OWNER'S & OPERATOR'S GUIDE: A330-200/-300

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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.

The A330-200 and -300 are twin-engined, medium- and long-range widebody sisters to the four-engined long-range A340-200/-300. Both types were launched in January 1986. Initial service entry for the A330-300 took place in December 1994, while the A330-200 followed in April 1998. Since 1998, all newly certified A330 models and engine combinations have received 180-minute extended range twin-engined operations (ETOPs) approval at entry-into-service (EIS).

Ascend/Airclaims forecasts that the A330-300 will continue to be a major player in the intra-Asian market for the next 10-15 years, notwithstanding the introduction of the smaller 787 and the A350-900, both of which are targeted at longer-range markets. Ascend expects the A350-900 to replace the A330-300 over the longer term, however. A freighter conversion programme for the A330-300 is now likely, since it could make a good long-term replacement for the A300-600.

Configuration

The A330-200 and -300 are available with three engine choices: the General Electric CF6-80E1; Pratt & Whitney PW4164/8; 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 wings are structurally similar, with differences mainly being due to the A330 having one engine pylon per wing, compared with the two on the A340.

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, -223 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 installed on the aircraft; and the use of a 4 indicates a Trent 700 *(see table, page 9)*.

In January 2007 Airbus launched a new factory freighter variant, the A330-200F. This can carry 141,096lbs payload over 4,000nm. It should be noted that this version has only two engine choices: the PW4168 and Trent 700.

There are two variants of the A330-200 Freighter; a 'payload' version and a 'range' version. The 'payload' version can carry 151,899lbs over 3,200nm with Trent engines, or 151,330lbs with PW4170s. The 'range' version can carry its 140,875lbs gross structural payload over 4,000nm with Trent 772B-60 engines, or 140,307lbs with PW4170 engines. The disparity in structural payload capability is due to engine weight differences, and so the operating empty weight (OEW). The first two aircraft will be delivered in the autumn of 2009, according to Airbus.

Aircraft weight options

Today Airbus offers two 'basic' factory production maximum take-off weight (MTOW) 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 MTOW of 507,000lbs, a maximum landing weight (MLW) of 396,900lbs, and a maximum zero fuel weight (MZFW) 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 MTOW of 513,700lbs, an MLW of 401,300lbs, and an MZFW of 374,850lbs *(see table, page 9)*. In addition to these two weight variants, there are many more possible combinations of MTOW, MLW and MZFW. The combination depends on individual customer requirements and engine thrust. In summary, the weights for the A330-200 series lie between the following ranges: MTOW of 192t-233t (423,288lbs-513,765lbs); MLW of 180t-182t (396,900lbs-401,300lbs); MZFW of168t-170t (370,440lbs-374,850lbs). Airbus states that the A340-200's typical OEW is 263,700lbs.

Meanwhile, the A330-300 has seven 'weight variant' numbers. According to FAA certification data, these are: '000' (basic), '001', '002', '020', '022', '050', and '052'. These draw from a range of possible MTOW, MLW and MZFW combinations. Examples of MTOWs are 405,720lbs, 467,460lbs, 478,400lbs, 507,000lbs, and 513,700lbs. The latter two are 'high gross weight' (HGW) options.

Examples of MLWs are 383,670lbs, 390,285lbs, 407,925lbs, and 412,335lbs. Examples of MZFWs are 361,620lbs, 368,235lbs, 381,465lbs, and 385,875lbs. As with the A330-200, there are additional Airbus weight variants besides those listed on the FAA certification data sheet.

To summarise for the -300 series, these span the following weight ranges: MTOW of 184t-233t (405,720lbs-513,765lbs); MLW of 174t-187t (383,670lbs-412,335lbs); and MZFW of 164t-175t (361,620lbs-385,875lbs). According to Airbus, the A330-300's typical OEW is 267,200lbs-274,500lbs.

In addition, for both the A330-200 and -300, Airbus points out that while the lower take-off weights still exist as certificated options, all recent customers have taken delivery of only the newest and most capable weight variants. This ensures ample range capability.

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 Mode' and 'Payload Mode'. For Range Mode (standard

A330-200/-300 SPECIFICATIONS TABLE

Aircraft variant	Engine type	Take-off thrust	EGT redline temp	MTOW lbs	MLW lbs	MZFW lbs	OEW lbs	Max payload lbs	Fuel capacity USG	Seats 3-class	Range nm	Belly freight cu ft
A330-201	CF6-80E1A2	64,350	975	513,765	401,300	374,850	266,850	108,020	36,744	253	6,450	4,108
A330-202	CF6-80E1A4	66,870	975	513,765	401,300	374,850	266,830	108,020	36,744	253	6,450	4,108
A330-203	CF6-80E1A3	68,530	975	513,765	401,300	374,850	266,830	108,020	36,744	253	6,450	4,108
A330-223	PW4168A	68,600	620	513,765	401,300	374,850	267,635	107,215	36,744	253	6,450	4,108
A330-243	Trent 772B-60	71,100	900	513,765	401,300	374,850	267,031	107,819	36,744	253	6,450	4,108
A330-243	Trent 772C-60	71,100	900	513,765	401,300	374,850	267,031	107,819	36,744	253	6,450	4,108
A330-301	CF6-80E1A2	64,530	975	467,460	412,335	385,875	277,368	108,507	25,858	295	5,400	5,056
A330-302	CF6-80E1A4	68,870	975	513,765	412,335	385,875	277,368	108,507	25,765	295	5,400	5,056
A330-303	CF6-80E1A3	68,530	975	513,765	412,335	385,875	277,368	108,507	25,765	295	5,400	5,056
A330-321	PW4164	64,500	620	467,460	401,300	379,195	278,175	101,020	25,858	295	5,400	5,056
A330-322	PW4168	68,600	620	467,460	401,300	379,195	278,175	101,020	25,858	295	5,400	5,056
A330-323	PW4168A	68,600	620	513,765	412,335	385,875	278,175	107,700	25,765	295	5,400	5,056
A330-341	Trent 768-80	67,500	900	467,460	401,300	379,195	277,593	101,602	25,858	295	5,400	5,056
A330-342	Trent 772-60	71,100	900	513,765	401,300	379,195	277,593	101,602	25,858	295	5,400	5,056
A330-343	Trent 772B/C-60	71,100	900	513,765	412,335	385,875	277,593	108,282	25,858	295	5,400	5,056

version), the MTOW is 513,765lbs, MLW is 401,300lbs, and MZFW is 381,400lbs. For the optional Payload Mode, MTOW is 500,450lbs, MLW is 412,335lbs, and MZFW is 392,423lbs *(see table, page 10)*. Both freighter variants have the same 36,744 USG maximum total fuel capacity as the passenger -200 version.

"The payload mode 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 reinforce 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) is driven by a two-stage high pressure turbine (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: 64,530lbs for the CF6-80E1A2 (A330-201 and A330-301); and 66,870lbs for the CF6-80E1A4 (A330-202 and A330-302). The more powerful 68,530lbs CF6-80E1A3 was launched on the A330-203 and is now also available for the -303. This model includes an R88DT material HPT and new Stage 1 LPT nozzle and which permits an 'actual' exhaust gas temperature (EGT) redline of 1,060°C (corresponding to an 'indicated' EGT of 975°C).

PW4100 series turbofan

Meanwhile, Pratt and Whitney's 100-inch fan diameter PW4000-100 series are axial airflow, dual-spool turbofans with a single-stage fan, five-stage LPC, 11-stage HPC, annular combustor, two-stage HPT, and a five-stage LPT. On the A330, these deliver the following take-off thrust performance: 64,500lbs for the PW4164 (A330-321); 68,600lbs for the PW4168 for the A330-322; and 68,600lbs for the PW4168A (A330-223 and A330-323).

The PW4168A engine model provides the same take-off thrust as the PW4168 model at or below sea-level pressure altitude, and increased take-off thrust at pressure altitudes above sea-level and below 14,100ft and below temperatures of 40°C. The PW4000 series 'indicated' versus 'actual' EGT values are controlled by engine control unit (ECU) software. ECU software version SCN5C permits maximum permissible EGTs of 625°C actual and 620°C indicated for take-off (five minutes) and 600°C for maximum continuous.

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 shaft links 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 67,500lbs thrust Trent 768-60 (A330-341). An increased thrust 71,100lbs Trent 772-60 version was

A330-200F SPECIFICATIONS

Aircraft variant	Engine	MTOW lbs	MLW lbs	MZFW lbs	OEW lbs	Structural payload-lbs
A330-200F	Trent 772C-60	500,450	412,264	392,422	240,524	151,899
A330-200F	Trent 772C-60	513,677	401,241	381,400	240,524	140,875
A330-200F	PW4170	500,450	412,264	392,422	241,093	151,330
A330-200F	PW4170	513,677	401,241	381,400	241,093	140,307

subsequently introduced (A330-342), and was first selected by Cathay Pacific. An improved version of this engine, the Trent 772B-60, delivers the same thrust and powers both the A330-243, and A330-343. 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 700 can accommodate any growth capability of the A330, and the latest versions incorporate materials capable of withstanding pressures and temperatures for 75,000lbs thrust.

Fuel capacities

The A330-300 is configured with fuel tanks in the wings plus a tail trim tank. The total usable fuel capacity of all the variants is very similar, but there are slight differences depending on the model and weight variant. The A330-301, A330-321/-322, A330-341/-342, and A330-342 (except for weight variants '022' and '052') all have a wing fuel capacity of 24,241USG and a tail trim tank capacity of 1,617USG, making a total of 25,858USG *(see table, page 9)*. Meanwhile, the A330-302/-303, A330-323, A330-343, A330-342 weight variant '022', and A330-342 weight variant '052' all have a wing fuel capacity of 24,119USG, plus a tail trim tank holding up to 1,646USG making a total of 25,765USG *(see table, page 9)*. For both groups, the unusable fuel is 94USG.

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 *(see table, page 9)*. 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 (29/30in, 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 pitch 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 - Mod 40161). The highest-density seating 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 'AMA' 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). AC

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A330 fleet summary

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.

There are 516 A330-200s and -300s in operation. The oldest are 14 years old and most are still flown by their original operators. There is a firm order backlog of about 370 aircraft.

The A330 and closely related A340 were launched in 1987. The A330-300 entered service with Air France Europe (Air Inter) in January 1994, powered by General Electric (GE) CF6-80E1 engines. The First Pratt & Whitney (PW) PW4000-100-powered A330-300 entered service with Thai International Airways in December 1994. This was followed by the Rolls-Royce (RR) Trent 700-powered A330-300, which entered service with Cathay Pacific in February 1995.

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 Canada 3000 in April 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 700-powered 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 772B-60s; 49 A330-323s with PW4168As; 26 A330-322s with PW4168s; 24 A330-342s with Trent 772-60s; 16 A330-302s with CF6-80E1A4s; 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. "Obviously there will not be many A330 retirements and there are very few parked A330s because of the A350 delay."

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 MyTravel Airways (four), SriLankan (four), Middle East Airlines (three), Air Transat (three), bmi British Midland (three), 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 A330-243 operators, Etihad and Emirates, together average an FC time of 4FH.

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

In contrast, Asia Pacific and Middle 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. About 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); THY Turkish (5); TAM Linhas Aereas (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 Aer Lingus (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

A330-200/-300 FLEET SUMMARY

	CF6 -80E1A2	CF6 -80E1A4	CF6 -80E1A4B	CF6 -80E1A3	PW4164	PW4168	PW4168A	Trent 768-80	Trent 772-60	Trent 772B-60	Trent 772C-60	Total
A330-202	4	18	21	9								52
A330-203				49								49
A330-223							63					63
A330-243										106		106
A330-301	16											16
A330-302		16	12									28
A330-303	3			7								10
A330-321					8							8
A330-322						26						26
A330-323							49					49
A330-341								6				6
A330-342									24			24
A330-343									1	64	14	79
Sub-totals	**23**	**34**	**33**	**65**	**8**	**26**	**112**	**6**	**25**	**170**	**14**	**516**

same engine variant: the 68,600lbs thrust PW4168A. 'A330-223' is the airframe/ engine designation applied to this aircraft. Swiss and Northwest are the largest operators with 11 aircraft each. Other significant operators are: LTU (nine); TAM Linhas Aereas (seven); TAP Portugal (seven); Eurofly (four); and Korean (three).

Of this fleet, Northwest, LTU and TAP Air Portugal all average flight sectors of 7-8FH, while Swiss averages 6FH. At the bottom end, Asian carriers, including Korean, Malaysia, and Vietnam Airlines all average no more than 4FH.

The first PW4168A-powered A330-200 entered service in August 1998. Like the other A330-200s, the oldest of these aircraft are only just reaching 10 years old, so most will have yet to undergo their first major heavy maintenance visit. The highest-time P&W-powered A330-200 is operated by Swiss and has accumulated 46,000FH, while the subfleet mean average is 27,200FH.

Trent 700-powered A330-300s

Of the 95 RR Trent 700-powered A330-300s, 31 are powered by the original 67,500lbs thrust Trent 772-60. 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. each. The sub-fleet average is 20,500FH.

CF6-A330-300s

Of the 54 GE-powered A330-300s, China Airlines operates the largest fleet with 16 CF6-80E1A4-powered A330-302s. Qatar Airways has 11 CF6-80E1A4B-powered A330-302s and Qantas has 10 -A2 and -A3-powered A330-303s. Philippine Airlines operates eight CF6-80E1A2-powered A330-301s and Aer Lingus has four 13-14- year-old A330-301s powered by the same engine type, plus one A330-302 delivered in 2007 powered by CF6-80E1A4Bs.

The average FC time is just under 4FH. At the top end, sectors flown by Qantas average 6-7FH. Qatar Airways averages 5FH. In contrast, China Airlines and Philippine Airlines fly shorter intra-Asian sectors of 2-3FH.

About 23 GE-powered A330-300s are now older than 10 years, and so will have undergone their first heavy check, leaving about 38, which are still in their 'first life'. 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 five A330-322s with PW4168s. Malaysia Airlines operates 11 PW4168-powered A330-322s and LTU has three. Thai Airways has 12 A330-300s with a mixture of PW4164s, PW4168s, and PW4168As. USAirways has nine A300-323s 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.

About 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 Airline's A330-300s all exceed 40,000FH, with its highest time aircraft having accumulated over 46,000FH. The sub-fleet mean average is 25,450FH. AC

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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.

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.

Another 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 FMS2 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

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.

The A330 has various structural modifications that relate to main landing gear bearing lugs, and inspection of cracks near to keel beem fastener holes.

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 FMS2 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 with ground obstacles. These operations are area navigation procedures requiring the 'authorised' aircraft to have a specific level of performance and capability.

For an aircraft to be capable of such improved operation, the flight management guidance and envelope computer (FMGEC) must be equipped either with the latest Honeywell's FMS2 'P3' standard, or the Thales/Smiths FMS2 revision '2+' standard (available from 2009). A first RNP-AR step was certified for the A330 at the end of 2007 with the Honeywell FMGEC referenced above, with a performance accuracy of up to 0.1nm in approach and departure phases. In addition to the FMGEC, 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 FMGEC 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 EFB 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 pylon 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 from service the very earliest landing gears, 'D' and 'E' standard, and restricted the maximum steering angle. Newer

Pratt & Whitney is testing a more powerful variant of the PW4000-100; the PW4170. This will be rated at 70,000lbs thrust, have 1.2% lower fuel burn, and increased durability.

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 Messier-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 SCN6B. 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 PW4000 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. AC

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A330-200 & -300 fuel burn performance

The operating and fuel performance of the A330-200 & -300 passenger variants with all three engine types are analysed on medium- and long-haul routes. The performance of both variants of the A330-200F are also examined.

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 CF6-80E1A3 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 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 (ESAD). 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 ESAD, 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 ESAD of 2,100nm *(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 ESAD value 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.

FUEL BURN PERFORMANCE OF PASSENGER-CONFIGURED A330-200 & -300

City-pair	Aircraft variant	Engine type	Seats	Payload lbs	MTOW lbs	Actual TOW lbs	Fuel burn USG	Block time mins	ESAD nm	USG per seat-nm
LAX-LGA	A330-203	CF6-80E1A3	253	55,777	513,765	385,900	7,641	301	2,100	0.0144
LAX-LGA	A330-223	PW4170	253	55,777	513,765	387,133	7,654	302	2,100	0.0144
LAX-LGA	A330-243	Trent 772B	253	55,777	513,765	386,700	7,638	301	2,100	0.0144
LAX-LGA	A330-303	CF6-80E1A3	295	65,036	513,765	410,016	8,164	301	2,100	0.0132
LAX-LGA	A330-323	PW4170	295	65,036	513,765	411,267	8,185	302	2,100	0.0132
LAX-LGA	A330-343	Trent 772B	295	65,036	513,765	410,840	8,157	301	2,100	0.0132
LGA-LAX	A330-203	CF6-80E1A3	253	55,777	513,765	394,937	8,891	342	2,420	0.0145
LGA-LAX	A330-223	PW4170	253	55,777	513,765	396,266	8,917	343	2,420	0.0146
LGA-LAX	A330-243	Trent 772B	253	55,777	513,765	395,751	8,891	342	2,420	0.0145
LGA-LAX	A330-303	CF6-80E1A3	295	65,036	513,765	419,095	9,396	342	2,420	0.0132
LGA-LAX	A330-323	PW4170	295	65,036	513,765	420,063	9,393	353	2,420	0.0132
LGA-LAX	A330-343	Trent 772B	295	65,036	513,765	419,757	9,385	342	2,420	0.0131
LAX-ARN	A330-203	CF6-80E1A3	253	55,777	513,765	463,268	18,357	653	4,850	0.0150
LAX-ARN	A330-223	PW4170	253	55,777	513,765	464,547	18,371	654	4,850	0.0150
LAX-ARN	A330-243	Trent 772B	253	55,777	513,765	464,369	18,393	653	4,850	0.0150
LAX-ARN	A330-303	CF6-80E1A3	295	65,036	513,765	493,361	19,691	653	4,850	0.0138
LAX-ARN	A330-323	PW4170	295	65,036	513,765	494,398	19,697	653	4,850	0.0138
LAX-ARN	A330-343	Trent 772B	295	65,036	513,765	494,223	19,706	653	4,850	0.0138
ARN-LAX	A330-203	CF6-80E1A3	253	55,777	513,765	473,644	19,801	692	5,160	0.0152
ARN-LAX	A330-223	PW4170	253	55,777	513,765	475,042	19,827	693	5,160	0.0152
ARN-LAX	A330-243	Trent 772B	253	55,777	513,765	474,740	19,837	692	5,160	0.0152
ARN-LAX	A330-303	CF6-80E1A3	295	65,036	513,765	503,718	21,138	692	5,160	0.0139
ARN-LAX	A330-323	PW4170	295	65,036	513,765	504,534	21,101	692	5,160	0.0139
ARN-LAX	A330-343	Trent 772B	295	65,036	513,765	504,543	21,144	692	5,160	0.0139

(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 18 knots. This increases the tracked distance from 1,314nm to an ESAD of 1,406nm *(see table, page 19)*. In the other direction to LAX, the aircraft faces a headwind of eight knots, which results in an ESAD value of 1,361nm.

In addition, a long-range freight route between London Heathrow (LHR) and Nairobi (NBO) has been analysed. This route has a tracked distance of 3,692nm. When flown in a north-westerly direction to LHR, the aircraft experiences a headwind of 31 knots. This increases the tracked distance from 3,692nm to an ESAD value of 4,013nm *(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).

Aside 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

FUEL BURN PERFORMANCE OF FREIGHTER-CONFIGURED A330-200F

City-pair	Aircraft variant	Engine type	ESAD nm	MTOW lbs	Available TOW lbs	Block burn USG	Block time mins	Available payload lbs
BOG-MIA	A330-200F 'Range'	PW4170	1,406	513,677	433,572	5,905	214	140,307
BOG-MIA	A330-200F 'Range'	Trent 772B	1,406	513,677	433,682	5,883	213	140,875
BOG-MIA	A330-200F 'Payload'	PW4170	1,406	500,450	446,118	6,084	214	151,330
BOG-MIA	A330-200F 'Payload'	Trent 772B	1,406	500,450	446,170	6,056	213	151,899
MIA-BOG	A330-200F 'Range'	PW4170	1,361	513,677	432,990	5,971	205	140,307
MIA-BOG	A330-200F 'Range'	Trent 772B	1,361	513,677	433,031	5,942	204	140,875
MIA-BOG	A330-200F 'Payload'	PW4170	1,361	500,450	445,123	6,097	205	151,330
MIA-BOG	A330-200F 'Payload'	Trent 772B	1,361	500,450	445,192	6,072	205	151,899
NBO-LHR	A330-200F 'Range'	PW4170	4,013	513,677	499,200	16,717	546	127,906
NBO-LHR	A330-200F 'Range'	Trent 772B	4,013	513,677	505,900	16,949	545	133,115
NBO-LHR	A330-200F 'Payload'	PW4170	4,013	500,450	499,200	16,717	546	127,906
NBO-LHR	A330-200F 'Payload'	Trent 772B	4,013	500,450	500,449	16,775	545	129,004
LHR-NBO	A330-200F 'Range'	PW4170	3,826	513,677	509,829	16,514	520	140,307
LHR-NBO	A330-200F 'Range'	Trent 772B	3,826	513,677	510,200	16,535	520	140,875
LHR-NBO	A330-200F 'Payload'	PW4170	3,826	500,450	500,450	16,229	521	133,109
LHR-NBO	A330-200F 'Payload'	Trent 772B	3,826	500,450	500,450	16,237	520	133,402

observation is the 14% increase in average block fuel burn across all the aircraft due to the headwind component and higher ESAD *(see table, page 18)*. This increases the block fuel burns per passenger *(see table, page 18)*.

On the longer LAX-ARN route, the most interesting observation is that the average block fuel burn per seat-mile is 4.4% greater on the longer sector (averaging both directions) than for the LAX-LGA city pair (again, averaging both directions). This is despite the fact that the aircraft spends more time at efficient cruise altitude as a proportion of the whole flight. By using the ESAD in the fuel per seat-mile, these calculations factor out any differences arising from headwinds or tailwinds. The principal reason for the higher fuel burn per seat-mile on the longer routes is the heavier weight of fuel carried to fly the extra distance, particularly during the earlier part of the flight. Indeed, this extra fuel load is reflected in the ATOWs which are about 80,000lbs higher on the longer LAX-ARN city-pair.

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 both 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 MSPs, 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 17°C.

In this example, the 'Payload' variants are the most suitable aircraft to deploy on this route because they can take advantage of their higher MZFWs 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 MSPs 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 23°C, 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 MSPs 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 MSPs. 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 MTOWs 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 MZFWs 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 MTOWs and can therefore carry the greatest combined payload plus fuel load without compromise. AC

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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, Middle East Airlines, Finnair and TAP 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 as their long-haul flagship include TAM, THY and Northwest. Average annual utilisation is 4,500 flight hours (FH). Average flight cycle (FC) time is 6.7FH.

Airlines that use their 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-haul operation assumes 3,750FH and 1,250FC per year, with an average FC time of 3.0FH. The 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 escalated 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 multiples of this group of tasks: 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 Pebarthe. "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 when the A330 went into service were 60 and 120 months. The 60-month tasks had their interval extended to 72 months, so they now coincide with the C4 check," continues Pebarthe. "The 10-year structural inspections are still at their original interval of 10 years/120 months. This used to coincide with the C8 check's original interval of 120 months. The 10-year interval may be increased to the C8's new interval of 144 months at the next revision in May 2008. This would be ideal for maintenance planning. Our own D check interval is 11 years, and we have a sampling programme to escalate it to 12 years."

The groups of inspections included in each base check are summarised *(see table, this page)*. The two heavy checks are the C4 and C8 checks. The C4 will comprise the 1C, 2C, 4C and 6-year groups of tasks. The C8 will comprise the 1C, 2C, 4C, 8C and 10-year tasks. While the MPD intervals of the 8C and 10-year inspections no longer coincide, actual utilisation of check intervals by most airlines and the desire to minimise downtimes for base checks mean that the two groups of tasks will be scheduled together in most cases.

Line & A check inputs

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 rotable 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

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

Check	Check task groups	Interval
Block A check system		
A1	1A	600FH
A2	1A + 2A	1,200FH
A3	1A	1,800FH
A4	1A + 2A + 4A	2,400FH
A5	1A	3,000FH
A6	1A + 2A	3,600FH
A7	1A	4,200FH
A8	1A + 2A + 4A + 8A	4,800FH
Block base check system		
C1	1C	18 months
C2	1C + 2C	36 months
C3	1C	54 months
C4/6-year	1C + 2C + 4C + 6-year	72 months
C5	1C	90 months
C6	1C + 2C	108 months
C7	1C	126 months
C8	1C + 2C + 4C + 8C + 6-year + 10-year *	144 months

** The 10-year tasks are likely to be extended to a 12-year/144-month interval in the next MPD revision that will be issued in May 2008.*

The A330's maintenance programme has evolved since it entered into service. Base checks now have an interval of 18 months, and the C8 check finishes the cycle at an interval of 144 months. The first group of structural inspections have had their interval escalated to 72 months to coincide with the C4 check, but the second group of tasks still have an interval of 120 months. These may be increased to 144 months. Further base check interval escalations may be to 24 months and a cycle of 192 months.

add 2.5MH, and changing a light can add 1MH. 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 2.5-3.0MH 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 1.5MH for the routine items that are included in the daily check plus another 1MH 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 3.0-6.0MH. 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. Hydraulic 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 MH. 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 Schlaefli, head of project management at SR Technics. "Traditional airlines may have time to clear defects that arise during operation in daily and weekly checks, 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 120-140MH, with the 1A tasks accounting for most of these. The additional 2A, 3A and 4A tasks in some checks need relatively few additional MH. Non-routine rectifications add another 25-30% to the routine MH, equalling 30-45MH. The remainder of the check involves minor modifications, clearing defects, cleaning and cosmetic work, and customer-specific items. A total of 180-450MH 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 300MH. About 120MH are used for the routine inspections, another 70MH are required for component changes, 70-100MH used for cabin cleaning and refurbishment work, and the remaining 40MH 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 300-400MH of labour and $12,000-15,000 in materials and consumables," advises a planning expert planning Abu Dhabi Aircraft Technologies. "Routine inspections use 150-200MH of the total, with component changes, interior work and non-routine rectifications accounting for the balance of MH input."

Taking average inputs of 400MH labour at $70 per MH 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)*.

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.

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 rotables 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 MPD 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.

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 Pebarthe. "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

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

all affected aircraft have passed the thresholds for compliance.

An example of a major SB on the A330 is 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."

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 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 2007-09-09 became effective in June 2007, and also affects the A340-200/-300. It concerns an undamped extension of the main landing gear, and requires replacement of the landing gear retraction links. It is estimated that it will take 10MH to comply.

AD 2007-16-02 became effective in September 2007, and affects the A330-200/-300 and A340-200/-300. It relates to the inspection of ruptured fasteners at the keel beam skin panel, which in turn concerns the structural integrity of the area. It is estimated to require 12MH and $400 of parts to comply with this AD.

The third AD issued in 2007 was AD 2007-23-02 in December 2007. It affects the A330-200/-300 and A340-200/-300. It has been issued because of missing fasteners on a longitudinal stringer between fuselage frames 18 and 19. 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 Motte 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."

Rotable components

Base checks will also include a small number of MH for the removal and replacement of some hard-time rotable components. The A330 has 2,500 rotable components installed, accounted for by 1,400 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. "We completely remove the interior during the C4 and C8 checks, which involves removing galleys, seats, toilets, and panels. Most items can be refurbished and do not require replacing. The interior is refurbished every four base checks, an interval of five to six years."

Stripping and repainting are carried out at every fourth base check, or every five to six years by most carriers, who take advantage of the downtime of the C4 and C8 checks, since stripping and repainting take up to 12 days. Stripping takes three to four days, while painting two layers takes eight days.

Other work

Most operators include some additional tasks in base checks. These will be OOP tasks that do not have intervals that coincide with most checks, and have to be added before reaching their own intervals and thresholds.

Removing and installing some rotable 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 MH required.

There are several other groups of routine inspections in addition to the basic 1C tasks. These can include lower A check items, OOP tasks, the removal and replacement of rotable components, and regular interior work and cleaning. This can increase the MH required for routine tasks considerably. For example, Didier Cojan, director of airframe maintenance at Montreal-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 MH.

Schlaefli estimates the routine portion of the C1/3 check to use 2,000MH, but hard-timed components, OOP 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 MH 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 3,500MH, and 5,000-6,000MH for mature and ageing aircraft. Using a standard labour rate of $50 per MH, 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.

Heavier C2/6 checks will have the 1C and 2C tasks, and so require higher MH for routine inspections. A planning expert at Abu Dhabi Aircraft Technologies estimates 2,000MH to be required. When other items of lower checks, OOP tasks, and interior work are added the routine portion will increase. Cojan says the complete routine package can exceed 4,000MH. Several hundred more MH can be added for clearing defects and EOs. This can add more than 1,000MH, taking the sub-total to 5,000-5,500MH.

A330-200/-300 HEAVY COMPONENT MAINTENANCE COSTS

Operation	Medium-haul	Long-haul
FH:FC	3.0	6.7
FH per year	3,750	4,750
FC per year	1,250	700
FH:FC	3.0	6.7
Number of main & nose wheels	8 + 2	8 + 2
main/nose tyre retread interval-FC	350/340	305/290
Tyre retread cost-$	600/450	600/450
Number of retreads	4	4
New main & nose tyres-$	1,200/1,000	1,200/1,000
$/FC retread & replace tyres	**19**	**23**
Main/nose wheel inspection interval-FC	260	230
Main & nose wheel inspection cost-$	**1,000**	**1,000**
$/FC wheel inspection	**38**	**43**
Number of brakes	8	8
Brake repair interval-FC	1,500	1,100
Brake repair cost-$	40,000	40,000
$/FC brake repair cost	**213**	**291**
Landing gear interval-FC	12,500	7,000
Landing gear exchange & repair fee-$	900,000	900,000
$/FC landing gear overhaul	**72**	**129**
Thrust reverser repair interval-FC	6,000	6,000
Exchange & repair fee-$/unit	215,000	215,000
$/FC thrust reverser overhaul	**72**	**72**
APU hours shop visit interval	8,000	8,000
APU hours per aircraft FC	1.0-2.0	2.0-3.0
APU shop visit cost-$	275,000	275,000
$/FC APU shop visit	**40-55**	**40-55**
Total-$/FC	**469**	**612**
Total-$/FH	**156**	**91**

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 MH is used.

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

The C4/6-year check is when most operators take the opportunity to refurbish the interior and also strip and repaint the aircraft.

The basic package of routine inspections in this check requires 3,500-4,000MH.

The aircraft can also use 1,000MH or more on regular EOs and modifications, and may use a further 1,000MH or more when large ADs are included. Several hundred MH 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

Total inputs for the cycle of eight base checks will consume 80,000-90,000MH and incur a total cost of $4.7-6.0 million. Consumption will be lower for aircraft operated on medium-haul operations, but reserves per FH will be higher than for long-haul aircraft.

labour rate of $50 per MH.

"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 8,000MH for the basic 4C, 8C, 6-year and 12-year routine tasks. This will increase when other groups of OOP tasks, customer items and hard-time rotables are added. Once non-routine rectifications are considered, the sub-total for the routine and non-routine portions will be 18,000-20,000MH.

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

Labour for interior refurbishment and stripping and repainting will add another 7,000MH, as in the C4/6-year check. This will take the total for the full workpackage up to 31,000MH, 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 3,750FH and 4,750FH. 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 4,500FH. Aircraft used on long-haul services would have a base check once every 5,700FH.

The cycle of eight base checks would therefore be completed in 36,000FH in the case of medium-haul operations, and 45,000FH 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 36,000FH. The reserves for the checks would therefore be $145 per FH *(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 45,000FH, so reserves will be $130 per FH *(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 3.0FH and 6.7FH 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 FH, APU shop visit interval and shop visit cost. The cost for these four components per FC is analysed, and translated to cost per FH 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.

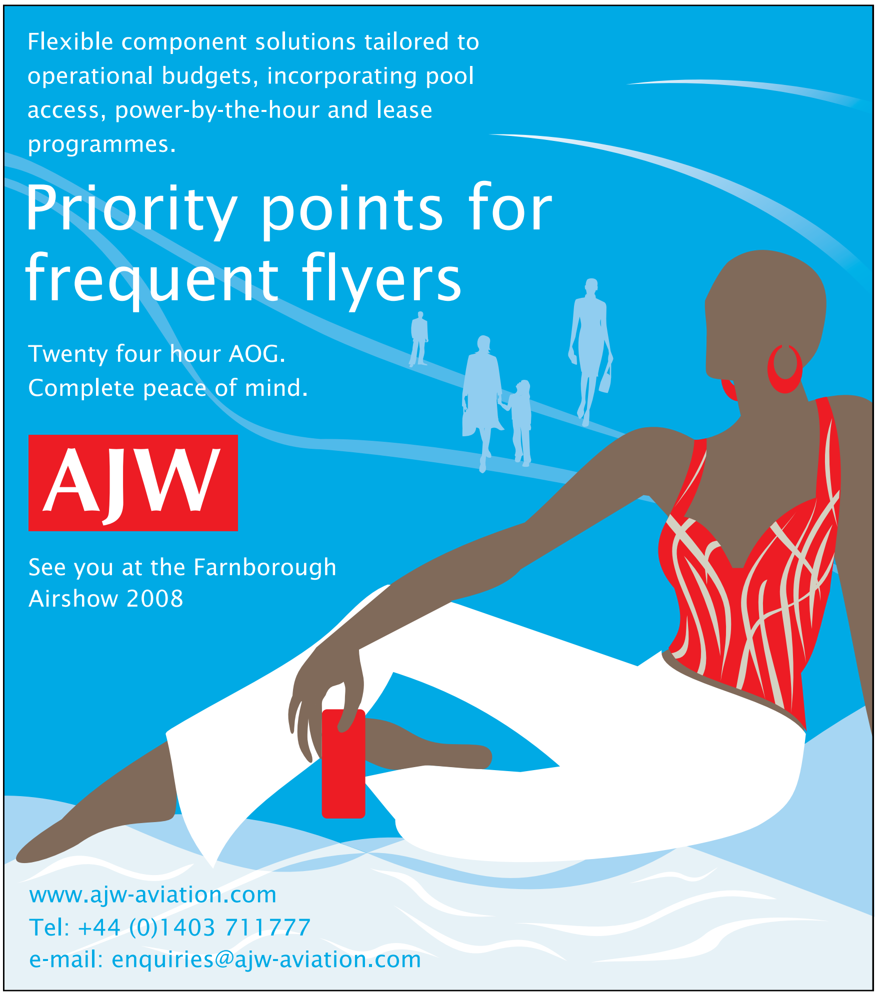
The A330-200/-300 are equipped with the GTCP 331-350 APU. Reliability rates for this have varied, but in recent years it has achieved intervals of 8,000 APU hours.

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 long-haul operations is equal to $91 per FH *(see table, page 27)*.



Rotable components

The A330 has 2,500-3,000 rotable 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.

Of the rotables 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 rotable 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 homebase 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 homebase 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 remaining rotables, which account for the majority required by the airline, can be accessed by the airline via a pool provided by the specialist rotable provider. The pool access fee will be $150-175 per FH, depending on aircraft utilisation and other operational factors.

The final element of such a one-stop rotable support package will be the repair and management fee for all the rotables. This can be simplified for airlines via a predictable flat rate per FH. This will be $50-70 per FH, depending on fleet size and several operational factors.

These three elements will total $275 per FH for aircraft used on medium-haul operations, and $220-250 per FH for aircraft used on long-haul services *(see tables, page 32)*.

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

The Trent 768/772 powering the A330 have longer removal intervals than the Cf6-80E1 and PW4000-100. The Trent engines, however, also have higher shop visit input costs and so similar reserves per EFH to their competitors.

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 6.25EFH 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 5.5EFH 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 9,500EFH, 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 5.0-6.5EFH are 18,000EFH, equal to 3,000-3,600EFC. Second removal intervals will be shorter at 16,000EFH and 2,500EFC. The LLPs will therefore have accumulated 5,000-5,500EFC by the second removal. Mature 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 shipset 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 EFH for aircraft operated on cycles of 6.7EFH, and $90-110 per EFH for engines operated in cycles of 3.0EFH.

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 EFH. Additional reserves for LLPs will take the total to $220 per EFH for engines operated at 6.7EFH *(see first table, page 32).*

Mature intervals will be 12,000-18,000EFH, depending on EFC time. Shop visit costs will be $2.8-3.2 million, so reserves will be $165-250 per EFH. With LLPs, total reserves for mature engines will be $210-295 per EFH.

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 14,000EFH, and second removals will take place at 12,000EFH. The two shop visit costs will total $5 million, resulting in a reserve of $290 per EFH 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 6.0EFH. 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 18,000EFH 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 14,000EFH, 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 14,000EFH and usually maintain the alternating pattern of performance restoration and overhaul workscopes.

Swiss operates the PW4168A at an average EFC time of 5.0EFH, and has operated the engines since 1998. Their first removal intervals were 10,000EFH, 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 16,000EFH. Removals were mainly due to hardware deterioration, and the

DIRECT MAINTENANCE COSTS FOR A330-200/-300: MEDIUM-HAUL OPERATION

Maintenance Item	Cycle cost $	Cycle interval	Cost per FC-$	Cost per FH-$
Line & ramp checks	340,000	Annual		90
A check	48,000	A check- 450FH		110
Base checks	4.7-5.2 million	36,000FH		145
Heavy components:			469	156
LRU component support				275
Total airframe & component maintenance				**776**
Engine maintenance: 2 X CF6-80E1/PW4000-100/Trent 768/772: 2 X $ 290-325 per EFH				580-650
Total direct maintenance costs:				**1,356-1,426**

Annual utilisation:
3,750FH
1,250FC
FH:FC ratio of 3.0:1

DIRECT MAINTENANCE COSTS FOR A330-200/-300: LONG-HAUL OPERATION

Maintenance Item	Cycle cost $	Cycle interval	Cost per FC-$	Cost per FH-$
Line & ramp checks	250,000	Annual		70
A check	48,000	A check- 450FH		110
Base checks	5.5-6.0 million	45,000FH		130
Heavy components:			612	91
LRU component support				225-250
Total airframe & component maintenance				**625-650**
Engine maintenance: 2 X CF6-80E1/PW4000-100/Trent 768/772: 2 X $ 230-295 per EFH				460-590
Total direct maintenance costs:				**1,085-1,240**

Annual utilisation:
4,750FH
700FC
FH:FC ratio of 6.7:1

engines required an overhaul at their second shop visit.

First shop visit workscopes average $2.5 million, while overhauls cost $3.5-4.3 million, depending on total accumulated time. The reserve for the first two shop visits will cost $6.5 million over an interval of 30,000-38,000EFH, equal to $185 per EFH.

The PW4000-100 has a shipset of LLPs with uniform lives of 15,000EFC, and a list price of $4.8 million. Mature intervals are expected to be 12,000-18,000EFH, depending on style and nature of operation. It will therefore be possible to replace LLPs at an accumulated time of up to 14,000EFC. This results in a reserve of $340 per EFC; equal to $51 per EFH at 6.7EFH per EFC.

The total reserve for shop visits and LLPs will therefore be $230-240 per EFH for engines operated at 6.7EFH for the first two removals *(see tables, this page)*.

Engines operated on medium-haul operations of 3.0EFH per EFC will have first removal intervals of 14,000EFH, and 12,000-13,000EFH for the second removal. First and shop visit workscopes will cost $1.9 million and $3.5 million respectively, resulting in a reserve of $200 per EFH. With LLP reserves added, total reserves will be $315 per EFH.

Trent 768/772

The Trent 700 series has a reputation for durability. It powers 106 A330-200s and 109 A330-300s. First run intervals often average more than 20,000EFH, and can be up to 23,000EFH. A core restoration is usually required at this stage. The second removal interval is typically in excess of 16,000EFH, and can average 18,500EFH.

Despite these long intervals, the engines usually incur high shop visit costs. The first shop visit will cost $2.5-2.7 million, and can often be higher. The heavier second shop visit will be $3.7-4.0 million, so the total cost for the first two shop visits will be $6.5-7.0 million. This will be equal to a reserve of $170-180 per EFH when amortised over the interval of about 40,000EFH and 6,000EFC for the two removals.

The Trent 700 series has LLPs with lives of 10,000EFC in the high pressure modules, and 15,000EFC in the low and intermediate pressure modules. The list price for a full shipset is $4.8 million. Given the typical removal intervals, it should be possible to replace the LLPs within 1,000-2,000EFC of life expiry. On this basis, reserves for LLP replacement will be $420 per EFC, and $60-65 per EFH at an EFC time of 6.7EFH. This takes total reserves over the interval of the first two shop visits to $235 per EFH.

Engines operated on EFC times of 3.0EFH will have first removal intervals of 16,000EFH, and second intervals of 15,000EFH. 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 Commerce, June/July 2007, page 17)*. 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. AC

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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 A330-200/-300. This means they provide most, if not all, of the technical support services that an operator would require, including: engineering management; line and light maintenance; base and heavy airframe checks; interior refurbishment; stripping and repainting; engine maintenance management; engine shop visits; repair; overhaul of major components; and rotable inventory supply and management services. In addition to the above, spare engine leasing support services may also be provided.

Third-party market share

The survey tables show the providers that are able to offer a complete range of base maintenance services, comprising airframe heavy maintenance as well as engine maintenance, repair and overhaul (MRO), for the A330 series. These providers 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 Philippines; Abu Dhabi Aircraft Technologies; Evergreen Aviation; SIAEC; AMECO Beijing; Lufthansa Technik; Air Canada Technical Services (ACTS); LTU Technik; Sabena Technics; ST Mobile Aerospace (MAE); 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 A330 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 (PW4100); Rolls-Royce Aero Engine Services (Trent 700); GE Engine Services (CF6-80E1); SAESL (Trent 700); KLM Engineering & Maintenance (CF6-80E1); SR Technics (PW4100); Jet Turbine Services Australia (CF6-80E1); Abu Dhabi Aircraft Technologies (CF6-80E1 and Trent 700); MTU Maintenance Hannover (CF6-80E1); GE Engine services Malaysia (PW4100); Ameco Beijing (PW4100); GE Caledonian (CF6-

There are about 530 A330s in operation, and there are several technical support providers that offer one-stop -shop services for the aircraft. Major support providers include Abu Dhabi Aircraft Technologies, Air France Industries, Ameco Beijing, Lufthansa Technik and Turkish Technik.

The A330 fleet is predicted to grow to about 1,100 units. Requirements for technical support will grow with the fleet. The current number of annual base checks for the fleet is about 300, but this is expected to grow to about 700 by 2017.

80E1); Evergreen Aviation (CF6-80E1); N3 Engine Overhaul Services (Trent 700); Lufthansa Technik (CF6-80E1 and PW4100); and Eagle Services Asia (PW4100).

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.

A330 MRO market and forecast

David Stewart, principal at AeroStrategy management consultants, calculates the worldwide A330 airframe heavy maintenance market today, for C and D checks, to be worth about $174 million annually, growing at a rate of eight per cent per annum through to $383 million in 2017. He notes that for the A330, the average cost per event is increasing due to the greater proportion of non-routine work as the aircraft age. "We recorded about 300 C and D check events in 2007, and because the number of deliveries is increasing, we will see a growing number of events, such that there will be approximately 700 in 2017," says Stewart.

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

A330-200/-300 ENGINEERING MANAGEMENT & TECHNICAL SUPPORT

	Outsourced engineering service	Maint records service	DOC & manuals manage	Maint prog manage	Reliability stats	AD/SB orders manage	Check planning	Config & IPC manage	Total tech support
Abu Dhabi Aircraft Technologies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Air Canada Technical Services	Yes	-	Yes	-	-	-	-	-	-
Air France Industries	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Airbus	-	-	Yes	-	Yes	-	-	Yes	-
GA Telesis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Iberia Maintenance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik Philippines	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Messier Services	Yes	Yes	Yes	Yes	Yes	-	Yes	-	Yes
SAA Technical	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sabena Technics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SIA Engineering Company	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SAS Component	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SAS Technical Services	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SR Technics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TAP Maintenance & Engineering	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

A330-200/-300 LINE & LIGHT MAINTENANCE SUPPORT

	Maint operations control	AOG support	Line checks	A checks	Engine QEC changes	Engine changes	Landing gear changes	APU changes	Thrust reverser changes
Abu Dhabi Aircraft Technologies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Air Canada Technical Services	-	Yes	-	-	-	Yes	Yes	Yes	Yes
Air France Industries	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Airbus	-	Yes	-	-	-	-	Yes	Yes	Yes
Ameco Beijing	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Austrian Technik	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Europe Aviation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Evergreen Aviation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
GA Telesis	-	Yes	-	-	Yes	Yes	-	-	-
GMF Aero Asia	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HAECO	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Iberia Maintenance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LTU Technik	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik Philippines	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Messier Services	Yes	Yes	-	-	-	-	Yes	Yes	-
Sabena Technics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SAS Technical Services	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shanghai Technologies (STARCO)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SIA Engineering Company	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SR Technics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TAP Maintenance & Engineering	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Turkish Technic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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

A330-200/-300 BASE MAINTENANCE SUPPORT

	C checks	IL & D checks	Composites	Strip/ paint	Interior refurb
Abu Dhabi Aircraft Technologies	Yes	Yes	Yes	Yes	Yes
Aeroframe Services	Yes	Yes	Yes	Yes	Yes
Air Canada Technical Services	Yes	Yes	Yes	Yes	Yes
Air France Industries	Yes	Yes	Yes	Yes	Yes
Ameco Beijing	Yes	Yes	Yes	Yes	Yes
Austrian Technik	Yes	-	-	Yes	Yes
Egyptair Maintenance & Engineering	Yes	Yes	Yes	Yes	Yes
Evergreen Aviation	Yes	Yes	Yes	Yes	Yes
GAMECO	Yes	Yes	Yes	Yes	Yes
GMF Aero Asia	Yes	Yes	Yes	Yes	Yes
HAECO	Yes	Yes	Yes	Yes	Yes
Iberia Maintenance	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik Philippines	Yes	Yes	Yes	Yes	Yes
LTU Technik	Yes	Yes	Yes	Yes	Yes
Malaysia Airlines	Yes	Yes	Yes	Yes	Yes
MASCO	Yes	Yes	Yes	Yes	Yes
Monarch Aircraft Engineering	Yes	Yes	Yes	Yes	Yes
Sabena Technics	Yes	Yes	Yes	Yes	Yes
Shanghai Technologies (STARCO)	Yes	Yes	Yes	Yes	Yes
SIA Engineering Company	Yes	Yes	Yes	Yes	Yes
SR Technics	Yes	Yes	Yes	Yes	Yes
ST Aviation Services	Yes	Yes	Yes	Yes	Yes
ST Mobile (MAE)	Yes	Yes	Yes	Yes	Yes
TAECO	Yes	Yes	Yes	Yes	Yes
TAP Maintenance & Engineering	Yes	Yes	Yes	Yes	Yes
Turkish Technic	Yes	Yes	Yes	Yes	Yes

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

	CF6-80E1	PW4100	Trent 700	Engine health monitor	Engine maint manage	On-wing engine maint	Engine shop visits	Parts repair schemes
Abu Dhabi Aircraft Technologies	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes
Air France Industries	-	-	-	Yes	Yes	Yes	-	-
Ameco Beijing	-	Yes	-	Yes	Yes	Yes	-	-
Eagle Services Asia	-	Yes	-	Yes	Yes	Yes	Yes	Yes
Evergreen Aviation	Yes	-	-	Yes	Yes	Yes	Yes	Yes
GA Telesis	-	-	-	Yes	Yes	-	-	-
GE Aviation Engine Services	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes
Jet Turbine Services	Yes	-	-	Yes	Yes	Yes	Yes	Yes
HAESL	-	-	Yes	Yes	Yes	Yes	Yes	Yes
IASG	-	-	-	Yes	Yes	-	-	-
Iberia Maintenance	-	-	-	Yes	Yes	Yes	-	-
KLM Engineering & Maintenance	Yes	-	-	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik Philippines	-	-	-	Yes	Yes	Yes	-	-
MTU Maintenance Hanover	Yes	-	-	Yes	Yes	Yes	Yes	Yes
Pratt & Whitney Eagle Services	-	Yes	-	Yes	Yes	Yes	Yes	Yes
Rolls-Royce Engine Services	-	-	Yes	Yes	Yes	Yes	Yes	Yes
SAESL	-	-	Yes	Yes	Yes	Yes	Yes	Yes
SR Technics	-	Yes	-	Yes	Yes	Yes	Yes	Yes
TAESL	-	-	Yes	Yes	Yes	Yes	Yes	Yes
Total Engine Support (UK)	-	-	-	Yes	Yes	-	-	-
Turkish Technic	Yes	-	-	Yes	Yes	Yes	Yes	-

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

	On-wing support	AOG services	Short-term leases	Med/long-term leases	Engine pooling
Abu Dhabi Aircraft Technologies	Yes	Yes	Yes	Yes	Yes
Air Canada Technical Services	Yes	Yes	-	-	-
Air France Industries	Yes	Yes	Yes	Yes	Yes
Ameco Beijing	Yes	-	-	-	-
Engine Lease Finance	-	-	Yes	Yes	Yes
GA Telesis	Yes	Yes	Yes	Yes	Yes
GE Engine Services	Yes	Yes	Yes	Yes	Yes
HAESL	Yes	Yes	-	-	-
Iberia Maintenance	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik Philippines	Yes	Yes	-	-	-
Pratt & Whitney Engine Services	Yes	Yes	Yes	Yes	Yes
Rolls-Royce	Yes	Yes	Yes	Yes	Yes
Snecma Services	Yes	Yes	Yes	Yes	Yes
SR Technics	Yes	Yes	Yes	Yes	Yes
TAP Maintenance & Engineering	Yes	Yes	Yes	Yes	Yes
Turkish Technic	Yes	Yes	Yes	Yes	-
Willis Lease	-	Yes	Yes	Yes	-

Airways and Dragonair.

Engine shops in the Asia-Pacific region include: AMECO Beijing (PW4000); Eagle Services Asia (PW4000); Evergreen Aviation (CF6-80E1); Jet Turbine Services, Australia (CF6-80E1); HAECO's associate 'HAESL' (Trent 700); Lufthansa Technik Philippines (CF6-80E1); and SIAEC's associate 'SAESL' (Trent 700).

Europe

The next largest geographical region for A330 overhaul is Europe with at least nine providers: Air France Industries; Austrian Technik; Iberia Maintenance; Lufthansa Technik; LTU Technik; Monarch 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), Monarch 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 Monarch. Meanwhile, the Dublin facility has contracts with Air Greenland, Corsairfly, SAS, and Air Europa. In addition, TAP M&E and LTU 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); MTU Maintenance Hannover (CF6-80E1); Rolls-Royce Engine Services (Trent 700); and SR Technics (PW4000).

A330-200/-300 ROTABLES & LOGISTICS

	Rotable inventory leasing	Rotable inventory pooling	Repair & doc manage	AOG support	PBH rotables support
Abu Dhabi Aircraft Technologies	-	-	Yes	Yes	-
Air France Industries	Yes	Yes	Yes	Yes	Yes
Airbus	Proprietary parts	-	-	Yes	-
AJ Walter	Yes	Yes	Yes	Yes	Yes
AvTrade	Yes	Yes	Yes	Yes	Yes
GA Telesis	Yes	Yes	Yes	Yes	Yes
Kellstrom	Yes	Yes	Yes	Yes	-
Iberia Maintenance	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik Philippines	Yes	Yes	-	Yes	Yes
Messier Services	Yes	Yes	Yes	Yes	Yes
Sabena Technics	Yes	Yes	Yes	Yes	Yes
SAS Component	Yes	Yes	Yes	Yes	Yes
SAS Technical Services	Yes	Yes	Yes	Yes	Yes
SR Technics	Yes	Yes	Yes	Yes	Yes
TAP Maintenance & Engineering	Yes	Yes	Yes	Yes	Yes
Triumph Group	Yes	Yes	Yes	Yes	Yes
Turkish Technic	-	-	-	Yes	Yes

A330-200/-300 HEAVY COMPONENT MAINTENANCE

	Wheels tyres & brakes	APU test & repair	Thrust reversers	Landing gear	Landing gear exchanges
Abu Dhabi Aircraft Technologies	Yes	Yes	Yes	-	-
Air Canada Technical Services	Yes	Yes	-	-	-
Air France Industries	Yes	Yes	Yes	Yes	Yes
Ameco Beijing	Yes	-	-	Yes	Yes
EPCOR APU	-	Yes	-	-	-
HAECO	Yes	Yes	Yes	Yes	Yes
Honeywell Aerospace	-	Yes	-	-	-
Iberia Maintenance	Yes	Yes	Yes	Yes	Yes
Lufthansa Technik	Yes	Yes	Yes	Yes	Yes
Messier Services	Yes	-	-	Yes	Yes
Revima APU	-	Yes	-	-	-
Sabena Technics	Yes	Yes	Yes	Yes	Yes
SAS Component	Yes	-	Yes	-	-
SR Technics	Yes	Yes	Yes	-	-
SIA Engineering Company	Yes	Yes	Yes	Yes	Yes
ST Aviation Services (SASCO)	Yes	Yes	Yes	Yes	Yes
TAP Maintenance & Engineering	Yes	-	Yes	-	-
Triumph Group	-	Yes	Yes	-	-
Turkish Technic	Yes	Yes	Yes	Yes	Yes

Middle East

In the Middle East there are four main players: Abu Dhabi Aircraft Technologies (ADAT), formerly GAMCO; EgyptAir M&E; MASCO; and Turkish Technic. ADAT overhauls aircraft from Etihad and a few from Corsairfly, while MASCO handles A330s from Middle-East Airlines (MEA), 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 MRO 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 (MAE). ACTS is, without doubt, the largest MRO 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, Ohio; P&W Cheshire CT; and Texas Aero 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 rotable 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 Material Operations' (TMO) provide a full spectrum of rotable inventory and logistical services for third-party operators.

Aside from the engine OEMs, 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 Messier Services for landing gear wheels and brakes, and Revima for APUs, which is the largest non-OEM provider of overhaul services. But the largest overhauler overall of the A330's GTCP331-350 APUs is the OEM, Honeywell. Honeywell has three strategically located facilities in Phoenix, AZ; Raunheim, 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 Raunheim and then Phoenix. AC

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A330-200/-300 aftermarket & values

The A330-200/-300 is one of the most popular widebody families. Market values and lease rates are some of the strongest as a consequence of the current shortage of aircraft.

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 with a total of 38 A330-300s in operation and on firm order, Dragonair (16), Thai Airways International (20), Qantas/Jetstar (18), Fly Asia Express (15), and Singapore Airlines (19). The A330-300 is also popular in the Middle East, with Qatar Airways (32) and Emirates (29). 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, so 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. AC

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The A330-200 and -300 have become popular medium- and long-haul workhorses, and demand for them is strong. Lease rates for young aircraft are in the $850,000-900,000 per month range, but few aircraft are coming available.