneficial if aircraft remain operational for an extended period. "Changing to an MSG-3 programme escalated a lot of inspection and C and D check intervals and incorporated the ageing aircraft inspections into the MPD. Overall it resulted in fewer total MH being consumed in C and D checks," says Pawliska. "As an example, the C check interval was extended from 3,600FH and 15 months to 6,000FH and 18 months. The D check interval was changed to a six-year interval, with no FH limitation. Changing to an MSG-3 programme obviously requires a bridging check, which is best done during a D check."

Heavy modifications

The 747-200/-300 has had several highly publicised, major structural modification programmes. The first of these is the Section 41 modification, which affects the front section of the fuselage. The pear-shaped profile of this section was found to cause cracks in the fuselage rings as early as an accumulation of 6,500FC. This was dealt with under airworthiness directive (AD) 86-03-51, which was later superseded by AD 86-23-06. This AD affected all 747s up to line number 603. This was an aircraft built in 1984 for Singapore Airlines. The AD was later revised and extended to line number 685, a -200B built in late 1987 for the US Air Force. The extension brought some -300s into the group of aircraft affected by the AD.

The AD requires a series of repetitive inspections to some of the structural parts in Section 41. The threshold for these inspections is 8,000FC, and the amount of Section 41 that is affected is initially small, but increases up to 19,000FC when the whole of Section 41 must be inspected. After this threshold is reached inspections have to be performed every 1,500FC or 3,000FC. The need to perform these inspections can be terminated by replacing part of the original structure. The 1,500FC repeat interval after 19,000FC effectively means the modification has to be performed by a total time of 20,000FC.

This modification was incorporated on the production line for aircraft with line number 686 and higher, so that these aircraft are not affected by the AD. This includes all -400 series aircraft.

The modification can be carried out in stages, since it concerns several zones of the Section 41 structure. The modification can also be completed in a single step, and is combined with a D check. The full cost is estimated to be up to about $2.0 million, which includes a labour input of up to 40,000MH. The modification kits are supplied free by Boeing.

Many, mostly older, 747s have completed their Section 41 modifications. The majority of the 281 aircraft still in operation have accumulated less than 20,000FC and so are unlikely to have had the full modification performed. This will be required for continued operation after 20,000FC. The age and market for used 747-200s/-300s has to be considered when assessing whether the Section 41 modification should be completed. No more 747-200s/-300s are likely to be converted to freighter, since the younger -400 is at an age and market value where modification to freighter is economic. The -400 has a larger payload capacity, longer range and lower operating costs than a -200 or -300. The implications therefore are that remaining 747-200s/-300s will continue in service until they reach the 20,000FC threshold for Section 41 modification, at which point the cost of the modification will be economically prohibitive and the aircraft will be retired. Many aircraft have accumulated between 10,000FC and 15,000FC, and so could remain operationally viable for up to another 15 more years.

The second major structural modification for the 747 was the engine pylons. This was initiated by separation of the engines from the wing during flight on three aircraft, resulting in total loss. This led to an AD 95-13-05 being issued in 1995 which required the modification of engine pylons on all 747s up to line number 1,046. This affects all 747-200s and -300s built, as well as some of the earlier production -400 series aircraft.

The modification requires the four original engine mountings to be strengthened with the installation of stainless steel bolts and the addition of two new mountings. The deadline for completing this modification was three to five years from the issuance of the AD in 1994, and so all affected aircraft will have been modified.

Line maintenance

On the basis of an annual utilisation of 3,600FH and 700FC per year, an aircraft will operate for up to about 330 days per annum. This implies that about 65 daily checks, 260 AF checks, about 375 transit checks and 325 pre-flight checks will be performed annually. This is a total of about 1,025 ramp checks per year.

The completion of the A check cycle will depend on the operator's A check interval and how much of it is actually utilised. Intervals vary between 300FH and 500FH, and utilisation rates are 60-80%. The A check cycle will thus be completed every 2,700-4,000FH, equal to between nine and 13 months of operation.

The total consumption of MH and materials for line, ramp and A checks will depend on various factors: the A check cycle completion interval; the number of ramp checks performed during this interval; the number of MH used in each check; the operator's policy for managing deferred defects; and labour efficiency. The policy of managing and clearing deferred defects will affect the non-routine portion of the checks.

Completion of the A check cycle every 2,700FH and nine months will result in about 525 pre-flight and transit checks, 195 AF checks and 50 daily checks being completed during the same period. This is a total of 775 ramp checks.

Keller estimates that pre-flight and transit checks each consume an average of seven MH and $500 in consumables and expendables. AF checks require 22 MH on average and use about $1,000 in consumables and expendables, while daily checks use about nine MH and a similar amount for materials. The inputs for these ramp checks over one A check cycle total about 8,500MH and about $600,000 in consumables and expendables. Line maintenance labour charged at an industry average rate of $70 per MH takes this to a total cost of about $1.2 million. This equals a cost of about $446 per FH when amortised over the 2,700FH interval.

Longer A check intervals of up to 600FH might allow actual A check intervals of 350FH, and the completion of the A check cycle every 4,200FH.

Total maintenance costs for the 747-200/-300 can be close to $3,000 per FH. Airlines can make reductions on this cost by managing engines to avoid LLP replacement, acquiring cheap rotables on the used market, minimising base check work packages, and even dispensing with reserves for a D check if its known the aircraft will be retired.

More line and ramp checks would be completed in this period, and their total cost would be $1.87 million. The overall cost per FH of performing these checks would still be about $445 per FH *(see table, page 22)*.

The routine MH input for A checks varies by check because of the block system. In addition to routine inspections, MH will be required for rectification and clearance of deferred defects. The A4, A8 and A12 checks will have the largest labour inputs and will use in excess of 1,000MH. An average consumption of 600MH should be used for a conservative budget for aircraft beyond their third D3 cycle. This is equal to $42,000 for labour charged at $70 per MH. Expenditure on materials and consumables will be $6,000, taking total cost for the check to $48,000. Performance of an A check every 350FH is equal to $138 per FH *(see table, page 22)*.

Base maintenance

Operators have a variety of choices for organising their base maintenance schedules. The most common is the standard MSG-2 system of block C checks and a D check performed at the C6 or C7 check, terminating the C check cycle.

Workscopes of C and D checks have several additions to the routine inspections of the MSG-2 task cards. The ageing aircraft programme will add inspections for the CPCP and SSID programmes. These and the routine task cards will result in findings and non-routine rectifications.

Another addition to this basic package of work will be engineering orders, Service Bulletins (SBs), Engineering Orders (EOs) and ADs. These vary in total quantity for each check, and according to the operator's policy for incorporating modifications. A further possible addition will be major modifications, such as Section 41 inspection. The third major addition to a base check work package will be interior work. This can involve cleaning and small rectifications, as well as major refurbishment of the galleys, toilets, overhead bins, sidewall panels, carpeting, seats, and in-flight entertainment (IFE) systems. In the case of freighter aircraft, many of these interior items will not be included, although the freight handling system will require inspections and rectifications. This is despite on-going repairs being made to the freight handling system during operation.

The last major item that can be added to the work package of a C or D check is stripping and repainting, which adds a significant number of MH and cost for paint.

The number of MH for routine inspections will be influenced by the timing of the specific ageing programme tasks included in each workscope, how well planned each check is, and the efficiency of labour. The non-routine labour requirement and ratio will also be affected by planning and labour efficiency.

"The amount of MH used for MSG-2 and ageing aircraft routine inspections varies by a small amount for the actual C check," explains Ralf Riemann, manager service engineering VIP & Government jet maintenance at Lufthansa Technik. "This can typically be 7,000-8,000MH if the check is planned and performed efficiently, but can rise to up to 12,000MH for a less efficient check.

"The non-routine ratio for aircraft that have accumulated a total time of about 60,000FH can be in the region of 50%, and so the number of non-routine MH arising from these inspections will be 3,000-4,000," continues Riemann. "This would take MH for routine and non-routine work to about 13,000MH."

A higher non-routine ratio of 100% is not uncommon in some aircraft, and so can be in the region of 8,000-12,000MH for some aircraft that are in their D3 or D4 check cycles. This could take the total for just the MSG-2 and ageing aircraft inspections up to 24,000MH.

"While modifications incorporated during C checks vary, only certain modifications can be made because of the restrictions imposed by downtime for the check and the requirement that power be switched off," explains Riemann. "Modifications, EOs, SBs and ADs can typically add 2,000MH to a C check. A further 800-1,000MH can then be added for the cleaning of the aircraft interior and maintenance of IFE equipment. Freighter aircraft will of course not require some of the work on interiors that passenger aircraft do, but the cargo handling system can still use 500-1,000MH for repairs. Therefore, even when the MH for MSG-2 and ageing aircraft inspections total about 13,000MH, the total labour consumption for the check would be in the region of

16,000MH. A higher non-routine ratio could see that total rise to more than 20,000MH for some aircraft. Downtime for this size of check will be five to eight days. The cost of consumables and expendables commensurate with this size of check will be in the region of $100,000."

Wallace at ANZES confirms that workscopes and inputs for C checks of 747-200s/-300s can be high. "Our 747-200s consumed in the region of 8,000MH when we first switched the aircraft to a block base system. The MH consumption had already climbed to 12,000-14,000 by the late 1990s just before we retired the aircraft," says Wallace. "The C check workscope includes: routine task cards and consequential rectifications; CPCP and ageing programme inspections and rectifications; EOs and ADs; and cabin work. The CPCP and ageing programme portion itself could consume up to 10,000MH, and the total for a C check would now be in the region of 20,000MH."

The D check will terminate the C check cycle. Routine task cards will therefore include various C check items. "Routine tasks and inspections for the MSG-2 items and ageing programme inspections can be as high as 40,000-50,000MH in a D3 or D4 check. An aircraft will have accumulated a total time of about 65,000FH at a D3 check and about 82,000FH at a D4 check," says Riemann. "The non-routine ratio for an aircraft of this age may only be as low as 25%, and so only 12,000-13,000MH are generated from these routine inspections. The total MH is thus 52,000-63,000. A higher non-routine ratio of up to 75% is seen in many aircraft, with 30,000-40,000MH being required. A total of 70,000-80,000MH is therefore used for this portion of the work package. Besides major modifications, the amount of labour required for EOs, SBs and modifications is in the range of 6,000MH to 8,000MH for most D checks. A similar amount of labour is required for interior refurbishment where seats, sidewall panels, and toilets and galleys are refurbished. Only 2,000-3,000MH would be required for interior-related work for freighter aircraft. Stripping and painting will use about 3,000MH."

This will take the total labour consumption to 67,000-83,000MH for a passenger-configured aircraft with a low non-routine ratio, but up to 95,000MH for an aircraft with a high non-routine ratio. Freighter aircraft will require marginally less MH. Downtime for a smaller work package will be about 50 days, climbing to 75 days for a heavy package. Riemann estimates the labour requirement for a D5 check can easily reach 100,000MH, since there is a higher requirement from the SSID programme. One example is the need for removal and non-destructive testing of the wing bolts.

Riemann estimates the cost of consumables and expendables associated with this check to be in the region of $700,000, which could easily climb to $900,000-1,000,000 for a check with a higher MH consumption, higher level of modifications and extensive IFE installation.

A full D check cycle might be completed about every 20,000FH, including five C checks. Consumption of 18,000MH and $100,000 in materials for each C check, and 90,000-100,000MH and $700,000-1,000,000 in materials for the D check would result in a total cost of $10.2-11.0 million for the D check cycle. Over the 20,000FH interval, this would be equal to $510-550 per FH *(see table, page 22)*.

Heavy components

This group includes four types of component, each of which has either its independent maintenance programme or 'on-condition' maintenance: wheels and brakes; landing gear; auxiliary power unit (APU); and thrust reversers.

The maintenance and repair of these components is mainly FC-related, and so the final cost per FH is dependent on the FH:FC ratio. This analysis assumes an average FC time of 5.0FH, although each operator's actual FC time will vary.

The overall cost per FC for the repair of wheels and brakes is a combination of the cost per FC of tyre remoulds and replacements and wheel inspections and repairs. There are 16 main wheels and brakes and two nose wheels. Average tyre remould intervals for main wheels are 280FC. Tyres might be remoulded four times at an average cost of $500 and then replaced at a typical cost of $1,800. Overall cost per FC for 16 main tyres is $43.

Nose wheels are remoulded about every 350FC at an average cost of $400, and are replaced for about $1,000. Overall cost per FC for two nose tyres is $3. The total for main and nose wheel tyre remoulds and replacement is $46 per FC *(see table, page 22)*.

Wheel inspections are made at tyre remoulds, with costs of $650 for main wheels and $600 for nose wheels, resulting in a cost per FC of $40 *(see table, page 22)*.

Each main brake unit is repaired about every third wheel removal, at about 850FC, and at a cost of about $13,000. Overall cost per FC for main brake repairs is $245 *(see table, page 22)*.

Landing gears can be removed every eight to 10 years, equal to every second D check. The most common method is an exchange of a landing gear shipset, which in the current market costs about $575,000. This is equal to $85-105 per FC, depending on actual removal interval, and $17-21 per FH *(see table, page 22)*.

Thrust reversers are removed for maintenance on an on-condition basis. Shipsets are removed every 6,000-8,000FC for the JT9D and CF5-50 engines. An average cost for a thrust reverser shipset shop visit is about $170,000. For the four shipsets, this is equal to about $115 per FC, or $24 per FH *(see table, page 22)*.

The 747-200/-300's APU is the GTCP 660. This has an average shop visit interval of about 3,000 APU hours. On the basis that an operator will use the APU for an average of two hours every flight, it will have an annual utilisation of about 1,400 hours. It will therefore have a shop visit about every two years. An average shop visit cost of $180,000 results in a cost per aircraft FC of $120, equal to $24 per FH *(see table, page 22)*.

The total for all heavy components is about $668 per FC, equal to $134 per FH *(see table, page 22)*.

Rotables

Remaining rotable components can be maintained according to the maintenance programme, on an on-condition basis or using soft times derived from the history services of these components to provide a preventative maintenance programme.

These rotables include: avionics; emergency equipment; galley and interior items; flap mechanisms; flight controls; hydraulic system items; pneumatic system items; fuel system items; electrical system items; and a large number of other components.

Collectively these rotables can be paid for using a flight hour agreement with a large 747-200/-300 maintenance provider or component specialist.

Rates will depend on exclusions, which are the items not covered in the flight hour agreement. These can vary. In some cases wheels and brakes are included in the agreement for rotables, while other heavy components are not included. Flight hour agreements often exclude cabin and IFE items.

When the heavy components previously described are excluded and all other rotables are included, a typical flight hour agreement will be in the region of $150 per FH for the lease of the components and an additional $400-450 per FH for the repair and management of the rotables. This would take the total cost for rotables to $550-600 per FH *(see table, page 22)*. There is now a high supply of many rotables on the aftermarket, which may allow lower costs.

Engine maintenance

The 280 747-200s/-300s still in operation are powered by a combination of JT9D, CF6-50 and RB211-524 engines. Potential and current operators are interested in the highest gross weight aircraft with the largest payload and longest range capability.

The majority of the lower gross weight aircraft are powered by the -7A and -7F variants of the JT9D. There are few of these left in operation. The highest maximum take-off weight for the 747-200 and -300 is 833,000lbs. These aircraft are powered by the JT9D-7Q, JT9D-7R4G2, CF6-50 and RB211. About 240 of the aircraft left in operation are equipped with these engines.

About 55 747-200s have the JT9D-7Q, while the majority of the 52 aircraft with the JT9D-7R4G2 are 747-300s. The most popular of all 747-200s/-300s are those with the CF6-50E2 engine. Atlas Air, for example, acquired all its 747-200s with CF6-50 engines. There are 86 of these aircraft still in operation.

Less important and less popular are the 40 aircraft with RB211-524 engines, the majority of which are the -524D4.

Aircraft with the JT9D-7Q/-7R4G2 and CF6-50 engines will remain the most important types in the future.

Like most Pratt & Whitney engines, the JT9D is usually managed so that it follows an alternating pattern of a performance restoration followed by an overhaul. The engines are now mature, and only have EGT margins of 20-50 degrees centigrade following an overhaul. These margins deteriorate at about 8-12 degrees per 1,000 engine flight cycles (EFC), and so could potentially remain on-wing for 2,500-4,000EFC. Actual average removal intervals between shop visits for an operation with an average EFC time of 5.0EFH are in the region of 6,000-7,000 engine flight hours (EFH) for the JT9D-7J and 7,000-8,000EFH for the -7R4G2. Removals to the first shop visit are longer than to the second removal.

The workscope for performance restoration shop visits for these two variants consumes about 4,500MH, $800,000 in materials and another $450,000 for sub-contract repairs. An average labour cost of $70 per MH results in a total shop visit cost of $1.6 million.

Overhauls use about 5,500MH, up to $1.5 million for materials and $550,000 for sub-contract repairs. This would take total cost to about $2.5 million.

These two shop visits amortised over the combined removal intervals of 14,000FH for the JT9D-7Q and 16,000FH for the JT9D-7R4G2 generate reserves of about $295 per EFH for the JT9D-7Q and $255 for the JT9D-7R4G2 *(see table, page 22)*. These rates would be lower for aircraft operating with longer average cycle times, since removal intervals are closely related to EFCs and shop visit inputs would be similar to those described. Some operators are also able to achieve removal intervals up to 2,000EFH longer than those described, which would also result in lower reserves per EFH.

The replacement of LLPs has to be considered in addition. All LLPs have lives of 15,000EFC for both variants, and a full set has a list price of about $1.7 million. Given that in this scenario -7Q engines will accumulate about 2,600EFC between overhauls and -7R4G2 engines about 2,800EFC between overhauls, LLP replacement would be most efficient at every fourth or possibly fifth overhaul. This interval, however, is equal to about 20 years of operation. Given that the youngest aircraft are 15 years old and the oldest aircraft with -7Q engines are 25-26 years old, and that most aircraft are only likely to be operated up to a maximum age of 30 years, airlines may be able to avoid the cost of replacing LLPs in most of their engines. This is because LLPs will have already been replaced one and are unlikely to require replacing a second time in their operational life.

Time-continued engines are often available on the market, as are LLPs, and values are likely to steadily decline over the long term. Airlines will thus only need to replace LLPs in some of their engines at a fraction of the cost of replacing all of them with complete new sets.

DIRECT MAINTENANCE COSTS FOR 747-200/-300

Maintenance Item	Cycle cost $	Cycle interval	Cost per FC-$	Cost per FH-$
Ramp checks	1,870,000	4,200FH		445
A check	576,000	4,200FH		137
C & D checks	10,200,000-11,000,00	20,000FH		510-550
Heavy components:				
Landing gear	575,000	5,600FC	103	21
Tyre remould & replacement	66,000	1,400/1,750FC	46	10
Wheel inspections	11,600	280/350FC	40	8
Brake inspections	208,000	850FC	245	50
Thrust reverser overhauls	680,000	6,000FC	113	23
APU	180,000	1,500FC	120	24
Total heavy components			668	134
LRU component support				550-600
Total airframe & component maintenance				**$1,775-1,865/FH**
Engine maintenance:				
4 X JT9D-7Q				$1,180/FH
4X JT9D-7R4G2				$1,020/FH
4X CF6-50E2				$1,040/FH
Total direct maintenance costs:				
Aircraft equipped with JT9D-7Q:				$2,955-3,045/FH
Aircraft equipped with JT9D-7R4G2:				$2,795-2,885/FH
Aircraft equipped with CF6-50E2:				$2,815-$2,905/FH

Annual utilisation:
3,500FH
700FC
FH:FC ratio of 5.0:1.0

The CF6-50 will achieve average removal intervals of 1,300-1,500EFC at an average EFC time of 5.0EFH, equal to about 6,500-7,500EFH in most 747-200/-300 operations, although some airlines can achieve up to another 1,000EFH on-wing.

The CF6-50 follows a shop visit pattern described by General Electric's workscope planning guide. This outlines the workscope at three levels for each of four modules based on the time since the last overhaul. The CF6-50 generally follows a shop visit pattern of alternating workscopes similar the JT9D.

A performance restoration shop visit will consume 4,000-5,000MH, about $600,000 for materials and $500,000 for sub-contract repairs. This will take total cost for the shop visit to $1.4-1.5 million.

An overhaul will consume about 5,500MH, $800,000-900,000 for materials and up to $800,000 for sub-contract repairs, taking total shop visit cost to $2.0-2.2 million.

The two shop visits will generate a reserve of about $260 per EFH. Like the JT9D, the life of LLPs in the CF6-50 is long compared to the probable remaining life of the aircraft. A full set of LLPs has a list price of more than $2 million, while the supply of time-continued engines and LLPs will be relatively high and so market values low. Like the JT9D, LLPs in the CF6-50E2 will have already been replaced once in most engines and will not need replacing a second time in their operational life. Airlines may be able to acquire time-continued LLPs at cheap rates on the used market for young engines that may require LLP replacement.

Maintenance cost summary

The costs for almost all direct maintenance for the 747-200/-300 are summarised *(see table, page 22)*. Absent costs are reserves for engine LLPs and spare engine provisioning. LLPs have been omitted because the age of the aircraft means that in many cases it will not be necessary to replace them again. Spare engine provisioning can now be variable and also less with a high supply of time-continued engines on the market.

The total maintenance costs for the aircraft are $2,800-3,050 per FH, depending on engine type, inputs required for airframe checks, and the negotiated terms for rotable support. This compares to a total maintenance cost of $1,500-1,600 per FH for the 747-400. The 747-200/-300 suffers partly because its assumed FH:FC ratio in this analysis is short compared to most -400 operations. This automatically increased engine- and component-related costs for the -200/-300. The 747-200/-300 is also at a disadvantage because of the high MH inputs into base checks and short removal intervals between shop visits.

There are also several limits to continued operation that operators must consider. The first of these is engine maintenance costs, which are increasing per FH because of reducing intervals. Engine LLP replacement is also high, at about $2 million per engine, which is equal to the current value of most some engines or about half the value of passenger-configured aircraft. The cost of four sets of engine LLPs exceeds the market value of most 747-200 and -300s.

Another issue is the high inputs required at the D5 check, which is likely to trigger retirement by most operators. There is also the issue of Section 41 termination. Most 747-200s/-300s in service have not reached the 20,000FC threshold for termination, and the cost of this is another cost barrier that is likely to trigger retirement, unless the modification has already been completed.

Operators can find ways to reduce maintenance inputs and costs. One consideration is to minimise the work performed on interiors, EOs, ADs and modifications during base checks. Time-continued engine modules and landing gear sets can sometimes be purchased on the aftermarket for less than the cost of a full shop visit.

Long-term considerations

Few of the aircraft that remain in operation are unlikely to go through their D5 check or pass the 20,000FC threshold for Section 41 modification. These both represent timings for probable retirement. The cost of completing both of these will exceed $7.5 million. The reserve for this, plus cost of C checks, engine LLP replacement and engine maintenance reserves make the maintenance costs of ageing 747-200/-300s excessive. This indicates that the remaining 280 aircraft in operation will retire at a high rate , with few left in operation in another 10 years. If Section 41 modification and engine LLP replacement can be avoided, the aircraft provides large capacity when its combined low capital cost and maintenance costs are considered. AC

747-200/-300 values & aftermarket activity

Values of most 747-200s/-300s are less than $10 million. Low-time aircraft can provide airlines with low-cost high capacity for up to 10 years. ¶

Values of most 747-200s have now fallen to scrap level. That is, the intrinsic value of an aircraft is directly related the market value of its engines and any salvage value that can be derived from its rotables. The aircraft that have values better than scrap are the youngest -200Fs built in the late 1980s, 1990 and 1991 that are powered by the JT9D-7R4G2 and CF6-50E2, as well as -300s with the same engines that have accumulated less 80,000 flight hours (FH) and 15,000 flight cycles (FC).

The poor value of the majority of aircraft is explained by several reasons. The first is that the age of the youngest aircraft is 18 years, while some are up to 30 years old. The implications of this are that aircraft fall into two categories. The first are those that have completed their Section 41 modifications, but have also surpassed their D4 or D5 check. The implications of this are that these aircraft are most likely to be retired when they reach their next D check, because of escalating maintenance costs.

The second group is aircraft that have not completed their Section 41 modifications. While these will be relatively young, the $1.5 million cost of completing the Section 41 modification will present a high cost barrier when the 20,000FC threshold is reached. Most aircraft that fall into this category are 15-20 years old and have accumulated 12,000-17,500FC. They will thus reach the threshold for Section 41 modification termination in the next three to 10 years. The timing of this threshold will coincide with a D check for some aircraft, and the two can total up to $7.5 million. During this same period less maintenance-intensive 747-400s will come onto the market and so operators will favour younger aircraft.

No more of the remaining passenger-configured or Combi 747-200s and -300s are being converted to freighter. This is because of high on-going maintenance costs, the cost of conversion being up to $16 million, the likelihood that to continue in operation aircraft will probably require more avionic upgrades, and the useful remaining life of most aircraft being less than 10 years.

There is thus little or no market demand for used 747-200s/-300s, resulting in a collapse in values.

The demand for good quality 747-200SFs remains strong, however. All good quality aircraft are flying. This is a result of a rebound in freight traffic, with volumes back at pre-9/11 levels.

This has pushed lease rates for 747-200Fs/-200SFs back up to about $350,000 per month. The aircraft, however, have high maintenance costs in the region of $2,800-2,900 per FH. This compares to total maintenance costs in the region of $1,600 per FH for the 747-400. The 747-400SF also has a payload capacity of about 253,000lbs, which compares to 190,000-230,000lbs for the 747-200SF. Operators of 747-200SFs are thus using the aircraft as a stop gap until 747-400s get converted in large enough numbers to provide replacements.

The 747-200SF provides low-risk capacity for start-up freight operators. Cargo 360 based in Seattle, Washington and Focus Air Cargo, based in Miami Florida are both commencing operations with 747-200SFs.

A few 747-200s and -300s have been acquired by passenger carriers. Aircraft that can operate for another five to eight or nine years before requiring heavy maintenance provide cheap lift for the large payload they provide. Better quality and younger -200s and -300s have a market value in the region of $8-12 million. Although a large range of recent avionics modifications are only mandatory in Europe and North America, most aircraft around the world will have had these incorporated because of the long-distance nature of their operations. Most large one-off maintenance or upgrade costs can thus be avoided with these aircraft. These -200s and -300s can provide capacity at a low total cost until used 747-400s start coming onto the market. AC

There are few low-time, high specification aircraft available, but if operators can acquire them these aircraft will provide low cost capacity for up to another 10 years. Despite high maintenance costs, low capital costs and lease rates mean total operating costs are low.