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