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**A330-200 & -300 specifications**

The A330-200/-300 family is powered by three main engine types. There are several MTOW, MLW & MZFW combinations and engine thrusts, making aircraft specifications complex.

For the passenger aircraft, there are five designations of the A330-200 series and nine of the A330-300 series. The five -200 variants are the -201, -202, -203, -204 and -243. The nine -300 variants are the -301, -302, -303, -321, -322, -323, -341, -342, and -343.

The last digit of the variant's suffix refers to the installed engine thrust rating (see table, page 9).

The middle digit refers to the engine family: the use of a 0 refers to the CF6-80E1; the use of a 2 refers to a PW4000 family; the use of a 3 refers to the installed engine thrust rating (see table, page 9).

To summarise for the -300 series, these span the following weight ranges: M TOW of 184t-233t (405,720lbs-513,700lbs); M LW of 180t-182t (396,900lbs-401,300lbs); M ZFW of 168t-170t (370,440lbs-374,850lbs). Airbus states that the A340-200’s typical OEW is 263,700lbs.

**Configuration**

The A330-200 and -300 are available with three engine choices: the General Electric CF6-80E1; Pratt & Whitney PW4164; and Rolls-Royce Trent 700. The shorter A330-200 is capable of flying up to 6,450nm with about 240 passengers. The longer -300 has a range of up to 5,400nm with 300 passengers.

The flightdeck design was finalised in 1988 and is virtually identical to that of the A320 family, with a six-screen electronic flight instrument system (EFIS) and side-stick controllers. Like the A320 family, the A330 and its sister A340 use a digital fly-by-wire (FBW) flight control system. This allows the two aircraft to benefit from a common type rating and cross-crew-qualification (CCQ).

The A330 and A340 flightdecks differ only in the number of engine throttles and engine-related displays. Meanwhile, the windows are structurally similar, with differences mainly being due to the A330 having one engine pylon per wing, compared with the two on the A340.

**Aircraft weight options**

Today Airbus offers two ‘basic’ factory production maximum take-off weight (M TOW) options for both the A330-200 and A330-300. These are marketed in European metric units as the standard ‘230-tonne’ aircraft (507,000lbs) and ‘233-tonne’ aircraft (513,700lbs).

The ‘basic’ A330-200 is today identified in Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA) certification documentation by the weight variant number ‘020’. This number is not used in the name suffix. This offers an M TOW of 507,000lbs, a maximum landing weight (M LW) of 396,900lbs, and a maximum zero fuel weight (M ZFW) of 370,440lbs (see table, page 9).

Meanwhile, the high gross weight version today is identified in certification documentation as ‘052’. It has a higher M TOW of 513,700lbs, an M LW of 401,300lbs, and an M ZFW of 374,850lbs (see table, page 9). In addition to these two weight variants, there are many more possible combinations of M TOW, M LW and M ZFW. The combination depends on individual customer requirements and engine thrust. In summary, the weights for the A330-200 series lie between the following ranges: M TOW of 192t-233t (423,288lbs-513,765lbs); M LW of 180t-182t (396,900lbs-401,300lbs); M ZFW of 168t-170t (370,440lbs-374,850lbs).

**A330-200 Freighter**

The A330-200F is the most recently launched version of the A330-200/-300 family. The A330-200F has just two combinations of weight and payload options. Airbus simply differentiates these two as ‘Range M o/e’ and ‘Payload M o/e’. For Range M o/e (standard
version), the MTOW is 513,765 lbs, M LW is 401,300 lbs, and M ZFW is 381,400 lbs. For the optional Payload MW, the MTOW is 500,450 lbs, M LW is 412,335 lbs, and M ZFW is 392,423 lbs (see table, page 10). Both freighter variants have the same 36,744 USG maximum total fuel capacity as the passenger -200 version.

"The payload module option is a paper option, so is physically the same aircraft," notes Didier Lenormand, head of freighter marketing at Airbus. "To go from the range version to the payload version, the customer just needs to buy a service bulletin (SB) to change the specification of the aircraft. Moreover, to be able to have the increase in zero-fuel-weight (for the payload mode), we had to take into account the fact that the aircraft, which necessitated a development cost on our part. We have an option that we sell because have to recover part of these development costs."

The A330-200F fuselage cross-section will be identical to the Airbus A300-600F, which will eradicate any structural difficulties associated with the design of the cargo door. The aircraft will also have a strengthened maindeck floor. Regarding changes to the landing gear bay, Lenormand explains that the attachment point of the nose landing gear to the primary aircraft structure has been lowered by about 40cm to allow the fuselage to be completely level when on the ground to aid loading of cargo. This modification results in a small blister fairing below the nose of the aircraft and does not incur a significant drag penalty.

**CF6-80E1 series turbofan**

The A330 series is powered by three engine types and various thrust variants of these. General Electric’s engine for the A330 is the CF6-80E1 turbofan. This engine family uses a dual rotor, axial flow, annular combustor configuration. The 14-stage high pressure compressor (HPC), the annular combustor, two-stage HPT, and the integrated fan and low pressure compressor (LPC) are driven by a five-stage low pressure turbine (LPT).

When flat rated at 30°C for the A330, the variants deliver the following take-off thrusts: 64,530 lbs for the CF6-80E1A2 (A330-201 and A330-301); and 66,870 lbs for the CF6-80E1A4 (A330-202 and A330-302). The more powerful 68,530 lbs thrust PW4000-100 series is available for the -303. This model includes an augmented HPT nozzle and which permits an ‘actual’ EGTs of 40°C. The PW4000 series ‘indicated’ versus ‘actual’ EGTs are controlled by engine control unit (ECU) software. ECU software version 1.5 permits maximum permissible EGTs of 625°C actual and 620°C indicated for take-off (five minutes) and 600°C for maximum continuous.

**PW4100 series turbofan**

PW4100 series was developed by Pratt & Whitney and the PW4100 is used on the A330. The PW4100 is a two-spool turbofan engine with a single-stage high pressure compressor (HPC), a single-stage IP turbine, and a five-stage LP turbine. The PW4100 has a maximum thrust rating of 68,000 lbs. A total of 68,000 PW4100 engines have been produced for the A330 family.

**Trent 700 series turbofan**

Rolls-Royce has delivered several variants of the Trent 700 for the A330. This axial flow engine family uses three independent coaxially rotating shafts. The central shaft (innermost) runs through the length of the engine and links the single-stage low-pressure (LP) wide-chord-fan at the front, to a four-stage LP turbine at the rear. The next shafts link the eight-stage intermediate pressure (IP) compressor to a single-stage IP turbine. The outermost shaft links the six-stage high pressure (HP) compressor to its single-stage turbine. The combustion chamber is annular.

The original base version of this engine is the 67,500 lbs thrust Trent 768-60 (A330-341). An increased thrust 71,100 lbs Trent 772-60 version was
subsequently introduced (A330-342), and was first selected by Cathay Pacific. An improved version of this engine, the Trent 772C-60, delivers the same thrust and powers both the A330-243, and A330-342. The Trent 772B-60 has the same ratings as the 772-60 except between 2,000ft and 8,000ft altitude, or when the ambient temperature is greater than ISA +15°C, where the 772B-60 produces increased thrust at take-off ratings. The magnitude of this increase varies with altitude and ambient temperature and is limited to a maximum of 5.4%.

In 2006, Rolls-Royce introduced the Trent 772C-60. This model has the same ratings as the 772B-60, except at altitudes above 8,000ft where the 772C can provide more thrust in both take-off and continuous conditions. The extent of this thrust increase is dependent on altitude, temperature and Mach number, but is limited to a maximum of 8.5%.

According to the original equipment manufacturer (OEM), this most recent model delivers improved fuel consumption and time on wing, and better hot and high sustained performance than the 772B-60. Moreover, Rolls-Royce says the Trent 772C-60 provides more thrust in both take-off and continuous conditions.

### Fuel capacities

The A330-200 series is not only configured with fuel tanks in the wings and tail trim tank, but it also holds fuel in the centre section; similar to the long-range A340. The capacity is made up as follows: the wing tanks hold 24,119USG; the tail trim tank capacity is 1,646USG; and the centre tank holds 10,979USG. This makes a total of 36,744USG. Unusable fuel is 1,154USG in the A330-200. The A330-200’s fuel capacity is therefore 40% more than the standard A330-300’s due to use of centre section fuel.

### Accommodation & interior

The A330-200 can carry 253 passengers in a typical three-class layout with 12 in first, 36 in business, and 205 in economy class (eight abreast). An alternative two-class layout for regional operations is 293 passengers, comprising 30 in first class and 263 in economy. High-density layouts, up to 380 passengers (293/301, nine-abreast). Lower-deck modular crew rest area or lavatories are available.

The A330-300 has a typical 335-seat configuration in a two-class arrangement for 30 first-class seats, at a 40-inch seat pitch, and 305 economy-class seats at a 34-inch pitch. For longer routes, a 295-seat three-class arrangement has 18 sleeper seats, 81 business-class seats at 36-inch and 196 economy-class seats at 34-inch pitch. Alternatively, the aircraft can typically accommodate 12 first at a 62-inch pitch, 42 business at 40-inch pitch, and 241 economy-class seats at 32-inch pitch. Lower-deck modular crew rest area or lavatories are available.

For both the A330-200 and -300, the maximum theoretical number of passengers certified for emergency evacuation is 375 basic (three type-A and one type-1 doors installed) and 406 option (four ‘type A” doors installed - M od 40161). The highest-density seating layout can be realised in a nine-abreast, 29/30-inch pitch configuration with a ‘Type A’ option for door 3. For the A330-300, 392 passengers can be accommodated in an all-economy arrangement with 31-inch pitch at eight-abreast.

For both versions, seat pitch can be adapted in units of one inch. Galleys, lavatories and stowage bins can be located in different various groupings and locations. In-flight entertainment can be incorporated in the seats or screens mounted on partitions below the overhead stowage bins.

### Freight capacities

The A330-200 passenger version’s basic underfloor freight capacity is 26 LD-3s plus bulk. This configuration allows for 4,108 cu ft total capacity. Alternatively, operators can choose a layout with eight 96-inch pallets plus three LD-3s. This configuration allows for 3,572 cu ft total belly freight capacity. The larger A330-300’s underfloor freight capacity is 32 LD-3s plus bulk. This configuration allows for 5,056 cu ft total capacity. Alternatively, operators can choose a layout with nine 96-inch pallets plus two 88-in pallets plus one LD-3 plus 695 cu ft bulk. This configuration allows for about 4,407 cu ft total belly freight capacity.

The dedicated A330-200F’s maindeck and lower deck can accept a wide variety of cargo configurations. On the maindeck, the highest freight volume, 11,865 cu ft, is facilitated by 18 pallets in two rows each measuring 96 inches X 125 inches X 96 inches plus four pallets measuring 96 inches X 125 inches at the rear. Other possible maindeck configurations include: 20 88-inch X 125-inch pallets, plus three 96-inch X 125-inch pallets, totalling 11,490 cu ft; or a single row of 16 96-inch X 125-inch X 96-inch pallets for 9,500 cu ft; or nine ‘AM A’ containers plus four 96-inch X 125-inch pallets totalling 7,840 cu ft.

There are two basic configurations on the temperature-controlled lower deck of the A300-200F. The first configuration is eight 96-inch X 125-inch X 64-inch pallets plus two LD-3s plus 695 cu ft bulk which total 4,909 cu ft. The second option is 26 LD-3s plus 695 cu ft bulk totalling 4,767 cu ft.

The maximum theoretical cargo volume on the A330-200F is therefore about 16,774 cu ft, combining the main and lower decks.

The A330-200 freighter also includes a customisable ‘courier area’ behind the flightdeck, protected by a 9G barrier, which can accommodate up to 12 seats and the installation of a flight crew rest compartment (FCRC).

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There are 516 A330s in operation, with the oldest aircraft now 15 years old. The majority are powered by the Trent 700 and CF6-80E1.

Airbus confirmed the go-ahead for the shorter-fuselage, longer-range A330-200 in November 1995. Powered by a 96.2-inch fan diameter GE CF6-80E1 series engines, the first delivery was made to Cathay Pacific in August 1998. The first delivery of a 100-inch fan diameter PW4000-powered A330-200 was to Austrian Airlines in August 1998, and the first delivery of a 97.4-inch fan diameter Trent 772-powered 71 A330-200 was to Emirates Airlines in March 1999.

There are 270 A330-200s in service compared with 246 A330-300s. This shows the popularity of the longer-range A330-200 compared with the -300; despite the fact that the -200 entered service four years after the -300.

According to the Aircraft Fleet & Analytical System (ACAS) database, there are 155 CF6-powered A330s, 146 PW4100-powered A330s, and 215 Trent 700-powered A330s in service (see table, page 12). This gives RR the highest market share of 42%, followed by GE with 30% and PW with 28%.

The basic engine families mentioned above are split into several sub-variants (see A330 specifications, page 8). For common fleets powered by a particular engine sub-variant, the largest is the A330-243 model which is powered by the Trent 772B-60 engine, of which there are 106 in operation.

The other popular airframe/engine sub-fleets of the smaller and longer range A330-200 model are: 63 A330-223s with PW4168As; 49 A330-203s with CF6-80E1A3s; 21 A330-202s with CF6-80E1A4Bs; and 18 A330-202s with CF6-80E1A4s (see table, page 12).

The most popular airframe/engine sub-fleets of the larger and shorter range A330-300 model are: 64 A330-343s with Trent 777B-60s; 49 A330-323s with PW4168As; 26 A330-322s with PW4168bs; 24 A330-342s with Trent 777S-60s; 16 A330-320s with CF6-80E1As; 19 A330-301/302s with CF6-80E1A2s; 14 A330-343s with Trent 772C-60s; and 12 A330-302s with CF6-80E1A4Bs (see table, page 12).

Fleet forecast

At the time of writing, the firm order backlog for all A330s stood at 369 aircraft, comprising 196 A330-200s, 96 A330-300s, and 77 A330-200Fs. David Stewart, principal at AeroStrategy management consultants, predicts that the A330 fleet will grow to 1,100 through to 2017. “This means about another 600 will be delivered from 2008, until the A330 falls off in 2013 as the A350 comes online.”

“From an annual delivery profile of 80 to 90 from 2008 to 2010, we forecast a drop in 2014 to 36,” adds Stewart. “That means about another 600 will be delivered from 2008, until the A330 falls off in 2013 as the A350 comes online.”

RR-powered A330-200s

The 106 A330-243s with the 71,100lbs thrust RR Trent 772B-60s (or 120 aircraft if Air China’s 14 Trent 772C-60-powered aircraft are included) form by far the largest sub-fleet of all the A330s. These are operated by 25 carriers. Emirates is the largest operator with 29 in service, followed by Etihad (14). Other notable operators include EgyptAir (seven), Gulf Air (six), and China Eastern/Southern which together operate 10. Other smaller fleets include M yTravel Airways (four), SriLankan (four), Middle East Airlines (three), Air Transat (three), bmi British Midland (two), and Thomas Cook Airlines (three).

Compared with the four-engined A340, most A330s are still flying with their original operators. The lowest flight hour (FH) to flight cycle (FC) ratio for this fleet is 3FH, while the highest is 8FH.

The two largest A330 operators, Etihad and Emirates, together average an FC time of 4FH.

Operators which make the most of the A330-243s’ long range generally include European holiday-oriented carriers such as bmi British Midland, Thomas Cook Airlines, MyTravel Airways, M onarch Airlines, Corsairfly, and Air Transat. These all fly sectors of 5-8FH. British M idland (bmi) and Thomas Cook are the highest, whose aircraft average more than 7FH per FC.

In contrast, Asia Pacific and M iddle Eastern operators fly the shortest sectors with this aircraft. These include EgyptAir, SriLankan, and China Southern, all of which average only 3FH.

Air China operates a very new fleet of 14 A330-243s which are powered by the latest Trent 772C-60 variant. These are all less than three years old, all with fewer than 6,000FH, and average FCs of 3FH.

The Trent 772B-60-powered fleet entered service in 1999 and the aircraft are therefore younger than 10 years. Consequently, most will not have undergone their first major heavy maintenance visit. The highest-time Trent-powered A330-200, operated by MyTravel, has accumulated 43,600FH, while the sub-fleet mean average is 22,000FH. A bout 30 of these have clocked fewer than 10,000FH.

GE-powered A330-200s

Of the 101 GE-powered A330-200s, 58 are powered by the 68,530lbs thrust CF6-80E1A3 variant. These tend to be operated by major flag carriers including: Air France (16); EVA Air (11); KLM (9); Qatar Airways (9); TH Y Turkish (5); T A M Linhas Aéreas (5); and Qantas (2).

The next largest grouping of GE-powered A330-200s includes 39 aircraft which are powered by the 66,870lbs thrust CF6-80E1A4 or the 68,530lbs thrust CF6-80E1A4B engines. Operators include: Qatar Airways (10); Jet Airways (5); Air Algerie (5); Air Europa (4); and A e r L i n g u s (3).

Only four 64,530lbs thrust CF6-80E1A2s are in operation, with Jetstar Airways.

Since the first CF6-80E1-powered A330-200 entered service in 1998, most are younger than 10 years old, so most will have yet to undergo their first heavy check. The highest-time GE-powered A330-200 is operated by Air Comet and has accumulated 41,000FH, while the subfleet mean average is only 14,300FH.

PW4000-powered A330-200s

There are 63 Pratt & Whitney powered A330-200s, all of which use the
Trent 700-powered A330-300s

The 95 RR Trent 700-powered A330-300s, 31 are powered by the original 67,500lbs thrust Trent 772-60 engine. Most of these are in operation with Cathay Pacific Airways, which has a fleet of 19. In addition, Garuda operates six, and Dragonair five. Apart from four recent additions to Cathay Pacific’s fleet, these aircraft were delivered during the mid- to late 1990s. Although the four recent Cathay Pacific aircraft are no more than three years old, they still use the original Trent 772-60 engine.

The other 63 RR-powered A330-300s use the more powerful 71,100lbs thrust Trent 772B-60. Thirty-six of these are operated in Asia-Pacific: China Eastern (12); Cathay Pacific (11); Dragonair (11); and China Southern (two). Air Canada has eight, while in Europe Lufthansa has 11, SAS four, and MyTravel Airways three.

Of this fleet, the average flight duration is just under 4FH. At the top end are Lufthansa, Cathay Pacific (its newer aircraft), SAS and Air Canada, which all average sectors of more than 5FH. In contrast, Cathay Pacific’s older aircraft fly shorter sectors of 2-3FH. The other Asia Pacific carriers fly high-density intra-regional sectors of no more than 3FH.

About 23 Trent-powered A330-300s are now older than 10 years, and so will have undergone their first heavy check, leaving about 70 which have not. The highest-time Trent-powered A330-300 is operated by Air Transat and has accumulated more than 40,200FH. The next five oldest examples are all Garuda A330-300s, with more than 37,000FH. The highest-time aircraft, with Aer Lingus, Cathay Pacific Airways, Qantas and Qatar Airways. The latter include the fleets of China Airlines, Qantas and Qatar Airways. The highest-time aircraft, with Aer Lingus, have accumulated over 55,600FH while the sub-fleet average is 17,670FH.

PW-powered A330-300s

Of the 83 PW-powered A330-300s, Northwest operates the largest fleet with 21 PW4168A-powered A330-323s. Korean has 11 A330-323s powered by PW4168As and four A330-322s with PW4168As. Malaysia Airlines operates 11 PW4168A-powered A330-322s and LTU has three. Thai Airways has 12 A330-300s with a mixture of PW4164As, PW4168s, and PW4168As. USAirways has nine A330-323s with PW4168As and Asiana Airlines has six.

All of the aircraft flown by Northwest and USAirways fly long sectors averaging 6-8FH. This compares with the sub-fleet average of 4.3FH.

As before, Asia Pacific operators (in this case Asiana, Korean, Malaysia, and Thai) operate their aircraft with sector times of 2-3FH. A bout 28 PW-powered A330-300s are now older than 10 years, and so will have undergone their first heavy check, leaving about 55 which have still to go through their first C8 check. The latter include the fleets of Northwest, US Airways, and Asiana. Malaysia Airlines’ A330-300s all exceed 40,000FH, with its highest time aircraft having accumulated over 46,000FH. The sub-fleet mean average is 25,450FH.

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A330-200/-300 modification programmes

The major modification programmes for the A330-200/-300 are avionics upgrades for surveillance and more accurate navigation, structural modifications, and engine upgrades.

Upgrades and modifications for A330 aircraft fall into three categories: flightdeck avionics; structural modifications; and engine performance enhancements.

Avionics upgrades

There is a lot of focus on upgrading flightdeck avionics to meet the latest navigation and surveillance requirements. Airbus is responding to increased worldwide use of automatic dependent surveillance (ADS-B) and required navigation performance (RNP). ADS broadcasts position, heading and altitude information from the aircraft. ADS-OUT receives this information at ground stations for display on air traffic control centres. ADS-IN gives aircraft the ability to receive the information and display it for aircraft in their immediate area on a flightdeck screen.

Although most A330s are already equipped with all the sensors for the necessary ‘ADS-B-OUT’ broadcast functions, including Mode-S transponders and ‘extended squitters’, most operators have not yet ‘activated’ their inherent ADS-B potential. This is due in part to a lack of worldwide ADS-B coverage.

Based on successful trials, notably in Australia, an optional service bulletin (SB) became available in March 2008 to allow A330 operators to implement ADS-B-OUT broadcasts so that ADS-B ground surveillance stations can track aircraft with precision, even in airspace not covered by radar. The required equipment includes: the existing elementary surveillance (ELS) and enhanced surveillance (EHS) air traffic control (ATC) transponder; plus a global position system (GPS)-equipped multi mode receiver (MMR), which recently-built aircraft already have installed as standard specification.

Various avionic upgrades are coming available that will give the aircraft increased surveillance power. This includes the ability to detect other aircraft up to 100nm away and display their position, heading and altitude and display it on a flightdeck screen.

Dimitri Carstensen, avionics senior engineer at Airbus Customer Support, explains that the next stage of ADS-B, referred to as ‘ADS-B-IN’, will allow A330s to track other aircraft which are broadcasting using ADS-B-OUT. This will be addressed by another set of SBs to be released in the second quarter of 2009.

Airbus has developed this functionality over the past four years as the ‘airborne traffic situational awareness’ (ATSAW) function. This may require operators to upgrade their existing traffic collision avoidance system (TCAS) to a new ‘traffic computer’, such as the Honeywell TPA-100A third-generation TCAS processor. TPA-100A will be able to actively track aircraft out to a range of 80-100nm, and it supports Mode-S-based ADS-B capability to extend passive tracking beyond 100nm.

For current A330s without the latest surveillance systems, Airbus is proposing a standard retrofit programme to upgrade the TAWS computers (enhanced ground proximity warning system (EGPWS) or T2CAS). This retrofit will enable them to use direct GPS data for aircraft positioning. This will ensure that the TAWS computer primarily uses GPS data for positioning the aircraft in latitude, longitude and altitude by blending the current air data/inertial reference unit’s (ADIRU’s) altitude and radio altitude with the GPS altitude. Airbus standard SBs are available for A330s already equipped with a TAWS computer.

A further navigation upgrade, an FMS landing system (FLS) feature, presents ILS-like vertical and lateral guidance on the primary flight display using the FMS computed position. This is also being adapted for the A330 flightdeck. FLS will enable autonomous non-precision approaches to airports not currently served by the traditional ILS. Certification is expected in 2009. Operators of older aircraft may need to upgrade to FMS release 1A standard, and ensure they have the latest Electronic Instrument System 2 (EIS2) standard cockpit displays and flight warning computer (FWC).

For precision approaches, the A330 may be upgraded with global navigation satellite system (GNSS) landing system (GLS) approach capability to allow...
operators to use destination airports with local area augmentation systems (LAAS). For both GLS and FLS, a Rockwell Collins multi-mode receiver GLU 925, certified mid-2008, is required to extend the use of satellite navigation from en-route and terminal operations to precision approaches.

Certification of GLS for precision Cat I approaches is expected in 2009, and precision Cat II & III approaches by 2015. Older aircraft may need to be upgraded to FM S2 release ‘1A’ standard, and be equipped with the latest standard of EIS1/2, radio management panel (RMP), audio control panel (ACP), and FWC.

Another possible A330 avionics upgrade covers RNP with ‘authorisation required’ (RNP-AR) approaches as defined by the International Civil Aviation Organisation (ICAO). RNP-AR approaches allow reduced minima and provide an unprecedented flexibility in constructing approach procedures, such as ‘curved flight path’, including those required to construct approach procedures, such as ‘authorisation required’ (RNP-AR) approaches as defined by the International Civil Aviation Organisation (ICAO).

For an aircraft to be capable of such improved operation, the flight management guidance and envelope computer (FM GEC) must be equipped either with the latest Honeywell’s FM S2 ‘P3’ standard, or the Thales/Smiths FM S2 revision ‘2+’ standard (available from 2009). A first RNP-AR step was certified for the A330 at the end of 2007 with the Honeywell FM GEC referenced above, with a performance accuracy of up to 0.1nm in approach and departure phases. In addition to the FM GEC, the aircraft’s ADIRU, MMR, EGPWS and EIS2 must all be the latest standard. Carstensen says that for RNP-AR, only EGPWS version ‘965-1676-002’ and subsequent versions are applicable, whereas T2CAS is not certified for RNP-AR.

A second RNP-AR step is to be certified by 2009 with the future FM GEC release 1A standards from Honeywell and Thales/Smiths. This will ensure a 0.1nm accuracy during missed approaches procedures.

Cockpit displays

Although Airbus introduced liquid-crystal displays (LCDs) in the A330/A340 (and A320 etc) with EIS2 standard from 2003, there does not seem to be a retrofit programme to replace the cathode-ray-tube (CRT) displays of the EIS1 standard in earlier models. However, Airbus says that the CRT displays can be changed on customer request via optional SBs.

Andreas Pakszies, director of aircraft system engineering at Lufthansa Technik, reports that it will upgrade all of Lufthansa’s A330s with class-2 EFBS.

“We will install a display module with a touch-screen function for each pilot, who will have a docking station for their EFBS on the flightdeck. These docking stations will be linked together with cross-video and Ethernet. Lufthansa Systems will provide the software. The supplemental type certificate holder for this modification is Goodrich Sensor Systems.

“We are now in the qualification phase and are installing the provisions into our A330s. The first provision installation will be in May 2008, following one we have already carried out on an A340-600,” adds Pakszies.

Structural modifications & ADs

About 100 airworthiness directives (ADs) have been issued on the A330, many of which also have equivalents on the A340. These ADs require structural inspections and modifications to be carried out. One notable example is Federal Aviation Authority (FAA) AD 2007-22-10, which details inspection of the main landing gear bearing lugs on wing rib-6. This requires an inspection every 300FC/1,500 flight hours (FH) for the A330-200 and 300FC/900FH for the A300-300. Other examples are AD 2007-09-09, replacing certain retraction links, and AD 2007-16-02, specifying the inspection for cracks adjacent to the keel-beam fastener holes at frame 40. This is related to SB A330-57-3081.

According to SR Technics (SRT) some of the most significant issues affecting the A330 aircraft are:

- SB A330-57-3088 and A330-57-3085, relating to crack propagation of the lower part of wing rib-6 aft aperture, between bottom skin stringers 18 and 20, extending from the lower edge of aperture in rib-6 to a fastener hole and then into the fuel pipe hole.
- A330-57-3082. This is the same rib-6 lug issue as detailed in FAA AD 2007-22-10 above.
- A330-57-3055. This Airbus SB, mandated by FAA docket no. 2001-NM-380-AD, covers the inspection and cold working of the wire harness slots in the inner rear spars of the wings between ribs -4 and -5.
- A330-54-3024 which replaces rib-18A in the pylons box structure.

SRT highlights Airbus’s SB numbers A330-53-3152 and A330-53-3160, which both relate to rear fuselage reinforcement. SRT notes that while it has yet to perform these modifications on any aircraft, the impact in the future ‘will be significant’.

Landing gear improvements

Operators have experienced problems with the landing gear, especially on earlier models due to stress concentrations in the top end of the main fitting, exacerbated by ground manoeuvres at high nose-wheel steering angles. Airbus removed service the very earliest landing gears, ‘D’ and ‘E’ standard, and restricted the maximum steering angle. Never
examples, ‘F’ standard, were replaced during routine 10-year heavy checks. Airbus has since reinstated the full 72-degree steering angle on newer landing gears, and those that have had the engineering rectification.

Pakszies says that the A330 landing gear originally had a life of 75,000FH or 50,000 flight cycles (FCs), based on an average FC time of 90 minutes. This is a particular issue for aircraft flying on long missions with a high hours-to-cycle ratio. For example, Lufthansa regularly flies its A330s on sectors of seven hours. “This meant we could not have the gears for a full second run after overhaul, because the FH limit forced us to remove them before we reached the second overhaul,”

Airbus and M easier-Dowty introduced enhanced gears for the A330, with a new extended design goal of 125,000FH and 50,000FC. These gears have already been installed on Lufthansa’s newest aircraft, and will last for the second period, thereby avoiding their removal during an intermediate layover (IL).

**Trent 700 EP**

Rolls-Royce provides a phased approach to upgrading the Trent 700 turbofan, referred to as ‘Trent 700EP’ (Enhancement Package). The first phase, available since 2007, covers a pocketless spinner fairing in front of the fan. Available later this year, Phase 2 will have: improved fan-tip clearance and turbine case cooling; and elliptical airfoil leading edges in the compressor section. Phase 3 in 2009 will introduce: improved blade tip clearance for the high pressure compressor (HPC), intermediate pressure compressor (IPC), high pressure turbine (HPT) and intermediate pressure turbine (IPT); a Trent 1000 style re-bladed low pressure turbine (LPT); and IPT nozzle-guide-vane re-profiled end-walls.

The original equipment manufacturer (OEM) says that the engine has benefited from continuous improvement, involving feeding back advanced technologies from newer members of the family. The HP module from the Trent 800 was incorporated into the Trent 700, resulting in longer on-wing life and performance enhancements. In addition, improvements are being fed back from the Trent 1000, including an LPT upgrade and improved fuel burn, to ensure the engine is the most fuel efficient on the A330.

**Tech CF6’ upgrade**

In 2006, GE launched the Tech CF6 programme to incorporate advanced technologies into the engine’s HPT area. The new technologies include HPT airfoil cooling advancements to improve operational reliability and fuel burn retention, and lower maintenance costs.

From mid-2008, the Tech CF6 advanced technology will be standard on CF6-80E1 production engines. In September 2007, Finnair chose CF6-80E1 engines which are the first to incorporate the new Tech CF6 HPT upgrade.

The new HPT material, R88DT, via SB72-0186 will increase the engine’s maximum exhaust gas temperature (EGT) redline limit (actual, not indicated) from 1,035°C to 1,050°C when coupled with an engine control unit (ECU) software upgrade. The R88DT HPT configuration includes enhanced blades (Stage 1 HPT blades with thermal-barrier coating (TBC) and Stage 2 HPT blades of ‘DSR142’ material). SB73-00422 and SB73-00433 raise the CF6-80E1A4’s EGT redline limit from 1,045°C to 1,050°C.

**PW4100 upgrades**

For the PW4100 series, the OEM offers an upgrade to give an additional 20°C EGT margin, which involves installing ECU software version SCN 6B. Later versions can provide maximum permissible EGT of 645°C actual (620°C indicated) for take-off, and 615°C actual (600°C indicated) for maximum continuous. The noted engine ratings and limits are controlled by EEC P/N and Engine Programming Plug (EPP) P/N, and are implemented by specific SB instructions. The engine data plate also reflects the engine rating.

Pratt & Whitney (PW) is testing a more powerful PW4170 variant, ‘Advantage70’ for service entry in 2009. As well as increased thrust, this model is expected to deliver 1.2% lower fuel consumption, increased durability, and a reduction of 20% in operating costs. It will also be available as a retrofit to earlier standard engines. Flyington Freighters, the launch customer for the A330-200F, chose ‘Advantage70’ PW4170s to power these aircraft, which are due to enter service in late 2009.

The PW 4000 upgrade includes a new HPC ring case to improve reliability and reduce fuel consumption. There is a new second-stage HPT vane, and improved thermal barrier coatings with half the conductivity of the current material. The first stage vane is strengthened for longer life, and the turbine will be fitted with more durable outer seals. Durability will be increased by an improved TALON II combustor. Software enhancements to the FADEC will be offered, allowing pilots more flexibility in take-off and climb thrust power to better match engine thrust with specific flight requirements.

An upgrade to the diagnostic engine management will better analyse engine performance data, providing input for more effective maintenance planning. PW will certify this upgrade package with the FAA in 2008, and all production engines will subsequently be delivered to this higher standard. Upgrade kits for in-service engines will also be available for incorporation at the next heavy maintenance shop visit.

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AIRCRAFT OPERATOR’S & OWNER’S GUIDE

The fuel burn and operating performance of the two passenger A330 family members, and also the new A330-200F freighter are analysed and assessed. All three engine families powering these aircraft are represented in this analysis.

Aircraft variants

The A330-200 and A330-300 variants analysed include: the A330-203/-303 powered by the CF6-50E1A3 rated at 68,530lbs thrust; the A330-223/-323 powered by the PW4170, a new variant of the PW4000-100 introduced by Pratt & Whitney, rated at 70,000lbs thrust; and the A330-243/-343 powered by the Trent 772B-60, rated at 71,100lbs thrust.

The aircraft chosen are the most recent and most capable versions, and they have the highest take-off weight (TOW) capabilities. These are marketed by Airbus as the ‘233-tonne’ versions, and they have a maximum take-off weight (MTOW) of 513,765lbs.

The factory-freighter aircraft analysed comprise four sub-versions: the A330-200F ‘Payload’ mode powered by the PW4170 rated at 70,000lbs thrust; the A330-200F ‘Payload’ mode powered by the Trent 772B-60 rated at 71,100lbs thrust; the A330-200F ‘Range’ mode powered by the PW4170 rated at 70,000lbs thrust; and the A330-200F ‘Range’ mode powered by the Trent 772B-60 rated at 71,100lbs thrust.

The maximum structural payloads (MSPs) of the ‘Payload’ mode aircraft are 151,899lbs for the Trent-powered aircraft and 151,330lbs for the PW4000-powered aircraft. The structural payloads of the ‘Range’ mode aircraft are 140,875lbs for the Trent-powered aircraft and 140,307lbs for the PW4000-powered aircraft (see A330-200/-300 specifications, page 9).

Parameters

Aircraft performance has been analysed in both directions on example routes to illustrate the effects of wind speed and direction on the actual distance flown, also referred to as equivalent still-air distance (ESA). The flight profiles in each case are based on international Federal Aviation Regulations (FAR) flight rules, which include standard assumptions on fuel reserves, standard diversion fuel, plus contingency fuel, and a taxi time of 20 minutes for the whole sector. This is included in block time. In addition, all sectors presented here are flown using an optimum long-range cruise (LRC) speed of Mach 0.82. This speed has been chosen as the best balance between fuel burn and sector time. Actual flight time is affected by wind speed and direction, and 85% reliability winds and 50% reliability temperatures for the month of June have been used in the flight plans produced by Airbus.

The two passenger aircraft analysed have been assumed to have full three-class passenger payloads. These are 253 passengers for the A330-200 and 295 passengers for the A330-300. The standard weight for each passenger plus baggage is assumed to be 220lbs, and no additional under-floor cargo is carried. The payload carried in both directions by each aircraft is therefore 55,777lbs for the A330-200 series and 65,036lbs for the A330-300 series.

For the freighter analysis, the objective is to carry the maximum possible gross payload for any of the missions. This is constrained by the mission range or ESA, required fuel load, airport elevation, and the different maximum zero fuel weights (MZFWs) and MTOWs of the ‘Payload’ and ‘Range’ variants of the A330-200F.

Routes described

Two city-pairs are used to analyse the A330-200/-300 passenger aircraft. The first is Los Angeles International (LAX) to La Guardia, New York (LGA). This route has a tracked distance of 2,188nm. When flown in an easterly direction to LGA, the aircraft experiences a tailwind of 20 knots. This reduces the tracked distance from 2,190nm to an ESA of 2,060nm (see table, page 8). In the other direction to LAX, the aircraft faces a headwind of 50 knots which increases the equivalent distance to an ESA of 2,420nm.

The same aircraft are also analysed using the longer-range route between LAX and Stockholm Arlanda airport.

Fuel burn per seat-mile varies little with different engine types powering the same weight specification variant of the A330-200 and -300. Moreover, fuel burn per seat-mile also varies little mission length.
In addition, a long-range freight route (ARN). This route has a tracked distance of 4,900nm. Aircraft operating in an easterly direction from LAX to ARN have a small tailwind averaging four knots, which takes the ESAD value down to 4,850nm. Operations in the other direction face a headwind of 14 knots increasing the ESAD to 5,160nm. On all passenger routes outlined above, the aircraft are not payload-restricted, and can therefore carry their maximum passenger load.

The A330-200F has been analysed on two routes. A medium-range route is represented by Bogota (BOG) to Miami (MIA). This route has a tracked distance of 1,314nm. When flown in a northerly direction to MIA, the aircraft experiences a headwind of 8 knots, which reduces the ESAD to 1,314nm. When flown in a south-westerly direction to LHR, the aircraft experiences a headwind of 18 knots. This increases the ESAD to 1,406nm.

The fuel burn for each aircraft/engine combination and the consequent fuel burn per passenger are shown (see table, page 19). This distance coincides with the maximum design range of the A330-200F 'Range' variant when carrying its MSP, and is greater than the maximum range of the 'Payload' variant. In the other direction to NBO, the aircraft faces a smaller headwind of four knots which results in an ESAD of 3,826nm. The latter distance is just within the 4,000nm range the 'Range' variant, but beyond the nominal 3,200nm range of the 'Payload' variant. The latter model must therefore reduce payload to fly the distance.

### A330 passenger aircraft

The fuel burn for each aircraft/engine combination and the consequent fuel burn per passenger are shown (see table, this page). The data show that for each respective passenger model, the block fuel burns increase in relation to actual take-off weights (ATOWs) and aircraft size. The engine type has very little effect, since they are extremely close in terms of specific fuel consumption (SFC). As an illustration of the small fuel burn difference with respect to engine type, the table shows there is no absolute leader. The Trent has the lowest block fuel burn in three missions, the CF6-80E1 has the lowest fuel burn in four missions, and the PW4100 has the lowest fuel burn in one mission (see table, this page).

On the outward LAX-LGA sector the A330-200s have block fuel burns of: 7,638USG (Trent); 7,641USG (CF6); and 7,654USG (PW4170). Fuel burns per passenger are: 30.19USG (Trent); 30.20USG (CF6); and 30.25USG (PW4170).

In contrast, the larger A330-300s have higher total fuel burns of: 8,157USG (Trent); 8,164USG (CF6); and 8,185USG (PW4100).

A side from size differences between the passenger A330-200 and A330-300, which affect operating empty weight (OEW) and TOW, other factors influencing fuel burn on any given city-pair are the respective headwind or tailwind component differences (and hence ESAD value) between outbound and return sectors. The A330-200 versions have lower OEWs (see table, this page), the lowest ATOWs, lower total drag, and therefore lower cruise thrust and lower fuel burn compared with the larger A330-300s. However, because the A330-200 carries fewer passengers, the fuel burn per passenger is proportionally higher.

In the LGA-LAX direction, the main
A330-200F

Two city-pairs have been chosen to illustrate how the fuel burn and aircraft performance of the two A330-200F variants are affected by the demanding ‘hot-and-high’ airport Bogota (BOG), and also by the long-range challenges of flying from Nairobi (NBO) to London Heathrow (LHR).

Taking the BOG-MIA sector, with an ESAD to MIA of 1,406nm, the results (see table, this page) shows that when taking off from BOG, all the aircraft variants can depart with M SPs, as described earlier. This is regardless of the ambient departure conditions and despite the high airport elevation of 8,361 feet, runway length of 12,467 feet and noon temperature of 17ºC.

In this example, the ‘Payload’ variants are the most suitable aircraft to deploy on this route because they can take advantage of their higher M ZFWs and more fuel loads to carry higher structural payloads from hot-and-high airports over short ranges, especially as fuel loads are relatively light for this long-range aircraft family. In terms of block fuel burn, there is a slight difference between the ‘Payload’ and ‘Range’ versions in either direction (see table, this page). This is due to the higher M SPs carried by the ‘Payload’ versions, which also increases respective TOWs.

For the NBO-LHR sector, not only must all the aircraft fly a very long range ESAD distance of 4,013nm (just beyond the 4,000nm limit of the ‘Range’ version, and exceeding the normal 3,200nm mission range of the ‘Payload’ version), but they must also depart from an airport which has an elevation of 5,330ft, has an ambient noon departure temperature of 23ºC, and a runway length of 13,507 feet. From here, three out of the four variants face ATOW restrictions, and all the aircraft variants face significant available payload restrictions (see table, this page). This is due to the severe combination of a hot-and-high departure and very high fuel load required for the 4,000nm mission.

Even from LHR (a sea-level airport from which all aircraft could depart at their full MTOWs if required), only the ‘Range’ variants can make the trip without payload restrictions. That is, they can carry their M SPs over this long sector as well as the high fuel load required. In contrast, the ‘Payload’ aircraft in the LHR-NBO direction are still restricted. That is, their available payloads are less than their M SPs. This is mainly because the ‘Payload’ variants have a lower MTOW than the ‘Range’ variants.

There is a significant difference in ESAD between the two directions (3,826nm for LHR-NBO versus 4,013nm for NBO-LHR), which is due to the headwinds (see table, this page). The fuel burns are consequently higher in the NBO-LHR direction, despite the lower payloads and take-off weights. When both ‘Payload’ and ‘Range’ variants are flying the same NBO-LHR sector, the variation in fuel burns between them is slight because M TOWs in this direction are very close. In the LHR-NBO direction, sea-level ambient conditions allow each aircraft to utilise their full MTOW (which differs between the ‘Payload’ and ‘Range’ versions).

In summary, the A330-200F ‘Payload’ versions have higher M ZFWs and are the best choice for operators flying high-density cargo on demanding short-range sectors, whereas on very long-range routes, the ‘Range’ variants have higher certified M TOWs and can therefore carry the greatest combined payload plus fuel load without compromise.

FUEL BURN PERFORMANCE OF FREIGHTER-CONFIGURED A330-200F

<table>
<thead>
<tr>
<th>City-pair</th>
<th>Aircraft variant</th>
<th>Engine type</th>
<th>ESAD nm</th>
<th>MTOW lbs</th>
<th>Available TOW lbs</th>
<th>Block burn USG</th>
<th>Block time mins</th>
<th>Available payload lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOG-MIA</td>
<td>A330-200F ‘Range’</td>
<td>PW4170</td>
<td>1,406</td>
<td>513,677</td>
<td>433,527</td>
<td>5,905</td>
<td>214</td>
<td>146,307</td>
</tr>
<tr>
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<td>Trent 772B</td>
<td>1,406</td>
<td>513,677</td>
<td>433,682</td>
<td>5,883</td>
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<td>500,450</td>
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<td>500,450</td>
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<td>133,402</td>
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</table>
A330-200/-300 maintenance analysis & budget

The A330-200/-300 have some of the lowest maintenance costs of current generation aircraft, and outperform the A340-200/-300 by $400-500 per FH.

The A330-200/-300 family is among the most successful widebody twinjets in operation. The A330-300 was originally pitched as a DC-10-30 replacement in the late 1980s. The shorter -200 variant was launched in 1994 and widened the A330 family's appeal. Orders are still being placed in large numbers prior to their replacements, the A350-800 and -900, going into service in 2013. With more than 500 A330s in service and another 370 aircraft on firm order, the A330-200/-300 can be expected to remain in operation for another 30 years. The A330-200/-300 are powered by three main powerplants: the General Electric (GE) CF6-80E1; the Pratt & Whitney (PW) PW4000-100; and the Rolls-Royce (RR) Trent 700. The aircraft's complete maintenance costs are analysed here.

A330-200/-300 in operation

The A330-200 and -300 are used as medium- and long-haul workhorses by most of their operators. The A330's main markets of operation include the transatlantic, Europe-Middle East, and trans-Asia Pacific.

The aircraft's earliest operators were Cathay Pacific, Thai International, Aer Lingus, Air France and Emirates. It is also operated in large numbers by USAirways (9 aircraft), Air Canada (8), KLM (9), Lufthansa (10), THY (5), Qatar Airways (28), TAM of Brazil (12) and Qantas (10). Smaller operators include Cyprus Airways, M Idde East Airlines, Finnair and TAM Air Portugal.

The A330-200 is used almost exclusively as a long-haul flagship. Its most prominent operators are Air France (16 aircraft), Northwest (32) and Swiss (11).

Most operators have the aircraft in a dual-class configuration, with 220-260 seats. The aircraft has a range of up to 6,450nm with this number of passengers.

Airlines that use the aircraft on medium-haul operations have FC times of 2.2-3.5FH and generate 3,500-4,500FH per year.

The A330-200 is also popular with European charter carriers, which use the aircraft in high-density seating configurations. Major operators include Monarch Airlines, MyTravel Airways, LTU and Thomas Cook Airlines.

The A330-300 is also used as a long-haul flagship by some operators, including Air Canada, USAirways and Lufthansa. For these operations most aircraft are in a dual-class configuration with 280-300 seats.

The A330-300 is also used for medium-haul and high-density regional operations, particularly in the Asia Pacific, by Air China, Cathay Pacific and Thai International. Most of these other operators configure the aircraft in two cabin classes with 300-320 seats.

Annual rates of FH and FC utilisation and average FC times are similar to the -200 fleet, with the -300 being used either for medium- or long-haul operations.

The maintenance costs of the A330-200 and -300 are analysed here in medium- and long-haul operations. The medium-long-haul operation assumes 3,750FH and 1,250FC per year, with an average FC time of 3.0FH. The long-long-haul operation assumes 4,750FH and 700FC per year, with an average FC time of 6.7FH.

Maintenance programme

The A330-200/-300's maintenance programme has the same basic structure as all other Airbus types. Since its entry into service, 15 revisions have been made, with the last one in September 2007. The next revision is expected in May 2008.

"There has been about one revision per year," says Michel Pebarthe, product support director at Air France Industries. "We follow the maintenance planning document (MPD), and we use the 14th revision of the MPD. Operators can, however, devise their own maintenance programmes and get extensions of the basic task intervals."

Line checks

The line checks start with the usual system of daily checks performed when the aircraft is at its homebase. This is usually every day, although the maximum interval is 48 hours.

Following a daily check and release to service the aircraft will have a pre-flight (PF) check. This includes mostly visual inspection tasks, and can in most cases be performed by the flightcrew, reducing the need for mechanics. Defects may require rectification by mechanics, however.

Transit (TR) checks are performed before all other flights operated during the day, usually by flightcrew. The content is slightly less than for pre-flight checks. Defects can arise, although it is possible to defer the rectification of most until the aircraft returns to its homebase. Since most A330s operate on long-haul services and consequently perform only two or three flights per day, only one or two TR checks will be made each day.

The routine content of PF and TR checks is mainly external visual inspections that include: the pitot tubes; lights; bay doors and access panels; slats and flaps; wheels and landing gears; and engine inlets. There are also a few interior inspections, of items like high frequency (HF) radios, fire detectors, flightdeck oxygen and other emergency equipment. The technical log will also be examined for outstanding defects in case any have exceeded their legal deferment time. "The routine tasks will also include items for extended range twin-engine operations (Etops). This will include ensuring the back-up generator is operational, the oxygen cylinder is functional, and that engine oil levels and consumption levels are within limits," explains Stephane Trochet, station manager at Paris Charles-De-Gaulle for Stella Aviation.

"The routine tasks and Etops tasks can be performed by flightcrew in some jurisdictions. Some aviation regulatory authorities still require line mechanics to perform PF checks. Where flightcrew can perform routine tasks, mechanics may be needed for non-routine items, particularly those defects that cannot legally be deferred."

Daily checks are slightly larger than PF and TR checks, and can be performed by one line mechanic. The routine tasks are those of the PF and TR checks, plus additional items for line mechanics which combine external and internal visual inspections. "These include the manual checking of tyre pressures and brake disc wear, and visual inspections of shock absorbers," says Trochet. "In addition to routine tasks, the engine oil levels can be checked via the electronic centralised aircraft monitoring (ECAM) on the flightdeck. The bay for the auxiliary power unit (APU) also has to be opened.
to check the component. Any defects must be written up in the technical log, while there is a cabin log to record cosmetic items such as lights, coffee makers and the in-flight entertainment (IFE) system. Additional tasks include cleaning the cabin, flightdeck centre pedestal and ECAM screens. Weekly checks have a maximum interval of eight days, and can also be performed by one line mechanic. They include a few tasks on top of the daily check: examining engine magnetic chip detectors and landing gear shock absorbers; draining water; refilling water tanks; and checking emergency gas bottles, the hydraulic accumulator, and cargo compartment doors. A flightdeck test on Cat IIIa equipment must be made.

### A checks
The maintenance programme is a system of A checks, with a group of 1A tasks that have an interval of 600FH. Originally 400FH, this was extended to 500FH in 1998, and then 600FH in 2002,” says Robert Bernhard, head of maintenance programmes and reliability at SR Technics. The 16th revision of the MPD in May 2008 is expected to increase the 1A task interval to 800FH.

There are another three multiples of these tasks: the 2A, 4A and 8A tasks with corresponding intervals of 1,200FH, 2,400FH and 4,800FH. The 2A tasks will have their intervals extended to 1,600FH and the 4A items escalated to 3,200FH at the next MPD revision. The 8A tasks will also be increased to 6,400FH.

The A2 check has an interval of 1,200FH and comprises the 1A and 2A tasks (see table, this page). The A4 check has an interval of 2,400FH and comprises the 1A, 2A and 4A tasks. The A8 check comprises the 1A, 2A, 4A and 8A tasks, and is the last check on the A check cycle.

### Base checks
The base maintenance programme is based on a cycle of eight checks that all Airbus aircraft have followed. “The group of 1C tasks has an interval of 18 months, which was escalated in 1998 from the original interval of 15 months,” says Bernhard. “There are three multiple groups of this task: the 2C tasks every 36 months; the 4C every 72 months; and the 8C every 144 months. Not all items can be escalated, so they drop out of the regular calendar intervals and become out-of-phase (OOP) tasks.”

These tasks are arranged into block C checks, so the C2 and C6 checks have 1C and 2C items, and the C4 check has 1C, 2C and 4C tasks (see table, this page).

“The MPD interval for the C check tasks was 15 months, so the full cycle of eight checks had an interval of 120 months,” says Pecharte. “The 18-month interval now extends this cycle by 24 months or two years to 144 months for the eight checks. The evolution exercise for the 1C and 2C tasks is expected to be completed by 2009, and the next revision of the MPD may extend the 1C interval to 24 months. This would increase the length of the cycle to 192 months, or 16 years. It is not clear when this will happen, however.

There are also two groups of structural inspections: the 6-year tasks and the 10-year tasks, which were called IL and D tasks in earlier Airbus models. Their original intervals were completed by 2002.”

The A330-200/-300 A & C CHECK TASK ORGANISATION

<table>
<thead>
<tr>
<th>Check</th>
<th>Check task groups</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3</td>
<td>1A + 2A + 4A</td>
<td>72 months</td>
</tr>
<tr>
<td>A2</td>
<td>1A + 2A + 4A + 6-year</td>
<td>72 months</td>
</tr>
<tr>
<td>A3</td>
<td>1A + 2A + 4A + 6-year</td>
<td>72 months</td>
</tr>
<tr>
<td>A4</td>
<td>1A + 2A + 4A + 6-year</td>
<td>72 months</td>
</tr>
<tr>
<td>A5</td>
<td>1A + 2A + 4A + 6-year</td>
<td>72 months</td>
</tr>
<tr>
<td>A6</td>
<td>1A + 2A + 4A + 6-year</td>
<td>72 months</td>
</tr>
<tr>
<td>A7</td>
<td>1A + 2A + 4A + 6-year</td>
<td>72 months</td>
</tr>
<tr>
<td>A8</td>
<td>1A + 2A + 4A + 6-year + 8A</td>
<td>144 months</td>
</tr>
</tbody>
</table>

The labour and material inputs for PF and TR checks are minimal. Trochet estimates that these checks use only one man-hour (MH) of labour, if a mechanic is used. “The only materials needed are two cans of oil for servicing the engine oil, and a litre of shock absorber cleaner,” says Trochet. “This will cost a total of $15-20. There may also be a few non-routine items to add to this, such as various-sized lightbulbs. A small lightbulb will cost $35, while a landing lightbulb can cost $60. There are four or five non-routine occurrences every 10 flights on average, related to problems with passenger seats or IFE equipment. A total budget averaging $50 of materials per check can be used.” The replacement of major components will be accounted for in rotatable costs.

A daily check will use a little more labour, and Trochet estimates that this will be 1.5-2.0MH, with one mechanic required to complete the check. “Non-routine items can be added, such as deferred defects at the request of the customer,” says Trochet. “This depends on the findings, and they are usually interior-related tasks. The other non-routine tasks are similar to those in the PF and TR checks.

“Other requirements include nitrogen gas to reinflate the wheels,” continues Trochet. “Changing a main wheel can
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add 2.5M H, and changing a light can add 1M H. Another problem, for example, is opening a thrust reverser and engine cowl to access a line replaceable unit (LRU) on the engine. Labour consumption on these checks is likely to be 2.5-3.0M H when non-routines are included. The related cost of materials and consumables will be that used for PF/TR checks plus the cost of nitrogen and hydraulic fluid. The total cost will be $100-120.”

The weekly check, which is the largest of all line checks, requires 1.5M H for the routine items that are included in the daily check plus another 1M H for the additional tasks. “The non-routines are the same as those included in the daily checks, but the weekly checks will have some additional cabin items,” explains Trochet. “These can be quick-to-fix items, such as coffee makers or life vests. The total labour required can be 3.0-6.0M H. The materials and consumables used will be the same as for daily checks, plus o-rings that are replaced each time a magnetic chip detector is inspected. Findings when magnetic chip detectors are inspected can cause an aircraft-on-ground (AOG) situation, especially if an engine has to be removed and replaced. Emergency gas bottles may also have to be replaced, and toilet pipes must be cleaned with crushed ice and a special fluid. The cost of materials for the routine portion of the check will be $150, while it will be highly variable for the non-routine part of the check. Replacement of an oxygen bottle, for example, can cost $1,500 and is required every three years. Hydrualic system fluid, engine oil and nitrogen for tyres will always need to be replaced, adding several hundred dollars. A wheel may also have to be changed. A budget of $250-350 can be used for non-routine materials and consumables, taking the total cost to $400-500.”

The aircraft will therefore require 350 daily and 350 TR checks each year, plus 900 PF checks, and 50 weekly checks on medium-haul operations. The total annual cost of these line and ramp checks will be $340,000, assuming a labour cost of $70 per M H. This is equal to $90 per FH (see first table, page 32), but the estimate is conservative, however, because it assumes that the TR and PF checks are performed by mechanics, not flightcrew.

For long-haul operations, the aircraft will need 350 each of daily, TR and PF checks per year, plus 50 weekly checks. The total cost of labour and material inputs, assuming mechanics perform all checks, is $250,000 per year, equal to $70 per FH (see second table, page 32).

A check inputs

A checks start with routine inspections, which inevitably lead to non-routine rectifications. There will also be outstanding defects that have arisen during operation, and have been deferred for clearing during A checks.

Airlines will also schedule some minor modifications, cleaning and cosmetic items, some component changes, and some additional customer-specific items. “The cabin and cosmetic, and customer-specific items will vary widely between operators,” says Benno Schlæffli, head of project management at SR Technics. “Traditional airlines may have time to clear defects that arise during operation, while inclusive tour operators, which utilise the aircraft more heavily, will defer more defects until the A check. These airlines will also do a lot more cabin cleaning and interior cosmetic work during A checks, since little will have been done during lighter line checks. Traditional scheduled airlines do less interior work during A checks, and more during daily and weekly checks. The routine tasks in the A check require 120-140M H, with the 1A tasks accounting for most of these. The additional 2A, 3A and 4A tasks in some checks need relatively few additional M H. Non-routine rectifications add another 25-30% to the routine M H, equalling 30-45M H. The remainder of the check involves minor modifications, cleaning defects, cleaning and cosmetic work, and customer-specific items. A total of 180-450M H is required for the check, with the cost of materials and consumables varying from $11,000 to $30,000.”

Air France is an example of a scheduled passenger operator. “Our A checks, which are performed as block checks, use an average total of 300M H. About 120M H are used for the routine inspections, another 70M H are required for component changes, 70-100M H used for cabin cleaning and refurbishment work, and the remaining 40M H is for non-routine rectifications,” says Pebarthe. “We do some interior refurbishment work in the A check, which includes seat cover replacements and work on IFE screens. The check also uses $12,000-15,000 in materials and consumables.”

Similar inputs are used by Abu Dhabi Aircraft Technologies for several of its customers. “An A check varies in workscope, but uses 300-400M H of labour and $12,000-15,000 in materials and consumables,” advises a planning expert planning A bu Dhabi Aircraft Technologies. “Routine inspections use 150-200M H of the total, with component changes, interior work and non-routine rectifications accounting for the balance of M H input.”

Taking average inputs of 400M H labour at $70 per M H and $20,000 for materials and consumables, the total cost for the check is $48,000. While the maintenance programme interval is 600FH, the actual interval achieved by operators will be 450FH, resulting in a cost per FH of $110 (see tables, page 32).
Base check contents
The grouping of the routine tasks and inspections in the cycle of eight base checks has been described. The routine inspections include corrosion prevention control programme (CPCP) items that were added to older types after several years of service.

Besides routine inspections, the base checks have several other elements to complete the total workscope. There are also OOP tasks, which are inspections that do not have the same intervals as A or C check inspections. These are often safety-related items which have life limits and intervals expressed in FCs.

There are also component changes. Some components and rotatables are tested as part of the routine inspections, but others have soft or hard times for removal and testing that coincide with the base checks.

A large part of a base check workscope is accounted for by service bulletins (SBs), airworthiness directives (ADs), and modifications. Inspections detailed in ADs result in findings, so ADs can include modifications.

These three groups of tasks and the routine inspections will all lead to rectifications being required.

In most cases operators will use the downtime provided by base checks to perform at least some interior cleaning and refurbishment. The longer downtime of the C4/5-year and C8/10-year checks is often used for refurbishing the interior, involving the complete removal of the seats, overhead bins, sidewall and ceiling panels, bulkheads, toilets and galleys.

Most airlines will also use the extended downtime of these two heavy checks to strip and repaint the aircraft.

Routine inspections
The organisation of routine base check inspection tasks is summarised (see table, page 21). The C4 and C8 checks are the heaviest. While the 10-year tasks have been included in the C8 checks and have an interval of 120 months, the actual utilisation of base check intervals, planning of check workscopes and downtimes required for several checks must be considered.

Most airlines use 85-90% of base check intervals, so they are likely to carry out a base check on the A330 once every 15-16 months. The complete cycle and C8 check is therefore likely to come due every 122-130 months. It would therefore make sense for most operators to perform the C8 check at 120 months, and still combine the 10-year tasks with the other four groups of C check tasks to simplify maintenance planning and minimise downtime.

Moreover, the interval for the 6-year tasks was extended from five years in 2002. Aircraft up to this point, and some aircraft after this M PD revision, would therefore have had these structural tasks performed at the 5-year interval, so the 10-year tasks would be in-phase with the C8 check for most of these aircraft. It is only since 2002 that some aircraft will have had this first group of structural tasks performed at the 6-year interval. The extension of the 10-year structural inspections to 12 years in 2009 means that only some of the aircraft in the fleet will have the second group of structural tasks out of phase with the C8 check for a few years.

The A330 has heavy checks at six year intervals. Most operators elect to perform interior refurbishments and strip and repaint the aircraft during these visits. Heavy modifications are also performed during these checks.

Engineering orders
Like its sister aircraft the A340-200/-300, the A330-200/-300 have had several major ADs. “One of these is the inspection of the main landing-gear aft-bearing lugs at the sixth wing rib,” says Pechbarthe. “This requires the aircraft to be immobilised for six days, and uses 100MH just for the inspection.”

AD 2007-22-10 relates to this inspection, and is the cover AD for the European Aviation Safety Agency (EASA) AD 2007-0247R1E. This affects all A330s, as well as all variants of the A340. The inspections are detailed in SBs A330-57-3096, -4104 and -5009.

“Inspections are required every 1,500FH and 300FC for the A330-200, and every 900FH and 300FC for the A330-300,” says Frank Koch, quality manager at LTU Aircraft Maintenance. “If there are findings, however, up to 600MH and a kit costing $10,000 are required to make the modification.”

Another major AD is AD 2007-0148, which incorporates an inspection detailed under SBs A330-57-3085/-3087/-3088. This relates to an inspection and modification on the left and right sixth wing ribs, due to cracks being found that could affect the structural integrity of the wing. This must be done before aircraft have accumulated 25,000FH and 8,000FC.

This requires a non-destructive test (NDT) type of inspection between wing stringers six and 20. It is usually done during a C4 check and is estimated to need 8MH. If there are findings at these inspections, the necessary modifications will require more labour and materials.

A third major AD relates to the protection of fuel tanks, which also requires six days of immobilisation. AD 2007-0278 encompasses SB A330-28-3092s and is required to inspect p-clips in the fuel tanks to stop electrical arcing. Koch comments that this needs the downtime of a C4 or C8 check to be done. It is estimated that it requires 300MH to complete.

A fourth major AD is AD 2001-070, which incorporates SB A330-53-3093 and relates to a heavy inspection and modification on frame 40 of the fuselage. “This uses 1,400MH to complete and a kit that costs $25,000,” says Koch. Line number 234 is the highest affected, and
It has been issued because of missing the A330-200/-300 and A340-200/-300. AD 2007-23-02 in December 2007. It affects $400 of parts to comply with this AD.

Two major ADs were issued in 2007, relating to the reinforcement of the rear fuselage: AD 2007-0269 and AD 2007-0284. These are required on an A330s that have had Airbus modification 44205, and both require an eddy current inspection in the upper shell structure of the fuselage tail cone. The thresholds for these first inspections are 10,700-13,500FC.

AD 2006-0125. “This relates to the engine pylon. It is carried out during a C4 or C8 check, and requires the removal of both engines and engine pylons,” explains Koch. “The pylons are disassembled, an intermediate rib is installed inside, and then they are re-assembled. This is mandatory and has a threshold for compliance of 120 months of age. Most operators will therefore do it at the C8 check. The whole process takes 1,000MH for both sides of the aircraft.”

Two major ADs on the A330 are alert SB A330-54A-3025. This is mandated by AD 2006-0125. “This relates to the engine pylon. It is carried out during a C4 or C8 check, and requires the removal of both engines and engine pylons,” explains Koch. “The pylons are disassembled, an intermediate rib is installed inside, and then they are re-assembled. This is mandatory and has a threshold for compliance of 120 months of age. Most operators will therefore do it at the C8 check. The whole process takes 1,000MH for both sides of the aircraft.”

Base checks will also include a small number of M H for the removal and replacement of some hard-time rotatable components. The A330 has 2,500 rotatable components, and 600 different part numbers.

A planning expert at Abu Dhabi Aircraft Technologies says, “The new bottom skin is installed with bolts in place of the rivets currently used. The whole process uses 100MH to complete.”

Inspections are required to detect missing fasteners and their replacement. About 4MH are needed to achieve compliance with this AD.

A major SB on the A330 is SB A330-25-3289, which modifies dado or decompression panels. De M otte estimates that it uses 500MH, and says that it requires extensive access for the modification, and for removal of seats, galleys and toilets.

“SB A330-57-3100 is a typical SB incorporated during a base check. This modifies the rear spar trailing edge, and introduces a new thicker, bottom skin panel to the shroud box on each wing,” says a planning expert at Abu Dhabi Aircraft Technologies. “The new bottom skin is installed with bolts in place of the rivets currently used. The whole process uses 100MH to complete.”

Heavy maintenance visit worksopes will include routine inspections, non-routine rectifications, ADs & SBs, removal and replacement of rotatable components, customer items, interior cleaning and refurbishment, and stripping & repainting.

All affected aircraft have passed the thresholds for compliance.

Rotable components

Base checks will also include a small number of M H for the removal and replacement of some hard-time rotatable components. The A330 has 2,500 rotatable components, and 600 different part numbers.

Of these, 2,100 are maintained on an on-condition basis. The remaining 400 are maintained on a hard-time basis. Half of these are cabin-related items. Rotables that are maintained on a hard-time basis are mainly airworthiness, safety or critical items which are life-limited.

Interior work

Interior work is split between cleaning and light refurbishment, and heavy refurbishment and installation of an all-new interior. “We usually change plastics and carpets, remove all seats for overhaul, and remove the carpet during the six lighter C checks,” says Pebarthe.

“Removing and installing some rotatable components can involve items as large as the APU, thrust reversers or the landing gear. These have their own removal intervals or are maintained on an on-condition basis. Defects that have been deferred from lower checks will have to be cleared. There will also be some customer items, such as cleaning the fuselage exterior.”

Base check inputs

The A330’s base check programme has a cycle of eight checks. The C4/6-year and C8/10-year checks are the heaviest. The remaining six checks are light, with the C1, C3, C5 and C7 checks having the smallest number of routine tasks with just the 1C group of inspections. The C2 and C6 checks are slightly larger, including the 1C and 2C inspections.

A planning expert at Abu Dhabi Aircraft Technologies explains that the routine 1C tasks and inspections in the C1/3 checks consume 1,300MH, although this varies depending on which base check cycle the aircraft is on. As aircraft age, additional structure/sampling tasks will be added to the 1C tasks, thereby increasing the M H required.

There are several other groups of routine inspections in addition to the basic 1C tasks. These can include lower A
check items, O O P tasks, the removal and replacement of rotatable components, and regular interior work and cleaning. This can increase the M H required for routine tasks considerably. For example, Didier Cojan, director of airframe maintenance at M ontreal-based ACTS, estimates that the total package of routine tasks for these lower C1/3 checks can require up to 2,900MH.

Cojan adds that additional items, such as clearing of defects, engineering orders (EOs) and ADs, can add several hundred M H.

Schlaefli estimates the routine portion of the C1/3 check to use 2,000MH, but hard-timed components, O O P tasks and interior cleaning can add another 400-500MH, taking the sub-total to 2,500-2,600MH. The labour required to complete various EOs, ADs and modifications will vary. The number of M H will be influenced by what ADs and SBs have been issued, and what inspections and modifications each operator can include and wants to perform during these lighter base checks. A typical amount of labour used would be 350-500MH. These would take the total labour required to 3,500-4,000MH.

Other major elements of the check will be non-routine rectifications, which can require as little as 500MH for a new aircraft that is in the early stages of its first base check cycle. A planning expert at Abu Dhabi Aircraft Technologies estimates that the amount of non-routine labour required for a mature aircraft, which is in the latter part of its first base check cycle or early part of its second base check cycle, will be similar to routine labour. This will add 1,300-1,400MH for the basic 1C tasks, but will add another 2,500MH when all routine items are considered. The total for these checks for young aircraft can therefore be 3,500-4,000MH for mature and ageing aircraft. Using a standard labour rate of $50 per M H, the labour portion of the check would be $175,000 for a younger aircraft, and $250,000-300,000 for a mature aircraft.

The cost of materials and consumables will vary from $40,000 to $80,000, depending on the amount of non-routine labour and the interior items that require work. H eavier C2/6 checks will have the 1C and 2C tasks, and so require higher M H for routine inspections. A planning expert at Abu Dhabi Aircraft Technologies estimates 2,000MH to be required. When other items of lower checks, O O P tasks, and interior work are added the routine portion will increase. Cojan says the complete routine package can exceed 4,000MH. Several hundred more M H can be added for clearing defects and EOs. This can add more than 1,000MH, taking the sub-total to 5,000-5,500MH.

Consideration again has to be given to non-routine rectifications and rectifying cabin items. A planning expert at Abu Dhabi Aircraft Technologies estimates labour for non-routine work on the basic 1C and 2C tasks to be 2,800MH for a mature aircraft. This can increase to 3,000-3,500MH when all items are considered. The total labour input for the check would therefore rise to 8,000-9,000MH. This would cost $400,000-450,000 when a standard labour rate of $50 per M H is used.

The cost of materials and consumables for this check would therefore be $70,000-100,000.

Another 500-800MH will also be needed more on regular EOs and modifications, and may use a further 1,000MH or more when large ADs are included. Several hundred M H will be added for component changes and customer items. Another 500-800MH will also be needed to clear defects that have accumulated on the aircraft during operation. A total of 11,500-13,500MH will be required, depending on the level of non-routine rectifications and EOs being incorporated into the check, and the quantity of customer and other items added to the workscope.

Interior refurbishment will be a major element, and Schlaefli estimates that this can add up to 5,000MH. A further 1,500-2,000MH will be used for stripping and repainting the aircraft, taking the total for the check to 18,000-20,000MH. Cojan similarly estimates the total input for the check at 19,000MH. This would have an equivalent cost of $900,000-1,000,000 at the standard.
labour rate of $50 per M H. “The cost of materials and consumables for this size of check will be $220,000, including materials and consumables used for interior refurbishment. It does not include major parts used for the interior refurbishment, such as new panels, carpet and covers,” explains Schlaefli. “Another $100,000 can be used for paint.”

New interior items will cost $250,000-300,000, taking the total of materials and consumables for the check to $470,000-520,000.

The total cost of these checks would therefore be $1.3-1.4 million. The total inputs required depend on the utilisation of the aircraft up to the check, the workscope, level of interior refurbishment, and the inclusion of stripping and repainting.

The C8/10-year check will be larger than the C4/6-year check. The C8 check has more routine inspections, and a planning expert at Abu Dhabi Aircraft Technologies says this portion of the check will consume 8,000FMH for the basic 4C, 8C, 6-year and 12-year routine tasks.

This will increase when other groups of O & P tasks, customer items and hard-time rotatables are added. Once non-routine rectifications are considered, the sub-total for the routine and non-routine portions will be 18,000-20,000FMH.

EOs and heavy modifications can add 1,500-4,000FMH, depending on the aircraft’s modification status. The total for the workscope would therefore be 20,000-24,000FMH.

Labour for interior refurbishment and stripping and repainting will add another 7,000FMH, as in the C4/6-year check. This will take the total for the full workpackage up to 31,000FMH, which is typical of this type of check.

Schlaefli estimates the cost of materials and consumables for the workpackage, excluding the interior refurbishment, to be $280,000. The inclusion of interior refurbishment and stripping and repainting would have similar costs to the C4/6-year check of $350,000-400,000.

This would take the total cost of the check to $2.2-2.3 million. Like the C4/6-year check, the total inputs required for the C8/10-year check would depend on aircraft utilisation, check workscope, and level of interior refurbishment.

Base check reserves
The aircraft are analysed on medium- and long-haul operations with annual utilisations averaging 3,750FMH and 4,750FMH. The base check interval is 18 months, with the C4/6-year check having a 72-month interval. The C8 check has a 144-month interval, and is usually combined with the 10-year structural tasks, although these have an interval of 120 months. The C8 check and 10-year tasks do not have intervals that coincide.

Typical rates of check interval utilisation are 80-85% with most operators, so most would perform a base check every 14-15 months with the MPD interval of 18 months. The C8 check would therefore come due every 116 months, so it could be combined with the 10-year structural tasks.

With a base check being performed once every 14-15 months, aircraft used on medium-haul operations would have a base check once every 4,500FMH. Aircraft used on long-haul services would have a base check once every 5,700FMH.

The cycle of eight base checks would therefore be completed in 36,000FMH in the case of medium-haul operations, and 45,000FMH in long-haul operations.

The total inputs for the eight base checks can reach $4.7-5.2 million for aircraft used on medium-haul operations. The cycle would be completed once every 10 years and 36,000FMH. The reserves for the checks would therefore be $145 per FMH (see first table, page 32).

The total inputs for the eight base checks for aircraft used on long-haul operations will be $5.5-6.0 million. This would be over an interval of 45,000FMH, so reserves will be $130 per FMH (see second table, page 32).

Heavy components
Heavy components include wheels and brakes, landing gear, APU and thrust reversers. The maintenance costs of these four component groups are analysed for medium- and long-haul services at FC times of 3.0FMH and 6.7FMH per FC (see tables, page 32).

The cost of wheels and brakes, landing gear, and thrust reversers is driven by FC intervals. APU costs are dependent on the ratio of APU hours per aircraft FMH. APU shop visit interval and shop visit cost. The cost for these four components per FC is analysed, and translated to cost per FMH according to the relevant FC time.

The interval for tyre retreads and wheel inspections depends on the condition of the tyres and depth of tread. This is influenced by weight at landing and severity of braking. Intervals are generally longer for medium-haul operations than for long-haul operations.

Tyres can be remoulded four or five times before being replaced. Wheels are inspected when tyres are remoulded, while brakes are repaired after disc thickness has been reduced.

The overall cost per FC of tyre retreads and replacement, wheel inspections, and brake repairs is summarised (see table, page 27), totalling $270 per FC for medium-haul operations, and $357 per FC for long-haul.

The landing gear overhaul interval is up to 10 years, and driven by an FC interval. This is equal to 12,500FC for medium-haul aircraft and 7,000FC for long-haul aircraft. The current market rate for a landing gear exchange and
overhaul fee is $900,000. The reserve for this is $72 per FC for medium-haul aircraft, and $129 per FC for long-haul aircraft (see table, page 27).

The aircraft has two engines, and two thrust reverser shipsets. Removal for maintenance is done on an on-condition basis. Longer intervals result in higher workscopes due to deteriorating condition. Average removal intervals are 6,000FC, while a typical intermediate shop visit will incur a cost of $215,000 per shipset, resulting in a reserve of $72 per FC for both units.

The A330-200/-300 are equipped with the GTCP 331-350 APU. Reliability rates for this have varied, but in recent years it has achieved intervals of 8,000 APU hours.

The APU-related cost per FC depends on how the APU is utilised between flights, and the number of APU hours per FC. The APU is usually started after landing. It can be left on for the complete turn time, in which case the APU will run for 1.5 to 3.0 hours per FC. In this scenario the APU will require a shop visit every 2,500-5,000FC. The APU can be turned off once ground power is connected after parking and then re-started prior to push-back and engine start. This can save APU time per FC, and reduce it to 1.0-2.0 APU hours per FC. In this case the APU will require a shop visit every 4,000-8,000FC.

The average shop visit costs $275,000 for an intermediate workscope. On this basis the APU-related maintenance cost will be $40-55 per FC where the APU is used for two to three hours between flights. This is equal to $18 per FH for aircraft used on medium-haul operations, and $8 per FH for aircraft used on long-haul operations.

The total cost per FC for these heavy components is $469 for medium-haul operations at 3.0FH, equal to $156 per FH. A higher reserve of $612 per FC for operations at 3.0FH, equal to $156 per FH. Components that have the highest failure rates are accounted for by 1,400 different part numbers. Of the rotatables installed, 1,800-2,400 are maintained on an on-condition basis, and the remaining 300-400 units have hard-time removal intervals. Another 300 components are condition monitored.

While operators with large fleets tend to own and maintain their own inventories, many carriers find it financially efficient to acquire rotatable inventories from third-party sources and have them managed and maintained by specialist providers. Specialist providers that offer these services include SAS Component, Lufthansa Technik, AAR and AJ Walter. Support packages for airlines can be structured in several ways. One method of providing a one-stop shop is for the airline to lease a homeseat stock of components that have the highest failure rates and are the most vital to the continued operation of the aircraft. The value of a homeseat stock for a fleet of 10 aircraft is $5 million. A monthly lease rate factor of 1.4-1.5% is typical, and is equal to $70,000-75,000 per month. This is equal to $90,000 per aircraft per year, and so $30 per FH for aircraft on medium-haul operations, and $20 per FH for long-haul aircraft.

The A330 has 2,500-3,000 rotatable components installed on each aircraft, although the number varies with various specification and configuration differences. These 1,400 components are accounted for by 1,400 different part numbers.

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**Engine maintenance**

The A330-200/-300 are powered by three engine types (see A330-200/-300 specifications, page 8): the CF6-80E1A2/A4/A3 rated at between 64,350lbs and 68,530lbs thrust; the Trent 4164/68 rated at 64,500lbs and 68,600lbs thrust; and the Trent 768/772 rated at 67,500lbs and 71,100lbs thrust.

The maintenance costs of the A330-200/-300 are examined on medium- and long-haul operations with average FC times of 3.0FH and 6.7FH. These average FC times influence removal intervals, particularly when engines are operated on shorter FC times. The rate of exhaust gas temperature (EGT) margin erosion is higher for engines operated on shorter FC times, and engine shop visit intervals are more related to EGT margin erosion and accumulated engine flight cycles (EFCs).

Shop visit intervals for engines operated on long-haul missions are generally more related to accumulated engine flight hours (EFH) on-wing and hardware
deterioration, rather than EGT margin erosion.

Removal intervals and EFC times also influence shop visit workscopes and the pattern of workscopes engines follow. An important issue of engine management and resulting maintenance costs are the EFC life limits of life limited parts (LLPs). Engine removals must be managed around these, and the need to remove and replace them results in heavier shop visits. It is therefore convenient to plan removals for heavy shop visits to coincide with LLP life expiry.

The in-service performance, removal intervals, shop visit workscopes, LLP management, and overall maintenance costs of the three main engine types are analysed.

**CF6-80E1**

The CF6-80E1 powers 101 of the 270 A330-200s in service, and 39 of the 231 A330-300s in service. The engine is more prominent on the -200 fleet, which is used more widely on long-haul operations.

CF6 operators include KLM, Air France, Turkish Airlines and TAM. KLM operates at an average EFC time of 6.25EFC and has the -80E1A3 rated at 68,530lbs. It has had the A330-200 in service since 2004. The engines have an EGT margin of 33 degrees centigrade when new. KLM’s engines have so far only been through their first shop visit, and the main removal causes were hardware deterioration. No removals have been due to EGT margin erosion. Most shop visits after the first removal were performance restorations, and the restored EGT margin was 25 degrees.

Turkish Airlines has been operating the CF6-80E1 on the A330-200 since late 2005. The average EFC time is 5.5EFC and the engines are the highest rated variants at 72,000lbs thrust. Turkish reports a higher initial EGT margin of 40-45 degrees, and says that in two years of operation, equal to 9,500EFC, the engines have lost 15 degrees of EGT margin. There have been no removals yet.

Denis Smink, chief operating officer at SGI Aviation Services, estimates that first removal intervals for engines operated at EFC times of 5.0-6.5EFC are 18,000EFC, equal to 3,000-3,600EFC. Second removal intervals will be shorter at 16,000EFC and 2,500EFC. The LLPs will therefore have accumulated 5,000-5,500EFC by the second removal. Removal intervals thereafter will be 2,500EFC.

The engine has LLPs with lives of 20,000EFC in the low pressure modules, and 8,400-20,000EFC in the high pressure modules. This implies most LLPs will not have to be replaced until the fifth or sixth shop visit at 15,000-18,000EFC. A full shopset has a list price of $5.0 million, so reserves for LLPs will be $280-330 per EFC, depending on actual replacement interval. This will be equal to $40-50 per EFC for aircraft operated on cycles of 6.7EFC, and $90-110 per EFC for engines operated in cycles of 3.0EFC.

First shop visits will be performance or core restorations in most cases, and will incur a cost of $2.0-2.5 million.

Second shop visits will be heavier, and will be a full workscope, with all modules requiring work. The cost of this level of workscope will be $3.0-3.5 million.

The average reserves for the two shop visits for the first two intervals will therefore be $175 per EFC. Additional reserves for LLPs will take the total to $220 per EFC for engines operated at 6.7EFC (see first table, page 32).

Mature intervals will be 12,000-18,000EFC, depending on EFC time. Shop visit costs will be $2.8-3.2 million, so reserves will be $165-250 per EFC.

With LLPs, total reserves for mature engines will be $210-295 per EFC. Engines operated at shorter EFC times of 3.0EFC will achieve shorter removal intervals, but will also have lower shop visit costs. First intervals will be at 14,000EFC, and second removals will take place at 12,000EFC. The two shop visit costs will total $5 million, resulting in a reserve of $290 per EFC once LLPs are included (see second table, page 32).

**PW4000-100**

The PW4000-100 powers 63 of the 270 A330-200s in operation, and 83 of the 231 A330-300s. Operators include Air Berlin (formerly LTU), TAM and Swiss. TAM and Swiss are large A330-200 operators.

Air Berlin operates the A330-200 and -300, and started with the -300 in 1995. It uses the PW4168 rated at 68,000lbs thrust, and aircraft operate at an average EFC time of 6.0EFC. The engines have an initial EGT margin of 35 degrees centigrade, and have a relatively low rate of EGT margin erosion. The first removal intervals averaged 18,000EFC and were caused mainly by hot section deterioration. As with all PW engines, most PW4000-100s follow an alternating shop visit pattern of a performance restoration and overhaul. Air Berlin says second removals average 14,000EFC, and again hot section deterioration is the main removal cause. The engines then have an overhaul. Mature engines then have a steady removal interval of about 14,000EFC and usually maintain the shop visit pattern of a performance restoration and overhaul workscopes.

Swiss operates the PW4168A at an average EFC time of 5.0EFC, and has operated the engines since 1998. Their first removal intervals were 10,000EFC, but this was due to an AD that forced engines off-wing early. The first shop visits were performance restorations.

The second removal interval was an improvement on the first, and averaged 16,000EFC. Removals were mainly due to hardware deterioration, and the
possible to replace LLPs at an
nature of operation. It will therefore be
18,000EFH, depending on style and
intervals are expected to be 12,000-
and a list price of $4.8 million. Mature
LLPs with uniform lives of 15,000EFC,
will therefore be $230-240 per EFH
equal to $51 per EFH at 6.7EFC per EFC.
The total reserve for shop visits and
accumulated time of up to 14,000EFC.
This results in a reserve of $340 per EFC;
equal to $51 per EFH at 6.7EFC per EFC.
The total reserve for shop visits and
LLPs will therefore be $230-240 per EFH
for engines operated at 6.7EFC per EFC.
Engines operated on medium-haul
operations of 3.0EFC will have first removal intervals of 16,000EFC , and second intervals of
15,000EFC . First and second shop visit costs will be $3.5 million and $5.7
million respectively. This will result in a
reserve of $185 per EFH over these first
two intervals. Once LLP reserves are
accounted for, total reserves will be $325
per EFH (see first table, this page).

Maintenance cost summary
Total maintenance costs are $1,356-
1,426 per FH for aircraft operated on
medium-haul services, and $1,085-1,240
per FH for aircraft operated on long-haul
services (see tables, this page). The
aircraft on long-haul operations have
maintenance costs of $400-500 per FH
less than the A340-200/-300 operated on
a similar FC time (see A340-200/-300
maintenance analysis & budget, Aircraft
The main differences between the A330-
200/-300 and A340-200/-300 are engine-
related costs, and all levels of airframe
maintenance. The A330-200/-300 therefore provide a lower cost alternative when mission lengths are within its
capabilities. 

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A330-200/-300 technical support providers

There are about 530 A330s in operation and are based on all continents. This survey summarises the technical support services available.

This survey summarises the major aftermarket and technical support service providers for the A330-200/-300 series. It is grouped into seven sections covering the different categories of support offered by each of the providers:

- Engineering management and technical support (see table, page 34).
- Line and light maintenance (see first table, page 35).
- Base maintenance (see second table, page 35).
- Engine maintenance (see first table, page 36).
- Spare engine support (see second table, page 36).
- Rotables and logistics (see first table, page 38).
- Heavy components maintenance (see second table, page 38).

Some of the providers of technical support are listed in most or all of the seven sections, and such organisations can loosely be referred to as one-stop-shop service providers for the A330 series. The survey provides include: Abu Dhabi Aircraft Technologies (formerly GAMCO), Air France Industries, AMECO Beijing, Evergreen Aviation, KLM Engineering & Maintenance, Lufthansa Technik (LHT); SIAEC/SAESL, and Turkish Technik. It is noteworthy that LHT is the only one of these providers capable of overhauling all engine types, if its ‘N3’ venture with Rolls-Royce is included.

According to Flightglobal’s ACAS database, which records actual maintenance contracts on an airframe-by-airframe contract basis, by far the largest proportion (22%) of A330 airframe maintenance checks is undertaken in-house by the maintenance department of each airline operator. The remainder are outsourced to third-party providers. Of these, the biggest provider of airframe heavy checks for the A330, according to ACAS, is HAECO. The rest, in descending order are as follows: Air France Industries; TAECO; SR Technics; Gameco; Lufthansa Technik Philippnes; Abu Dhabi Aircraft Technologies; Evergreen Aviation; SIAEC; AM ECO Beijing; Lufthansa Technik; Air Canada Technical Services (ACTS); LTU Technik; Sabena Technics; ST Mobile Aerospace (M AE); TAP M & E; EgyptAir Maintenance & Engineering; SR Technics (Ireland); Malaysia Airlines; Turkish Technic; Iberia; and MASCO. The tables list additional A330 airframe heavy maintenance providers which were not logged by ACAS.

The biggest recipient of third-party contracts for engine overhaul is HAESL, with 18% of all A330s outsourced engine overhaul work, in this case for the Trent 700 turbofan.

The next biggest slice of work is undertaken by in-house airline engine shops. In descending order the remainder are as follows: P&W Cheshire Engine Center (PW 4100); Rolls-Royce Aero Engine Services (Trent 700); GE Engine Services (CF6-80E1); SIAEC (Trent 700); KLM Engineering & Maintenance (CF6-80E1); SR Technics (PW 4100); Jet Turbine Services Australia (CF6-80E1); Abu Dhabi Aircraft Technologies (CF6-80E1 and Trent 700); M TU M maintenance Hannover (CF6-80E1); GE Engine Services Malaysia (PW 4100); AMECO Beijing (PW 4100); GE Caledonian (CF6-80E1).
It is also worth looking at the maintenance of auxiliary power units (APUs). In this category, the largest single APU overhauler, with 58% is the original equipment manufacturer (OEM), Honeywell, which has overhaul facilities in: Phoenix, Arizona, USA; Raunheim, Germany; and Singapore. Other significant APU overhaulers include: Revima APU; Abu Dhabi Aircraft Technologies; Iberia; Epcor APU; Lufthansa Technik; THY Technik; TAP Maintenance & Engineering; Air France Industries; and Triumph Air Repair.

Stewart has calculated that the engine overhaul market for the CF6-80E1, Trent 700, and PW4100 was worth $634 million in 2007, and expects this to rise to $1.47 billion in 2017. This is equal to an annual growth rate of nine per cent. The biggest suppliers for the CF6-80E1 are GE and KLM. For the PW4100, the main providers are SRT and P&W. As for the Trent 700, Stewart notes that most overhauls are undertaken by Rolls-Royce and its joint ventures including: SAESL in Singapore; HAESL in Hong Kong; and TAESL in the US. ‘N3’, Rolls-Royce’s engine MRO venture with LHT, will also add significant capacity to the market in the coming years. There are a limited number of suppliers of A330 engine maintenance. This is because it is undertaken primarily by the OEMs, their joint ventures, or by SRT for PW4100s plus KLM for CF6-80E1s. In particular, there are also relatively few events on the CF6-80E1 at the moment because it is a youthful fleet.

Overall, Stewart observes that with the increased delivery profile of the past five years there will be numerous first-time events coming through the system. In terms of engine events for all three engine types, AeroStrategy recorded 225 events in 2007, which will grow to 575 events in 2017. The chances are that over the next 10 years the market will require more
sources of supply for the CF6-80E1 which is currently rather limited," says Stewart. "Rolls-Royce operators will benefit from the N3 facility. Moreover, PW4000-94 overhaulers will gradually move out of that type and more into the PW4000-100 that powers the A330. In short, there will be more suppliers, especially for the CF6-80E1."

Asia Pacific

The majority of A330 airframe heavy maintenance providers are located in the Asia Pacific region, reflecting the large installed base of A330 fleets based there. These providers include: AMECO Beijing; Evergreen Aviation (Taiwan); Gameco; GMF AeroAsia; HAECO; Lufthansa Technik Philippines; Malaysia Airlines; Shanghai Technologies (STARCO); SIA Engineering Company; ST Aviation Services (SASCO); and TAECO Xiamen.

Notably, STARCO is driven by its parent fleet, China Eastern. Gameco looks after the fleet of China Southern, as well as some A330s from China Eastern. Meanwhile Air China's A330 fleet is overhauled by AMECO Beijing. LTP is LHT's main presence in Asia, and it overhauls A330s from Philippine Airlines, Qantas, and Hi Fly. Although HAECO has long been associated with Cathay Pacific and overhauls that carrier's aircraft including A330s, it also overhauls those of Air Calin, Qantas, and Dragonair. TAECO in Xiamen China also overhauls A330s from Cathay Pacific
AIRCRAFT OPERATOR'S & OWNER'S GUIDE

A330-200/-300 ENGINE MAINTENANCE - CF6-80E1, PW4100 & TRENT 700

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A330-200/-300 SPARE ENGINE SUPPORT - CF6-80E1, PW4100 & TRENT 700

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European region: The next largest geographical region for A330 overhaul is Europe with at least nine providers: Air France Industries; Austrian Technik; Iberia Maintenance; Lufthansa Technik; LITU Technik; M onarch Aircraft Engineering; Sabena Technics; SR Technics; and TAP M & E.

Air France Industries, in addition to overhauling its host carrier’s A330-200s, also has contracts with XL Airways (France), M onarch Airlines, KLM Royal Dutch Airlines, Corsairfly, Yemenia, and Air China. Iberia overhauls Iberworld’s A330s, and LHT overhauls Lufthansa’s, bmi British Midland’s and also those of the operator Livingston.

Meanwhile, Sabena Technics has two main locations in Brussels and Dinard. At the latter, Aer Lingus’s A330s are overhauled, while Brussels handles the A330s of Brussels Airlines, Cyprus Airways, and Hi Fly.

SR Technics’ two main bases are in Dublin and in Zurich. At the latter facility, the following carriers’ A330s are overhauled: Swiss; Eurofly; Air Caraibes; Gulf Air; Edelweiss Air; Qantas; and M onarch. M onarch, the Dublin facility has contracts with Air Greenland, Corsairfly, SAS, and Air Europa. In addition, TAP M & E and LITU both overhaul their respective host airlines’ fleets.

Engine shops in the region include: Air France Industries (CF6-80E1); GE Aviation Engine Services, Wales (CF6-80E1); KLM Engineering & Maintenance (CF6-80E1); Lufthansa Technik (all three engine types if N3 is included); M TU M aintenance Hanover (CF6-80E1); Rolls-Royce Engine Services (Trent 700); and SR Technics (PW4000).
Middle East

In the Middle East there are four main players: Abu Dhabi Aircraft Technologies (ADAT), formerly GAMCO; EgyptAir M & E; M ASCO; and Turkish Technic. ADAT overhauls aircraft from Etihad and from a few from Corsairfly, while M ASCO handles A330s from Middal-East Airlines (M EA), and Turkish looks after its host airline’s fleet.

According to ACAS, and based on contracts logged, the A330 engine overhaulers in the region include ADAT (CF6-80E1 and Trent 700) and Turkish Technic (CF6-80E1). Probably the most notable recent development in this region is the transformation of the former GAMCO into ADAT, which has begun constructing a dedicated single-bay maintenance hangar for Etihad, the UAE’s national airline, as part of a $500-million, five-year M RO contract between the two. Services to be provided will include airframe maintenance (A checks and C checks), technical, procurement and logistics, including ‘total care APU’ support.

Developed to service Etihad’s fleet of 14 A330s, as well as the carrier’s nine A340s, six A320s and five 777-300ERs, the new hangar will be completed in July 2008. The re-launch of the company is part of a long-term strategy of targeting an $800 million revenue stream by 2012.

North America

The region with the fewest number of A330 players is the US, which has only three providers: Aeroframe Services; Air Canada Technical Services (ACTS); and ST Mobile (M AE). ACTS is, without doubt, the largest M RO provider for A330 overhauls in the region, and its three largest A330 customers are Air Canada, ILFC, and Air Transat.

In terms of engine providers, the US has: GE Engine Services; O hio; P & W Cheshire CT; and Texas A e ro Engine Services (TAESL), a venture between Rolls-Royce and American Airlines.

Specialist services

In addition to the main airframe and engine support providers, there are specialist providers for spare engine leasing, heavy component repairs, and rotables support. Companies which specialise in rotatable support packages include AJ Walter, Avtrade, Triumph Group, and SAS Component. Of course, ‘full service’ providers such as SR Technics with its ‘Integrated Component Solutions’ (ICS), and Lufthansa Technik with its ‘Total Aerial Operations’ (TMO) provide a full spectrum of rotatable inventory and logistical services for third-party operators.

A side from the engine OEM s, which all have divisions that handle engine leasing/finance, independent engine lessors include Engine Lease Finance, GA Telesis and Willis Lease. Examples of specialist heavy component repair providers are the OEM M essier Services for landing gear wheels and brakes, and Revima for A PUs, which is the largest non-OEM provider of overhaul services. But the largest overhauler overall of the A330’s GTCP331-350 A PUs is the OEM, Honeywell. Honeywell has three strategically located facilities in Phoenix, AZ; R auneheim, Germany; and Singapore. Together these facilities mean that Honeywell handles at least 60% of all APU shop visits. Of these, its Singapore facility undertakes the most APU overhauls (reflecting the large number of A330s operating in the Asia-Pacific region), followed by R auneheim and then P h oenix.

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The past two years have seen a growing shortage of widebodies, and the A330-200/-300 family has suffered the biggest supply problems. This has pushed values and lease rates to high levels.

The shortage of widebodies started with the revision of the A350 programme, delays with A380 deliveries and a lack of interest and orders for the A340-500/-600. This delay in new widebody programmes has coincided with continued high levels of traffic growth on all long-haul markets, which has increased demand. Delays in new widebodies and a lack of interest in others has tightened supply of all widebodies. The 787 has achieved unprecedented success for a new aircraft, with more than 800 firm orders prior to entering service. The programme has now suffered serious setbacks, with deliveries in the initial years of production being deferred by an average of 24 months.

This leaves airlines with no choice but to extend the operational life of current fleets. There is now a shortage of all major types, and demand from all airlines is such that few aircraft are becoming available for trade or lease. Any that do come on to the market are quickly acquired.

Orders for the larger A330-300 slowed and the smaller -200 series became the favoured model. This is not surprising, since its 240-seat capacity and 6,400nm range make the aircraft unique. The A330-200 has been ordered by a large number of carriers, has another 126 firm orders outstanding, and is the long-haul flagship of many operators.

The A330-300 has experienced a renaissance in recent years, however, due mainly to the general shortage of widebodies and limited types to choose from. The A330-200 and -300 have both had their range performance improved since their initial inception, and now come close to their heavier, four-engined counterparts of the A340-200/-300 family. The A330 models have superior fuel burn and maintenance costs to the two A340 models, so interest in the A340-200/-300 has waned. Besides the A330-200 and -300, the only other types that most airlines will consider are the 777-200 and -300. This maintains a strong interest in the A330.

The A330 is a strong medium-range regional performer, but also has range capability of more than 5,000nm which makes it an attractive long-haul aircraft. Several carriers in the Asia Pacific have large fleets, particularly Cathay Pacific have a total of 38 A330-300s in operation and on firm order, Dragonair, Thai Airways International, Qantas/Jetstar, Fly Asia Express and Singapore Airlines. There are smaller numbers operated in Europe and North America.

The A330-300 is also almost in a class of its own. Despite having 10-15 fewer seats than the 777-200, the A330-300 is lighter and can operate with similar costs per seat. There are a large number of outstanding orders for the 777, but orders for A330-300 have increased in recent years. Order positions are now sold out until 2012/13, when the first A350s are due for delivery.

Values of two- and three-year-old -300s are estimated at $78-85 million, which compares to a list price of $110 million. Mid-1990s vintage aircraft are valued at about $45 million, with late 1990s aircraft at about $58 million. These values are mainly theoretical, however, due to the limited number of trades taking place. The exceptions are some sale and leaseback deals.

Meanwhile, new -200s are valued at about $90 million. Actual values depend on aircraft specification.

Lease rates are also high compared to the market lows of 2003-2004 when there was a surplus of aircraft. Rates for young -300s are $850,000-900,000, which is equivalent to a lease rate factor of 0.8-0.9% per month. Rates are $650,000-725,000 for five-year-old aircraft.

Lease rates for -200s are $100,000 less per month for -300s of similar vintages.

High lease rates for A330s are matched by other aircraft, following the general shortage of all types. Lease rentals for 767-300ERs up to 15 years old are as high as $650,000 per month. This compares to rates of $290,000-300,000 per month that were being realised from 2001 to 2003.

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