AIRCRAFT OWNER'S & OPERATOR'S GUIDE: A320 FAMILY

A320 family specifications

The A320 family has four main variants. Each has several gross weight and engine options to choose from, making many combinations possible.

The evolution of the A320 family has led to four main variants: the A318, A319, A320 and A321. These share a common fuselage design, with a standard six-abreast economy class configuration, and have different lengths that accommodate between 107 and 185 seats. The range of seat sizes is similar to that offered by the 737NG family, although the A321 has five more seats than the 737-900ER.

The fuselage is known for its passenger comfort, offering 1-inch wider seats than its 737/757 rivals. The A320 family's main features, however, are: its fly-by-wire (FBW) flight control system; a common flightdeck and single pilot type rating; and use of common engine types and rotable components in two or more of its variants. These features give a high level of commonality that provides reductions in flightcrew- and maintenance-related operating costs. The FBW flight-control system and common flightdeck not only allow the single type rating between the four variants, but also cross-crew qualification with other Airbus types that have FBW systems and the same or similar flightdecks.

These technical features and a wide range of seat capacities, which satisfy many airlines' requirements, make the A320 family an attractive choice.

A320

The A320 family's principal variant is the A320. Its cabin allows 150 seats in a two-class layout *(see table, page 7)* of 12 first-class and 138 economy seats. This can be increased to 164 seats in an all-economy layout at 31-inch seat pitch, or as many as 180 seats at 29-inch seat pitch.

The initial A320 model, the A320-100, has a fuel capacity of 4,185 US Gallons (USG) and maximum take-off weight (MTOW) of 145,504lbs. It is powered by CFM56-5A1 engines, rated at 25,000lbs thrust. Its combination of gross weight and fuel capacity give it a range of about 1,800nm with a load of 164 passengers.

This initial model was not ordered in large numbers, since most potential customers showed more interest in having a higher gross weight and fuel capacity. Only 19 -100 series aircraft with CFM56-5A1 engines were ordered by British Caledonian, Air Inter and Air France. Two have been destroyed, leaving just 17 in operation with British Airways and the Air France group.

A higher weight A320-200 model was also available from initial offerings to potential customers. This used the same CFM56-5A1 engine, but had a higher MTOW of 162,040lbs (73.5 tonnes) and fuel capacity of 6,300 USG. This weight variant has a range of 2,600nm *(see table, page 7)*.

Later developments with the CFM56 engine led to an aircraft powered by the CFM56-5A3 rated at 26,500lbs thrust and with an MTOW of 166,450lbs (75.5 tonnes), while sharing the same fuel capacity of 6,300 USG. This weight variant has an extended range of 2,850nm *(see table, page 7)*.

The CFM56-5A series could not be developed much further in additional thrust. Because this would prevent the -5A series being used on the stretched A321, the CFM56-5B series was developed to provide higher thrust growth potential. The CFM56-5B series' main difference over the -5A was an additional high- pressure compressor (HPC) stage. Both variants have a 68.3-inch wide intake fan and utilise a single-stage high-pressure turbine (HPT). The additional HPC stage allowed the CFM56-56B to be developed up to a rating of 33,000lbs thrust, thereby enabling the engine to be employed for a wider range of variants.

The CFM56-5B4, rated at 27,000lbs thrust, was first offered on the A320 in the mid-1990s. The -5B series was used to power the highest MTOW variant of the A320, which had a gross weight of 169,750lbs (77.0 tonnes). With the same standard fuel capacity of 6,300 USG, the aircraft had a range of 2,850nm.

The same weight variant is also available with supplementary fuel tanks, taking total capacity to 7,066 USG, and giving the aircraft a range of 3,050nm *(see table, page 7)*.

Airbus offers customers flexibility in the A320 family with several engine thrust variants of the two main engine types for each MTOW variant. The three MTOW variants of the A320 are 162,050lbs (73.5 tonnes), 166,450lbs (75.5 tonnes) and 169,750lbs (77.0 tonnes). Each can be powered by three variants of the CFM56-5B: the -5B4 rated at 27,000lbs thrust; the -5B5 rated at 22,000lbs thrust; and the -5B6 rated at 23,500lbs thrust *(see table, page 7)*.

There are five gross weight variants of the A320-200, and CFMI offers two variants of the CFM56-5A and three variants of the -5B series.

A320 FAMILY SPECIFICATIONS

A320	-100	-200	-200	-200	-200	-200
MTOW lbs	145,504	162,040	166,450	162,050	166,450	169,750
MTOW tonnes	66.0	73.5	75.5	73.5	75.5	77.0
Dual-class seats	150	150	150	150	150	150
Engine variants	CFM56-5A1	CFM56-5A1/ V.2500-A1	CFM56-5A3/ V.2500-A1 bump	CFM56-5B5/ V.2527-A5	CFM56-5B6/ V.2527-A5	CFM56-5B4/ V.2527-A5
Fuel volume USG	4,185	6,300	6,300	22,000	23,500	27,000
Range nm	1,800	2,600/ 2,600	2,850/ 2,870	2,600/ 2,600	2,850/ 2,870	2,850/ 2,870
Supplementary fuel volume USG						7,066
Range nm						3,050

A321	-200	-200	-200	-200
MTOW lbs	183,000	187,400	196,200	206,130
MTOW tonnes	83.0	85.0	89.0	93.5
Dual-class seats	185	185	185	185
Engine variants	CFM56-5B4/ V.2530-A5	CFM56-5B1/ V.2530-A5	CFM56-5B2/ V.2533-A5	CFM56-5B3/ V.2533-A5
Fuel volume USG	6,260	6,260	7,040	7,800
Range nm	2,200/ 2,200	2,340/ 2,370	2,670/ 2,700	3,000/ 3,000

A319	-200	-200	-200	-200
MTOW lbs	141,100	149,920	154,330	166,450
MTOW tonnes	64.0	68.0	70.0	75.5
Dual-class seats	124	124	124	124
Engine variants	CFM56-5A4/-5A5/ V.2522-A5	CFM56-5B5/ V.2522-A5	CFM56-5B6/ V.2524-A5	CFM56-5B7/ V.2527-A5
Fuel volume USG	6,300	6,300	6,300	6,300/7,070/7,830
Range nm	1,800	2,600	2,950	3,050/3,450/3,700

A318	-200	-200	-200	-200	-200	-200
MTOW lbs	130,070	135,580	138,890	142,200	145,500	149,900
MTOW tonnes	59.0	61.5	63.0	64.5	66.0	68.0
Dual-class seats	106	106	106	106	106	106
Engine variants	CFM56-5B8 PW6122	CFM56-5B8 PW6122	CFM56-5B8 PW6122	CFM56-5B9 PW6124	CFM56-5B9 PW6124	CFM56-5B9 PW6124
Fuel volume USG	6,300	6,300	6,300	6,300	6,300	6,300
Range nm	1,450/ 1,400	1,950/ 1,850	2,200/ 2,150	2,500/ 2,450	2,800/ 2,700	3,200/ 3,100

In most cases airlines select a high gross weight and high-thrust airframe-engine combination, with high-rated engines providing better field performance but higher fuel burn *(see A320 family fuel burn performance, page 16)*. Airlines may select a lower-rated engine for high gross weight aircraft, however.

Other developments of the -5B4 employed a dual annular combustor (DAC) to reduce NOx emissions.

Alongside the CFM56, International Aero Engines (IAE) developed the V.2500-A1 for use on the first models of the A320-200 in 1988, which were rated at 25,000lbs thrust. No -100s were equipped with the V.2500-A1.

The first V.2500-powered A320-200 had the same MTOW of 162,040lbs (73.5 tonnes) and fuel capacity of 6,300 USG, as the CFM56-5A1-powered aircraft. This gave it a range of 2,600nm *(see table, this page)*.

The V.2500-A1 was developed with a thrust bump, which gave the engine a rating of 26,500lbs thrust for take-off in hot and high conditions. This engine was used to power aircraft with an MTOW of 166,450lbs (75.5 tonnes), a fuel capacity of 6,300 USG and range of 2,870nm *(see table, this page)*.

Like the CFM56, the V.2500 had to be adapted to provide enough power for larger developments of the aircraft. The V2500-A5 series was therefore evolved, its key differences over the -A1 series being an increase in fan width from 63 to 63.5 inches, and a higher coreflow allowing higher thrust ratings. There are five -A5 series variants rated at between 23,000lbs and 32,000lbs thrust.

The V.2527-A5 was developed for the A320-200, rated at 26,500lbs thrust. This is used to power the three gross models of the A320, the highest of which is 169,750lbs (77.0 tonnes), and has a range of 2,870nm with the standard fuel capacity of 6,300USG. With supplementary fuel tanks and a total capacity of 7,066 USG, the aircraft's range is extended to 3,050nm.

A321

The A321 was the second variant to be developed, following large sales of the similarly-sized 757 in the 1980s. The A321 has a standard two-class seat capacity of 185, about 10 seats fewer than the 757-200 when the two aircraft are similarly configured.

The first orders for the aircraft were

IAE offers just one or two thrust variants of the V.2500-A5 for each member of the A320 family.

placed in 1989. Like the A320, the initial A321 models were light and had a short-range capability.

There are five MTOW variants of the A321: 183,000lbs (83.0 tonnes); 187,400lbs (85 tonnes); 196,200lbs (89.0 tonnes); 205,000lbs (93.0 tonnes); and 206,130lbs (93.5 tonnes).

These are all available with the standard fuel capacity of 6,260 USG, but there are also two options for supplementary fuel tanks that take total capacity to 7,040 USG and 7,800 USG.

As with the A320, there are several engine thrust variants available for the CFM56-5B and V.2500-A5: the CFM56-5B4 rated at 27,000lbs thrust); -5B1 rated at 30,000lbs thrust; -5B2 rated at 31,000lbs thrust; and the -5B3 rated at 33,000lbs thrust. Each is available for all the five different gross weight variants.

When equipped with CFM56-5B engines, the 83.0 tonne and 85.0 tonne variants have a range of 2,200nm and 2,340nm with a standard fuel capacity of 6,260 USG *(see table, page 7)*. The 89.0 tonne gross weight aircraft has a range of 2,670nm, and the 93.5 tonne gross weight aircraft has a range of 3,000nm *(see table, page 7)*.

Only 18 aircraft are equipped with CFM56-5B1 engines; these are operated by Air France, Swiss and Austrian Airlines. Another 14 have CFM56-5B2 engines and are in operation with Alitalia, an early customer for the A321.

More than 170 aircraft with -5B3 engines have been ordered to date.

There are two variants of the V.2500-A5 available for the A321: the V.2530-A5 rated at 30,400lbs thrust; and the V.2533-A5 rated at 33,000lbs thrust.

When equipped with V.2500-A5 engines, aircraft with a gross weight of 83.0 tonnes and 85.0 tonnes and standard fuel capacity of 6,260 USG have a range of 2,200nm and 2,370nm. Aircraft with a gross weight of 89.0 tonnes and fuel capacity of 2,700nm, or with a gross weight of 93.5 tonnes and fuel capacity of 7,800 USG, have a range of 3,000nm.

A319

The A319 was shortened and accommodates 124 seats in a two-class configuration. It has four gross weight options of 141,100lbs (64.0 tonnes), 149,920lbs (68.0 tonnes), 154,330lbs (70.0 tonnes) and 166,450lbs (75.5 tonnes). The aircraft has a standard fuel capacity of 6,300 USG, while the highest gross weight variant also has two supplementary fuel tank options that take fuel capacity to 7,070 USG and 7,830 USG *(see table, page 7)*.

The aircraft utilises both CFM56-5A and -5B engines. The -5A series engines are the -5A4 and -5A5 rated at 22,000lbs thrust and 23,500lbs thrust.

The -5B5 variants are the -5B5,-5B6 and -5B7 rated at 22,000lbs thrust, 23,500lbs thrust and 27,000lbs thrust. This makes it possible for airlines to select a large number of airframe-engine combinations. The most popular engines on the A319 are the -5A5, -5B5 and -5B6, powering more than 530 aircraft.

When equipped with CFM56-5B engines, the four different gross weight models with a fuel capacity of 6,300 USG have a range of 1,800nm, 2,600nm, 2,950nm and 3,050nm. The higher gross weight variant has an extended range of 3,450nm with a supplementary fuel capacity of 7,070 USG and range of 3,700nm with a fuel capacity of 7,830 USG *(see table, page 7)*.

There are three variants of the V.2500-A5: the V.2522-A5 rated at 22,000lbs; the V.2524-A5 rated at 23,500lbs; and the V.2527-A5 rated at 26,500lbs.

More than 110 A319s powered by the V.2522-A5 have been built and are in service with Air China, British Airways, South African Airways and United Airlines.

More than 120 aircraft with the V.2524-A4 engine have been delivered to Air Macau, America West, Lan Airlines, Spirit Airlines, TACA and TAM.

Only a small number are powered by the V.2527-A5.

The different weight and fuel-capacity variants of the A319 have the same range when equipped with V.2500-A5 engines as those equipped with CFM56-5B series engines.

A318

The A318 was developed as a further shortening of the fuselage, taking two-class seat capacity down to 107 seats. This is similar to the 737-600. The aircraft has five gross weight options of 130,070lbs (59.0 tonnes), 135,580lbs (61.5 tonnes), 138,890lbs (63.0 tonnes), 142,200lbs (64.5 tonnes), 145,500lbs (66.0 tonnes) and 149,900lbs (68.0 tonnes). The aircraft uses the standard fuel capacity of 6,300 USG *(see table, page 7)*.

The A318 utilises the CFM56-5B series and PW6000 series. In the case of the CFM56-5B, the variants available are the -5B8 and -5B9 rated at 21,600lbs thrust and 23,300lbs thrust. These are simply de-rated versions of the same basic -5B engine that powers the A319, A320 and A321.

The PW6000 was developed as an all-new engine with two variants available: the PW6122 rated at 22,100lbs thrust, and the PW6124 rated at 23,800lbs thrust.

When equipped with CFM56-5B engines, the A318 at its lowest gross weight option of 59.0 tonnes has a range of 1,450nm, while the highest gross weight option of 68.0 tonnes has a range of 3,200nm.

Range is slightly reduced for aircraft equipped with PW6000 engines, at 1,400nm for the lowest gross weight aircraft and 3,100nm for the highest gross weight model.

A320 family fleet analysis

The A320 family fleet is dominated by the A320 and A319, which account for 85% of all aircraft sold. The fleet is split 50:50 by CFMI & IAE.

The A320 family is the single most successful commercial jetliner. Orders for the four variants had reached 4,283 by the end of 2005 since the first order was placed in 1983. The 737NG is closest to this, with 2,967 orders since 1992.

The A320's success can partly be attributed to its fly-by-wire (FBW) flight control system, wide seats and cabin comfort, operating efficiency, family concept and commonality, and four models that offer between 107 and 185 seats. The A320 family replaced a large number of BAC 1-11s, Caravelles, F.28s and Tu-134s/-154s, but also managed to win large orders from long-time Boeing and McDonnell Douglas customers.

More than 2,600 aircraft have already been delivered, and the current backlog exceeds 1,650 units. The A320 family's most successful year was 2005, when 918 orders were won. To keep up with demand, Airbus has had to increase its production level several times, and is now increasing it to 32 units per month, equal to 384 per year. This is in contrast to annual production rates of 60 to 200 aircraft up to the end of the 1990s.

The A320 family market is divided between those powered by CFM56-5A or -5B engines and V.2500-A1 or -A5 engines. A third engine, the PW6000 series, is the alternative to the CFM56 on the A318.

The CFM56 powered the first aircraft, and was already established on the 737 and DC-8. These factors helped it win the majority of orders, although its share has declined in recent years. The CFM56 has been chosen to power 2,111 of the A320 family aircraft ordered so far. The V.2500 has been selected for 1,725 aircraft, and the PW6000 for 30. Engine selections are outstanding for about 380 aircraft ordered in late 2005.

A320

The A320 was the first aircraft to be launched, with Air France signing a letter of intent for 25 aircraft in 1981. It is the most successful variant with a total of 2,428 firm orders at the end of 2005 *(see table, page 10)*. The A320 actually achieved its highest annual sales in 2005, with 568 firm orders. The A320 is itself one of the most successful aircraft types. Its firm orders to date exceed those of the 727-100/-200, 737-300/-400/-500 and 737-800. Moreover, the A320 will probably continue to sell well for another eight to 10 years before a successor is launched.

The A320's largest customers include Air Asia (60), Air Berlin (60), Air Canada (52), Air Deccan (62), Air France (67), America West (57), CASC (100), China Eastern (63), Iberia (66), IndiGo (70), jetBlue (173), Northwest Airlines (80), TACA (45), TAM (41), and United Airlines (117). The aircraft is also popular with lessors: AERCAP (ex-Debis AirFinance) has ordered a total of 61; and other large portfolios are held by CIT Leasing (53), GECAS/GPA (158) and ILFC (198).

The A320 market is split almost equally between the CFM56 and V.2500.

Of the 1,152 aircraft ordered with CFM56s, 386 are powered by CFM56-5A1 and -5A3 engines *(see A320 family specifications, page 6)* and the other 766 aircraft by the CFM56-5B4 *(see table, page 10)*.

The major operators of -5A1-powered aircraft are Air Canada (45), Air France (55), All Nippon Airways (38), Iberia (22), Lufthansa (36) and Northwest (33). The largest -5A3 fleets are operated by Condor Berlin (12), Gulf Air (10) and Northwest (45).

More than 310 -5B4-powered A320s are operated by a large number of carriers that include Aer Lingus, Air Berlin, Air Canada, Air China, Air France, Alitalia, Austrian Airlines, Finnair, Philippine Airlines, Swiss, TAP and USAirways. The largest fleets are operated by China Eastern (54) and Iberia (37).

A further 380 -5B4-powered aircraft are on order from IndiGo Aviation (70), Air One (30), Air Berlin (57), Air Asia (57) and GECAS (32). Other outstanding orders have been placed by Air Cairo, Cebu Pacific Air, China Southern, CSA Czech Airlines, Iberia, ILFC, Jazeera Airways, USAirways and Virgin America.

The V.2500 has been chosen for 1,071 A320s to date, split between the V.2500-A1 for 139 aircraft and the V.2527-A5 for 932.

Major -A1 operators include America West (24), Indian Airlines (47) and Mexicana (32). The largest V.2527-A5 fleets are with America West (38), British Airways (17), China Southern (24), jetBlue (82), Jetstar (20), TAM (28) and United (97). Other operators include Dragonair, British Midland Airways, Air New Zealand, Air Deccan, Kingfisher,

The V.2527-A5 has gained share of the A320 market in recent years, and the V.2530/33-A5 now have a larger share of the A321 market than their CFM56-5B series rivals.

A320 FAMILY SALES & ENGINE SELECTION AT DECEMBER 2005

Aircraft type	A318	A319	A320	A321	Total
Engine type					
CFM56-5B8/P	59				59
CFM56-5B7/P		31			31
CFM56-5B6/P		164			164
CFM56-5B6/2		3			3
CFM56-5B6/2P		32			32
CFM56-5B5/P		295			295
CFM56-5B4/2P			28		28
CFM56-5B4/2			26		26
CFM56-5B4/P			560		560
CFM56-5B4			22		22
CFM56-5B3/2P				20	20
CFM56-5B3/P				137	137
CFM56-5B3				10	10
CFM56-5B2/P				9	9
CFM56-5B2				14	14
CFM56-5B1/2P				5	5
CFM56-5B1/2				6	6
CFM56-5B1/P				2	2
CFM56-5B1				5	5
CFM56-5A5		138			138
CFM56-5A4		9			9
CFM56-5A3			114		114
CFM56-5A1			272		272
Recent orders		28	130	30	188
Total CFM56	**59**	**692**	**1,122**	**238**	**2,111**
V.2533-A5				175	175
V.2530-A5				54	54
V.2527M-A5		6			6
V.2527E-A5			78		78
V.2527-A5			744		744
V.2524-A5		225			225
V.2522-A5		148			148
V.2500-A1			139		139
Recent orders		16	110	30	156
Total V.2500	**0**	**395**	**1,071**	**259**	**1,725**
PW6124	30				30
Undecided	8	144	205	22	379
Total	**97**	**1,239**	**2,428**	**519**	**4,283**

Qatar Airways, Sichuan Airlines, Spanair, Syrianair and Tiger Airways.

The V.2527E-A5 has been specified by a small number of carriers, including Lan Airlines, TACA and TAME Ecuador.

More than 400 A320s, with V.2527-A5s specified, have been ordered by Air Deccan (30), jetBlue (97), Kingfisher (37), South African Airways (15), TAM (20), THY (17) and United Airlines (19). Other smaller fleets are on order for Asiana, British Airways, Mexicana, Qantas, Sichuan Airlines, Silkair, Tiger Airways and Wizz Air.

A321

The A321 was the second aircraft in the family to be launched, and has won 519 firm orders since winning its first firm sale from ILFC and Egyptair in 1989. More than 100 firm orders were won in 2005. The A321's biggest customers are Air France (13), Alitalia (23), Asiana Airlines (13), CASC (30), China Eastern (15), Iberia (19), IndiGo (30), ILFC (80), Lufthansa (26) and USAirways (41).

Like the A320, the A321 market is split between the CFM56 and V.2500, with the V.2500 being selected for 259 aircraft and the CFM56 powering 238. Engines have yet to be selected for 22 aircraft on order.

There are 54 A321s in service with V.2530-A5 engines, operated by Air Macau, ANA, Asiana, Lufthansa, Onur Air, SAS and TransAsia. Another 115 aircraft are in operation with V.2533-A5 engines. Operators include Asiana, BA, British Midland Airways, China Southern, and Lufthansa.

There are 171 A321s in operation with CFM56-5Bs, and 18 aircraft with -5B1s, which are operated by Air France, Austrian Airlines, Swiss and THY. Alitalia operates 23 -5B2-powered aircraft. There are 130 -5B3-powered aircraft in service with Air Canada, Air France, China Eastern, Iberia, US Airways, and Finnair.

A further 179 A321s are on order, including 67 powered by the CFM56-5B for China Eastern, Iberia, IndiGo Aviation, and USAirways. V.2533-A5s have been selected for another 90 aircraft on order with Kingfisher, TACA, TAM and THY. Engines have not yet been selected for 22 other aircraft on order with AerCap and ILFC.

A319

The A319 is the second most successful variant, with firm orders for 1,239 since its launch order in late 1992. This sales volume compares to 1,260 and 1,113 achieved by the 727-200 and 737-300, as well as 1,173 sold to date by the similarly-sized 737-700.

The A319's largest orders have been placed by AERCAP (35), Air Canada (48), Air France (44), America West (38), British Airways (36), CIT Leasing (37), easyJet (140), Frontier (42), GECAS (75), ILFC (150), Lufthansa (20), Northwest Airlines (82), TAM (18), United Airlines (78), and USAirways (66).

The CFM56 has been selected for 700 aircraft and the V.2500 for 395.

While CFMI offers several variants of the CFM56-5A and -5B across the A320 family, a few engines dominate each family member. The -5B5 and -5B6 dominate the A319 fleet, the -5B4 and -5A1 dominate the A320 fleet, and the -5B3 dominates the A321 fleet.

The CFM56 is divided between the -5A4/-5A5 models and the -5B5, -5B6 and -5B7 variants.

Only nine aircraft are operated by Air France with the -5A4, while 131 are in service with the -5A5. The largest fleets are with Air Canada (35), Lufthansa (16) and Northwest (73). German Wings and Tunis Air also operate smaller fleets.

The -5B5 is in operation with 161 aircraft for: Air France (31), easyJet (58), Frontier (32), TAP Air Portugal (16), and other smaller fleets operated by Air China and Iberia.

The -5B6 powers 188 aircraft in service, with the largest fleets being operated by Air Canada (13), Alitalia (12), China Eastern (10), Frontier (10), German Wings (15), Mexicana (12) and USAirways (47). Other smaller fleets are operated by Austrian Airlines, China Southern, Croatian Airlines, Swiss and SN Brussels.

A smaller fleet of 21 aircraft are in service with the -5B7, mainly for Air China and Air France.

A total of 492 A319s are on order. The CFM56 has been selected for 190 of these, with the -5B5 being chosen for 134 aircraft. Customers include easyJet (80), Frontier (11), GECAS (27), Iberia (7) and ILFC (6). The -5B6 has been selected for 11 aircraft for Shenzen and CSA Czech, while the -5B7 has been chosen for 10 aircraft. Northwest has ordered five -5A5-powered A319s.

The V.2522/24-A5 has been chosen for 158 aircraft on order. The V.2522-A5 has 36 orders, including 23 aircraft for United. The V.2524-A5 has 113 orders, including America West, Kingfisher, German Wings, TAM, LAN Airlines, Spirit Airlines and Volaris.

Engine selections have yet to be made for 144 A319s on order. These include aircraft for CASC and AerCap.

A318

The smallest variant, the 107-seat A318, has won 97 firm orders since receiving its first order in 1999. Although its sales performance is disappointing compared to that of the other three variants, it nevertheless exceeds that of its closest competitor, the 737-600.

The A318's customers include 60 CFM56-5B8-powered aircraft for: Air France (18), Comlux Aviation (3) Frontier (5), Iberia (10), ILFC (10) Mexicana (10), and Tarom (4).

Another 30 PW6124-powered aircraft have been ordered by America West (15) and LAN Airlines (15).

National Air Service has yet to select engines for the five aircraft it has ordered.

Common fleets

The main appeal of the A320 is the family concept, which allows a single type rating for all four variants, the common use of components, and the possibility to share the same engine between two, three or four variants.

The A320 family is operated by more than 180 different airlines, the majority of which take advantage of the family concept and operate two or three variants. The main benefits of the A320 family's commonality features are the cross-crew qualification (CCQ) and single type rating allowed by its FBW flight control system, and possible use of a common engine between two, three or even all four types. Use of the common engine across all four types is only possible with the CFM56-5B series engine. The V.2500-A5 can be used across the A319/320/321, while the CFM56-5A is restricted to the A319 and A320.

Common engine use gives airlines the ability to operate the engine initially at a high thrust rating on the A321 or A320. The engine is then de-rated when most of its exhaust gas temperature (EGT) margin is used. This process gives the engine more EGT margin, which can be used while operating on-wing with a smaller type, either the A320 or A319. Overall, this process extends the total time on-wing between shop visits. A common engine type also contributes to lower costs related to engine inventory.

Many large operators have taken advantage of these commonality benefits by ordering two or more A320 family variants, and selecting a common engine type for them.

Airlines operating aircraft with -5A1 and -5A3 engines include Air Canada, Air France, German Wings, Northwest Airlines, and Tunis Air.

Air France and Iberia use the CFM56-5B across all four variants. Airlines that use the -5B series across two or three variants include Aer Lingus, Aeroflot, Air Canada, Air China, Alitalia, Austrian Airlines, China Eastern, CSA Czech, Finnair, Swiss, TAP and USAirways.

The V.2500-A1 only powers lower gross weight variants of the A320-200, but the V.2500-A5 is used on two or three family variants by several airlines. Airlines that have the A319, A320 and A321 include British Airways, British Midland, China Southern, Sichuan Airlines and TACA. Airlines with two family variants include Air Macau, America West, Dragonair, Kingfisher, Qatar Airways, Spirit Airlines, South African Airways, United Airlines and Wizz Air.

A320 family modification programmes

The A320 is compliant with recent mandatory avionic modifications. There are, however, modification and upgrade packages for the CFM56-5B and V.2500-A5 series engines, designed to improve operating performance and reduce maintenance costs.

Modification and upgrade programmes available for the A320 family fall into three categories: engine upgrades; avionics; and future passenger-to-freighter conversions.

Engine upgrades

CFM56-5A and -5B

The CFM56-5A was the first engine to power the A320 into service and to be certified for extended twin-engine operations (Etops) on the aircraft. A derivative of the ubiquitous CFM56-3 engine for the classic 737 family, the CFM56-5A and -5B series has gone through a number of thrust upgrades and performance improvements.

CFM claims there are currently no mandatory modifications against the engine, either the -5A1/A2 or the higher rated -5B4, which power the A320.

There are three main differences between the -5A and -5B engines: the addition of a fourth booster stage in the low-pressure compressor (LPC) of the -5B; the incorporation of the -5C core technology from the A340 engine; and an optional double annular combustor (DAC). There are nine main thrust ratings of -5B:

Variant	Thrust lbs
CFM56-5B1/P	30,000
CFM56-5B2/P	31,000
CFM56-5B3/P	32,000
CFM56-5B4/P	27,000
CFM56-5B5/P	22,000
CFM56-5B6/P	23,500
CFM56-5B7/P	27,000
CFM56-5B8/P	21,600
CFM56-5B9/P	23,300

In 2004, CFM launched a single major modification package for the -5B that encompassed major changes in the compressor section, and also some enhancements in the combustor and turbine. These were aimed at improved fuel burn, increased durability and an improvement in exhaust gas temperature (EGT) margin.

CFM has just completed the Tech Insertion package, an extensive 63-hour flight test programme, and announced its availability.

The Tech Insertion programme incorporates technologies developed and validated as part of Project TECH56, and includes improvements to the HPC, the combustor, and the high- and low-pressure turbines (HPT and LPT). The package will provide operators with longer time on-wing, 5% lower maintenance costs, 15-20% lower oxides of nitrogen (NOx) emissions, and better fuel burn. The price for kits at this stage is undisclosed, but they will be available from 2007.

The modification can be incorporated at a normal shop visit for engine overhaul. From 2007, the Tech Insertion specification will become the production build standard for the -5B. It will also become the technology standard for the -7B engine on the 737-NG. The last major engine enhancement for the -5B was in 1996 with the introduction of the -5B/P standard, replacing the original build standard from 1994.

V.2500

International Aero Engines (IAE) offers the V2500-A5 engine on the A320 family. Two models power the A320 and A321, although the -A1 series is no longer manufactured.

There are several mandatory modifications on the engine -A5 at the moment.

Airworthiness directive (AD) number 99-13-01 mandates a borescope inspection for evidence of oil or heat damage in the HPT hardware. This AD is applicable to early engines only.

AD 2004-12-08 adds (HPT) 1st and 2nd disks to the Federal Aviation Administration (FAA) enhanced inspection at piece part opportunity, and is part of an FAA life limited part (LLP) evaluation programme being conducted across the industry, with contributions from each manufacturer.

AD CN U2003-355(B) R1 mandates a fuel-cooled oil cooler (FCOC) Inspection within every 500 hours.

AD 2003-10-14 requires shutting off the engine bleed following an oil filter clog message during flight, to prevent possible number-3-bearing failure. The fix is incorporated in production engines.

AD 2003-11-23 requires inspection of the magnetic chip detector (MCD) within 125 hours of service, and repetitive inspection every 125 hours on a group of engines that have a particular number-3-bearing part number. The fix is incorporated in production engines.

IAE has introduced a major modification enhancement package. Called V.2500Select, it is in response to market demands and can be tailored for individual customers. It offers up to 1% fuel burn improvement and a 20-30% reduction in maintenance costs. It will be available from mid-2008 as a retrofittable modification package that can be incorporated at an engine shop visit. The modification involves a number of hardware and engine control unit (ECU) software changes.

Avionics

There are a number of avionic modifications available on the A320 family that operators and owners need to consider.

Airbus has decided to embark on a fleet-wide retrofit of the previous flight warning computer (FWC) to the more recent H2-F2 standard. This is available free of charge.

Autoland is prohibited at some airports if air data inertial reference units (ADIRU) installed on aircraft have obsolete magnetic variation tables, and Airbus offers a free retrofit with a new magnetic variation table for the ADIRU.

Airbus has decided to certify the enhanced ground proximity warning system (EGPWS) with a direct link to global positioning system (GPS) to avoid false warning caused by FM position shift. This modification is offered free of charge to airlines.

Airbus is offering a new electronic

IAE has launched a modification enhancement package for the V.2500 termed V.2500Select. This involves a retrofittable upgrade package which results in up to a 1% reduction in fuel burn and a 20-30% reduction in maintenance costs.

instrument system (EIS) based on liquid crystal display (LCD) technology.

Mandatory modifications

There are a number of structural and systems modifications and ADs.

In ATA chapter 53, which relates to the fuselage, there are two engineering changes.

First, cracks were detected around the rivets of the keel beam side panels below the centre wing box due to fatigue. A mandatory inspection CN 2003-146 was introduced for this area.

Second, in the main landing gear (MLG) area, the MLG door actuator fitting installed on the keel beam and the related upper strap were found to have cracked on some aircraft, due to fatigue. Two ADs were introduced, CN 2004-189 and LTA 2001-120 rev.01.

In ATA chapter 55, which relates to the stabiliser, there are two modifications addressing water ingress. This was detected in the honeycomb panels of A320 elevators, due to cracked honeycomb core. These are CN 2001-062 and LTA 2001-197.

Chapter 57, which relates to wings, includes five modifications. Starting with hydraulic lines, a finding due to modification EO118653 identified chafing marks on both engine suction lines during the second structural check, caused by wrongly-installed struts. This resulted in inspection EO 136097.

Lufthansa has also detected corrosion in the holes and in the flanges of the gear attachment rib 5 on several aircraft. Modification EO125264 has been introduced to address the corrosion.

Chrome flaking of the flap track aft spigot has been detected. Modification EO 116560 has been introduced.

Again in the flap area, loosened and damaged cushion seals have been detected, due to damaged inserts, loose and missing bolts and elongated holes. This is addressed by inspection EO 143870.

Finally, corrosion has been detected on the lower wing skin inside the dry bay, resulting in inspection EO 131951.

There are three main modifications in the systems areas.

First, there is a major AD that addresses cracking in the MLG shock absorber sliding tube. A linear crack of about six inches in length was discovered at the intersection of the cylinder and the axle by Lufthansa Technik during a routine visual check of the right-hand MLG. Laboratory investigations performed by Messier-Dowty have revealed that the cause of the crack was the presence of non-metallic inclusions in the shock-absorber sliding tube base metal. This led to AD CN 2004-022 and AOT A320-32A1273 (5 February 2004).

The second modification addresses in-board flap trunnion wear, which currently only affects seven airlines, one of which is Lufthansa. There is a slot in the belly fairing of the A320 family due to the movement of the in-board flap trunnion during normal flight. This slot is closed in flight by the so-called belly fairing sliding panel, which is connected to the trunnion by a hook. To avoid wear damages, the trunnion is protected by clamp-type steel rubbing pads, which were introduced by SB A320-27-1117 that terminated SB A320-27-1108/CN 1996-271-092.

Finally, an inspection regime has been introduced to combat the cracking of ram air turbine (RAT) carbon blades. Currently this only affects Lufthansa aircraft. Three chord-wise cracks were found on the aft side of the carbon blade. The affected RAT-type was developed by Hamilton Sundstrand for A319 and A321 aircraft and later also became a substitute for the Dowty RAT which was installed on A320 under serial number MSN 1000. For this purpose the A320 RAT box had to be extended in the forward belly fairing. AD CN: F-2005-212 addresses the issue.

Future freighter conversions

While the current fleet of A320s is still far too young to have any candidates for freighter conversion, the aircraft is an ideal fit between the 737- and 757-sized market. Although it will be several years before freighter programmes will become viable, EADS-EFW has ensured that it is well prepared. Jürgen Habermann, vice president sales & customer support for EADS-EFW in Dresden outlines the engineering and preparatory work. "There will definitely be a conversion programme for the aircraft, entering service about 2010 or 2011. The aircraft still retain high residual values and it will take four or five years before the older aircraft in the fleet become good candidates. To launch a freighter conversion programme you need two things: enough customers who want the aircraft; and a large enough supply of economically attractive airframes. We have conducted an initial feasibility study, looking at an outline cost of conversion and at the engineering aspects to ensure it will work. The detailed engineering work will begin in 2008. We have to obviously install a side door and blank other passenger doors, remove the interior, strengthen the floor, install smoke detection systems and change the flight deck and associated systems for freighter mode. In all we expect the conversion to cost $3.5-4.0 million."

As with other aircraft types, undoubtedly there will be a choice of other third-party conversions made available if market demand is strong enough. Gross weight enhancements and engine modifications may also be required to ensure that payload range meets market needs.

A320 family fuel burn performance

The fuel burn performance of the most numerous of the airframe-engine combinations in the A320 family variants are analysed.

The A320 family has a large number of airframe-engine combinations. This is because each family member has several maximum take-off weight (MTOW) variants, as well two or three fuel capacity options. The A321, for example, has up to five different MTOW variants. Airbus also offers between two and four variants of the CFM56-5B and V.2500-A5 for each family member, which means that there can be more than 20 airframe-engine combinations for each family member.

The fleet, however, is dominated by several engine types *(see table, page 17)*. The CFM56-5B and V.2500-A5 series both use the same basic engine and hardware and have up to eight different thrust ratings. These are controlled by the engine's full authority digital engine control (FADEC) system, which allows thrust ratings to be easily changed. Each thrust rating has a different list price, and upgrades to a higher rating incur a cost.

Airbus offers the CFM56-5B8 and -5B9 rated at 21,600lbs and 23,300lbs on the A318 *(see A320 family specifications, page 6)*. It similarly offers the -5B5, -5B6 and-5B7 on the A319. These three variants are rated at 22,000lbs, 23,500lbs and 27,000lbs. The -5A1, -5A3 and -5B4 are available on the A320 at between 25,000lbs and 27,000lbs thrust, and the -5B4, -5B1, -5B2 and -5B3 are available on the A321 rated between 27,000lbs, 30,000lbs and 33,000lbs thrust.

A similar scenario exists with the V.2500 on the A319, A320 and A321. The V.2522-A5 and V.2524-A5 rated at 22,000lbs and 23,500lbs are offered on the A319. Only the V.2527-A5 rated at 26,500lbs thrust is available on the A320's three MTOW variants. The V.2530-A5 and V.2533-A5 rated at 31,000lbs and 33,000lbs are available for the A321's five different MTOW options.

While airlines may usually combine a high-rated engine with a high-MTOW airframe variant, there is still the option of using a lower-rated engine for an aircraft with one of the higher MTOWs. Engine and thrust rating influence field and operating performance, while MTOW and fuel capacity affect range. A higher-rated engine will offer better field performance, but have higher fuel burn.

Fuel burn performance

The differences in fuel burn between the different engine types powering the same MTOW variant of a family member have been examined. Only a few examples of the A319, A320 and A321 have been studied, but these demonstrate the differences in fuel burn of some of the V.2500-A5, CFM56-5A and CFM56-5B series variants on each model.

The present study has been conducted on a typical European route representative of many operated by these aircraft: London Heathrow-Munich. To illustrate the effects of wind strength and direction the aircraft have been analysed for operations in both directions.

The tracked distance for this sector is 536nm. The flight performance and plans for each aircraft have been calculated using historical winds and temperatures for January, with 85% reliability for winds and 50% reliability for temperatures. The flightplans for all aircraft have been examined with the aircraft cruising at a speed of Mach 0.80. In all cases, the aircraft have been studied with payloads of a full two-class passenger layout. The A319 has been analysed with 124 passengers, the A320 with 150, and the A321 with 185. The standard weight for each passenger has been taken as 220lbs. The payload for the A319 is therefore 27,280lbs, for the A320 33,000lbs and for the A321 40,700lbs *(see table, page 17)*.

The aircraft experience a small headwind of only 2 knots flying south from London to Munich, so the equivalent still air distance is almost equal to the tracked distance, and the flight time is 78-80 minutes.

The aircraft experience a 60-knot headwind flying north from Munich to London, which increases the tracked distance from 549nm to 628nm *(see table, page 17)*. This subsequently increases flight time to 90-92 minutes.

Two A319 variants with an MTOW of 154,330lbs (70 tonnes) and 166,450lbs (75.5 tonnes) have been studied with four different engine types: the V.2524-A5, the CFM56-5B5 *(see table, page 17)*. The two MTOW variants have the same fuel capacity of 6,300 US Gallons (USG).

The first point from the analysis on the A319 is that aircraft powered by the V.2524-A5 burn less fuel than their CFM56-powered counterparts. In the case of the A319, with an MTOW of 154,300lbs (70 tonnes), flying from London to Munich, the CFM56-5A5 is the least fuel-efficient, burning 2.4% more fuel than the V.2500-powered aircraft. Aircraft powered by the CFM56-

In most cases, the V.2500 is more fuel efficient than the CFM56-5A/-5B in the order of 0.5-5%.

FUEL BURN PERFORMANCE OF A319, A320 & A321

City-pair	Aircraft variant	MTOW lbs	Engine model	Fuel USG	Flight time	Passenger payload	Fuel USG per passenger	ESAD nm	Wind speed factor
London-Munich	A319	154,330	V.2524-A5	1,030	1:18	124	8.31	536	-2
	A319	154,330	CFM56-5B5	1,037	1:18	124	8.36	536	-2
	A319	154,330	CFM56-5B6	1,048	1:19	124	8.45	536	-2
	A319	154,330	CFM56-5A5	1,055	1:16	124	8.51	536	-2
	A319	166,450	V.2524-A5	1,030	1:18	124	8.31	536	-2
	A319	166,450	CFM56-5B5	1,037	1:18	124	8.36	536	-2
	A319	166,450	CFM56-5B6	1,048	1:19	124	8.45	536	-2
	A319	166,450	CFM56-5A5	1,055	1:16	124	8.51	536	-2
	A320	166,450	V.2500-A1	1,027	1:19	150	6.85	536	-2
	A320	166,450	CFM56-5A1	1,031	1:17	150	6.87	536	-2
	A320	166,450	CFM56-5B4	1,144	1:20	150	7.63	536	-2
	A320	169,800	V.2527-A5	1,078	1:20	150	7.19	536	-2
	A320	169,800	CFM56-5A3	1,094	1:19	150	7.29	536	-2
	A320	169,800	CFM56-5B4	1,144	1:20	150	7.63	536	-2
	A321	196,200	V.2530-A5	1,297	1:19	185	7.01	536	-2
	A321	196,200	CFM56-5B2	1,256	1:19	185	6.79	536	-2
Munich-London	A319	154,330	V.2524-A5	1,153	1:32	124	9.30	627	-60
	A319	154,330	CFM56-5B5	1,160	1:31	124	9.36	627	-60
	A319	154,330	CFM56-5B6	1,167	1:31	124	9.41	627	-60
	A319	154,330	CFM56-5A5	1,175	1:30	124	9.48	627	-60
	A319	166,450	V.2524-A5	1,153	1:32	124	9.30	627	-60
	A319	166,450	CFM56-5B5	1,160	1:31	124	9.36	627	-60
	A319	166,450	CFM56-5B6	1,167	1:31	124	9.41	627	-60
	A319	166,450	CFM56-5A5	1,175	1:30	124	9.48	627	-60
	A320	166,450	V.2500-A1	1,139	1:33	150	7.60	627	-60
	A320	166,450	CFM56-5A1	1,144	1:29	150	7.62	627	-60
	A320	166,450	CFM56-5B4	1,270	1:33	150	8.46	627	-60
	A320	169,800	V.2527-A5	1.192	1:33	150	7.95	627	-60
	A320	169,800	CFM56-5A3	1,204	1:33	150	8.03	627	-60
	A320	169,800	CFM56-5B4	1,270	1:33	150	8.46	627	-60
	A321	196,200	V.2530-A5	1,390	1:32	185	7.51	627	-60
	A321	196,200	CFM56-5B2	1,365	1:31	185	7.38	627	-60

Source: Jeppesen

5B5 and -5B6 burn 0.7% and 1.7% more fuel respectively *(see table, this page)*.

These differences are reduced when flying in the other direction, which increases the travelled distance by about 17%. In this case the CFM56-5A5-powered aircraft burns 1.9% more fuel than that powered by the V.2524-A5. The CFM56-5B6 burns 1.2% more fuel and the -5B5 0.6% more *(see table, this page)*.

The second point is that an aircraft with an MTOW of 166,450lbs (75.5 tonnes) burns the same amount of fuel as that with a lower gross weight and equipped with the same engines. This is because the actual take-off weight of the two aircraft is the same despite the higher gross-weight variant being used.

The A320 has been analysed with MTOWs of 166,450lbs (75.5 tonnes) and 169,800lbs (77 tonnes). The aircraft with a gross weight of 166,450lbs have been analysed with the V.2500-A1, CFM56-A1 and CFM56-5B4 engines.

In this case the V.2500-A1 has the lowest fuel burn, with the CFM56-5B4 burning 11.4% more fuel. This engine was developed for higher gross weight variants of the A320, however, and also for all other models of the A320 family. The V.2500-A1 was only used on early-production aircraft with lower gross weights. Aircraft with the CFM56-5A1 burn less than 1% more fuel than those with the V.2500-A1 *(see table, this page)*. Similar differences in fuel burn are seen with aircraft operating in both directions.

The A320 with the higher gross weight of 169,800lbs was analysed with V.2527-A5, CFM565-5A3 and CFM56-5B4 engines. This is more representative of later-built aircraft, which are also currently being ordered by airlines.

As with all other cases, aircraft with the V.2500 engine are the most fuel-efficient. The CFM56-5B4 has a 6.1-6.5% higher fuel burn, while the CFM56-5A3 has a 1.5-5.5% higher burn *(see table, this page)*, despite the V.2527-A5-equipped aircraft having a 4,000lbs higher operating empty weight (OEW).

Of the five MTOW variants of the A321 the highest is 206,130lbs (93.5 tonnes). The variant analysed here has an MTOW of 196,200lbs (89 tonnes), and a fuel capacity of 7,040 USG. This variant has been analysed with V.2530-A5 and CFM56-5B2 engines. In this case, the V2527-equipped aircraft has a marginally higher fuel burn of 1.8-3.3% *(see table, this page)*.

Besides differences in fuel burn between different engine types on the same aircraft, the analysis also shows that the A321 is the most fuel-efficient family member in terms of fuel burn per seat *(see table, this page)*. The A319 burns about 1.5 USG more per passenger than the A321, equal to about $2.4. AC

A320 family maintenance analysis & budget

The A320 family has the benefit of a low line and ramp check maintenance requirement and a long base check cycle interval.

The oldest A320s are now more than 18 years old. They have completed their first full heavy-cycle check and are approaching their second. New aircraft continue to be delivered at a high rate.

More than 1,400 A320s, 750 A319s and 340 A321s are in operation. The A320 is already the second most popular jetliner in service, making it an important aircraft for most maintenance providers. Its order backlog, and the likelihood that it will remain in production for another eight to 10 years, will take the total number built beyond the 6,000 mark, until a successor is launched. This implies that the A320 could continue operating in large numbers for another 40 years.

A320 in operation

Most A320s operate average flight cycle (FC) times of about 1.5 flight hours (FH), and accumulate about 2,800 FH per year. The A320 has been embraced by several low-cost carriers in recent years, including jetBlue, easyJet, Frontier and Air Asia. These airlines achieve utilisations closer to 10FH per day. In some cases aircraft are flown on routes where flight times approach 2-3FH.

The pattern of operation, average FH:FC and annual utilisation all influence the number of checks and MH consumed over a year of operation or a complete heavy-cycle check. This analysis assumes an average FC time of 1.5 FH, and annual utilisation of 2,800FH and 1,850FC. Based on 355 days of actual operations, with an average of 10 days for downtime for base checks and other maintenance, the aircraft completes an average of 5.3FC and 8.0 per day.

Aircraft operating for 10FH per day, at an average FC time of 2.0FH, would complete up to 3,500FH per year.

Aircraft older than nine years will be approaching their second heavy-check cycle, and experiencing maturity in their airframe and engine maintenance costs.

Maintenance programme

Until the latest revision to its maintenance planning document (MPD), the A320's maintenance programme was similar to that of all other Airbus types, comprising three main groups of independent checks: A Check, C check and structural inspections. The basic 1A group of tasks had three multiples and an interval of 500FH. If performed as block checks, the A cycle would be completed at the fourth check, the A4, which has an interval of 2,000FH.

The 1C tasks had an interval of 15 months, and comprised four multiples of 1C, 2C, 4C and 8C items. These could be grouped into block checks, forming a programme that terminated at the C8 check with an interval of 120 months, equal to 10 years.

The two structural checks had intervals of five and 10 years. For the sake of simplicity, most operators combined the five-year structural check with the C4 check and the 10-year structural check with the C8.

The ability of most operators to utilise intervals between base checks meant that the D check was being performed after eight or nine years of operation. The oldest aircraft that entered service in 1988 and 1989 will therefore go through their second D checks between 2005 and 2007.

The latest revision to the A320 family's MPD contains several changes, including the introduction of some new tasks. Its main effect, however, is to replace letter checks with a usage parameter concept and to further escalate intervals. Former A and C check tasks, for example, now have intervals in one of three task primary usage parameters of FH, FC or calendar time.

"The interval for 1A check tasks was changed from 500FH into system tasks with an interval of 600FH or 750FC based on the primary usage parameter, and zonal tasks with an interval of 100 days," explains Damir Ostojic, project manager of maintenance programmes at Lufthansa Technik. "The decision to perform those tasks together in one work package or to split them into two or three separate ones depends on the operator's FH:FC ratio, monthly utilisation and available downtimes for maintenance. Performing all former A check tasks together for an operator with an FC time of 1.5–2.0FH would mean only about 300-400FC would be reached when the 600FH interval was reached. It is likely, however, that most operators will still perform a generic A check."

While A check inspections have been split into three different interval categories, Emil Frehner, planning at SR Technics, explains that there are still three multiples. "The 600FH tasks have multiples of 600FH, 1,200FH and 2,400FH. The 500FC tasks have multiples of 1,000FC and 2,000FC. The calendar items have intervals of 100, 200 and 400 days. The utilisation pattern of most operators means that these intervals coincide relatively closely, so most perform generic A checks and group these three types of tasks together. Most carriers accumulate about 400FC and 600FH in about 80 days, so they will take advantage of the escalated interval."

"Some operators that Lufthansa Technik supports have an FH:FC ratio of about 1:1 and fly about 200FH per month, so we try to make maximum use of their intervals," continues Ostojic. "We give system tasks an interval of 600FH and zonal tasks a 100-day interval. This different grouping of tasks means we now have to consider complex planning issues such as labour requirements, spares availability, and the discovery of non-routine work in the case of short maintenance downtimes."

A similar escalation and re-definition of task intervals has been made to C check items. "C check items have been split into three groups based on task-specific primary usage parameters of 6,000FH for system tasks, 4,500FC for structural items and 20 months for zonal tasks," says Ostojic. "This allows greater flexibility in planning. Some fleets we support get to 4,500FC and 4,500FH at about the same time, so we would lose about 1,500FH of our 6,000FH interval on system tasks."

Like the A check items, the C check items have retained their multiple intervals. "The four intervals in the old MPD have been retained, so the multiples are now: 6,000FH, 12,000FH, 24,000FH and 48,000FH for tasks with an FH parameter; 4,500FC, 9,000FC, and 18,000FC for tasks with an FC parameter; and 20, 40 and 80 months for tasks with calendar time as a primary usage parameter," says Ostojic.

The structural tasks have also been escalated from five- and 10-year to six- and 12-year intervals. These new intervals allow more flexible planning of base checks, but Frehner explains that most operators will still group the three groups of C check tasks together which causes difficulties in planning. "The generic 4C and 8C checks have intervals of 80 and 160 months, compared to the 72- and 144-month intervals of the structural checks. The timing of the C4/6-year and C8/12-year checks closely coincides, because the full structural check intervals can rarely be utilised due to factors relating to operating schedules, and maintenance planning and availability. Combining these checks avoids increased maintenance downtime and simplifies base-check planning."

Line & ramp checks

Traditional line and ramp maintenance schedules and programmes have specified pre-flight (PF), transit (TR), daily and weekly checks. These checks have included routine inspections from the MPD, but have also been used to clear technical defects as they arise in operation. "The MPD is not intended to be a complete maintenance programme, and so, with the exception of some 'weekly' tasks with an eight-day interval, it only suggests maintenance items below the former A check. The MPD does not actually have any inspections or tasks with an interval lower than 36 hours," explains Ostojic. "Operators define checks that are smaller than the former A check. Many A320 operators have found there are no actual PF or TR checks, but still retain them. The routine tasks can be performed by the flightcrew. Only some technical defects have to be cleared between flights, which is the only time that line mechanics are required."

The 36-hour interval for the 'daily' check means that operators are no longer forced to do this check every single night. On most occasions the check can now be done at an operator's home base, when the aircraft returns home. "We actually have a 48-hour interval for the daily check on the aircraft operated by Swiss," says Jean-Marc Lenz, line maintenance Switzerland at SR Technics. "This allows virtually all of these checks to be done at the home base."

Besides the daily checks, the weekly check is the largest in the line-and-ramp check cycle. PF checks are performed before the first flight of the day, and TR checks prior to all subsequent flights. "The PF check is actually a requirement of Joint Aviation Requirements Operations (JAROPs) or the European Aviation Safety Agency (EASA), so it is the responsibility of operators to include it in the maintenance concept. Most local authorities accept delegation of those tasks to the flightcrew, but some may still require the PF check to be performed by the station mechanic," says Ostojic. "The PF check is mainly limited to a visual walk around and check of emergency equipment that can be performed by the flightcrew, so that no man hours (MH) have to be consumed by line mechanics for the routine parts of these checks."

Nevertheless, on some occasions line mechanics do carry out the routine parts of these checks. "Longer ground times between flights when there is a change of flightcrew may result in line mechanics having to perform the visual inspection," explains Lenz. As a result of these inspections or technical defects that arise in operation, line mechanics are required to work on non-routine maintenance.

Daily checks generally include the visual inspection of PF and TR checks on items such as engines and the brake system, as well as items such as draining fuel tanks, replenishing engine oil, and checking tyre pressures. These checks are usually done overnight and are also often used to clear technical defects. Weekly checks comprise daily checks plus more in-depth inspections of items such as cabin lighting, crew oxygen system, and emergency actuators.

Technical defects

The process of clearing technical defects starts with logging and trouble-

The A320's MPD does not require routine items for transit or pre-flight checks. These can be accomplished by flightcrew, although defects would have to be cleared by line mechanics. The routine tasks in the MPD with the lowest interval are 36 hours.

shooting, followed by either clearing or deferring them. This is streamlined with the aid of the on-board fault detection and analysis system, transmission of default messages to ground stations and automatic on-the-ground analysis.

The A320's centralised fault display system (CFDS) receives system failure messages from the aircraft's components' built-in test equipment (BITE). These messages are displayed on the electronic centralised aircraft monitor (ECAM), which is the top screen in the centre of the flightdeck's main panel. These ECAM messages are sent to the centralised fault display interface unit (CFDIU), which sends them to the multifunction control and display unit (MCDU), but can also transmit them to the operator's maintenance operations control centre via the aircraft communication and reporting system (ACARS) if this is installed on the aircraft. This allows maintenance control staff to analyse fault messages while the aircraft is in flight. Technicians can independently analyse many of the fault messages to a deeper level using the MCDU. The flightcrew are also required to log ECAM messages in the post-flight technical log. The ECAM messages are automatically recorded and produced by the CFDIU, and in addition, these fault and BITE codes can be printed and downloaded. The messages and data on the post-flight report (PFR) are used by line mechanics to isolate and troubleshoot the faults. Fault messages that are transmitted in flight by ACARS can automatically be analysed and displayed by AIRMAN, a computerised tool developed by Airbus that analyses fault codes using electronic versions of troubleshooting and fault isolation manuals, as well as the minimum equipment list (MEL).

This system is designed to reduce both the time spent analysing faults, and the number of MH spent on non-routine maintenance in line-and-ramp maintenance. The system also makes it possible for line mechanics to be ready with the required line replaceable units (LRUs), other spare parts, tools and required labour when the aircraft arrives at the gate. This can avoid an extension of scheduled time at the gate, thereby leading to fewer flight delays and cancellations.

While the system cannot influence the number of MH spent on routine items in line-and-ramp checks, it has contributed to a reduction in MH expenditure on non-routine items. "The on-board computer provides good indications for troubleshooting defects," says Lenz. "The system saves operational time and MH in clearing defects because it provides more accurate information, and is more efficient in locating the exact component with the problem. This reduces the incidence of no-fault-found."

Line & ramp inputs

As described, there are routine and services tasks in PF and TR checks. These are defined by the operators and are required by local authorities in addition to the MPD.

Some airlines can therefore avoid using line mechanics for PF and TR checks, although they may be required on some occasions when the flightcrew are unavailable. "Zero MH are required for PF and TR checks, although some will be used when technical defects arise that cannot be deferred until the daily check is performed," explains Ostojic.

While PF checks for A320s are mostly carried out as a visual walkround inspection of the aircraft, followed by flightdeck systems checks performed by the flightcrew, MH are consumed for non-routine work that arises. An allowance of 0.5MH and $7.0 for materials and consumables, but excluding rotables and LRUs that might be exchanged, should be made for PF checks. On the assumed pattern of operation, 355 PF checks will be performed each year. These will consume about 180MH per year, and cost about $12,600 at a labour rate of $70 per MH. The additional annual cost for materials will be $1,260. The total annual cost for PF checks will be about $14,000.

While TR checks can also be made by flightcrew, some carriers use line mechanics instead. Non-routine work also arises, so MH from line mechanics are consumed. United Services terms its TR checks Number 1 service checks, and uses an average of 0.5MH for the routine inspection and 2.1MH for the non-routine work. LTU Maintenance records a similar total expenditure of 3.0MH for the check. A similar budget of $7 can be used for materials and consumables. The assumed pattern of utilisation means that about 1,480 TR checks will be performed each year. This will take annual total MH consumption for these checks to about 4,40MH, which will cost in the region of $275,000. Use of consumables and materials will be about $10,400 per year.

Daily checks can be performed by one mechanic, and are often done overnight. Estimates of total MH required vary, and largely depend on the number of defects that are selected to be cleared, or remain deferred until weekly checks or A checks. Realistic MPD task quantification estimates are that up to a total of 3.5-5.0MH are consumed during a daily check, being split about 50:50 between routine and non-routine work. A budget of $500 should be allowed for materials.

Given that the pattern of operation will be 355 days per year, 250 daily checks will be performed annually, resulting in a total MH expenditure in the region of 1,250MH, with a cost of about $90,000. Annual cost of materials for these checks will be about $125,000.

Taking into account the MPD tasks for weekly checks, it is estimated that they require about 8MH to complete.

Again, the split between routine and non-routine is about 50:50. Others consume up to 12.0MH, and United Services says that average routine consumption is 3.7MH, and for non-routine work it is 7.6MH. The actual MH used will depend on an operator's policy for clearing defects. About $700 of materials and consumables are used.

While the MPD interval for weekly checks is eight days, operational and planning constraints mean that checks are actually made every six to seven days.

Considering the aircraft will operate for 355 days a year, about 60 weekly checks will therefore be performed. Taking a conservative average of 11.0MH for a weekly check means that about 660MH will be consumed annually for these checks, at a cost of $46,000. Materials and consumables will cost about $42,000.

The total annual cost for these line-and-ramp checks will be $595,000, equal to a rate of $212 per FH *(see table, page 31)*. This cost per FH would fall with a longer average FC time of 2.0FH. The number of TR checks would be reduced to about 950, with a consequent drop in total MH and materials consumed. Small reductions in the number of MH used in line and ramp checks can significantly lower maintenance costs.

A checks

A check intervals have been extended, and tasks split into three groups, as a result of revision 28 to the A320's MPD.

The pattern of operation, average FH:FC ratio and level of aircraft utilisation mean that many operators group these tasks together as a generic A check. This also simplifies planning.

The interval of 600FH for system tasks means that the interval of 500FC for structural tasks will only be partially used if these two groups are performed together. With an annual utilisation of 2,800FH, the 600FH limit will be reached in about 78 days, meaning that the calendar limit of 100 days will not be reached. A checks are more likely to be performed every 450FH, given typical operational and planning constraints. On this basis, six to seven A checks will be performed each year.

Realistic MPD quantifications estimate MH consumption for routine tasks to be 80MH, versus about 27MH specified by the MPD. "About another 10% should be added to this for non-routine items and clearing defects. Interior work, such as cleaning and replacing a few items will add about another 10MH to the total," says Ostojic."

Other maintenance providers report similar MH consumption. "The generic A check consumes about 80MH in the case of the aircraft that we manage," says Lenz. LTU Maintenance reports up to 86MH for larger A checks, while United Services records an average total of 75MH for A checks.

This will will result in about 520MH per year being consumed for A checks, with a cost of up to about $36,500, when charged at a typical industry rate of $70 per MH.

Material and consumables consumption is in the region of $5,000-6,000 per check. Six or seven A checks per year will use about $40,000, taking the total annual cost for A checks to about $77,000. This will be equal to a rate of $28 per FH *(see table, page 31)*.

Base check inputs

Despite revision 28A splitting C check tasks into three groups, many operators still combine these as a generic C check. The content of these checks is different to the C checks under the previous MPD," explains Ostojic. "This is due to 'drop out' tasks, ones that have not been escalated under Revision 28A."

Under the new MPD, the C4 check has an interval of 80 months, which is eight months longer than the six-year structural check. The C8 check has an interval of 160 months, 16 months longer than the 12-year structural check. Since the basic C check has a 6,000FH and 20-month limit, and most airlines will only be able to use about 18 months of this interval, an aircraft completing about 2,800FH per year will have a C check performed about every 4,200FH. This means that the C4 check will actually come due after about 16,800FH and 72 months, making it convenient to combine it with the six-year structural check.

The C8 check will come due after about 34,000FH and 144 months, so it will be convenient to combine it with the 12-year structural check.

This compares to a shorter actual C8/D check interval of about nine years and 26,000FH that aircraft have been achieving under the previous MPD. Since Revision 28A is only about a year old, most airlines will still be bridging their aircraft onto new maintenance programmes.

Under Revision 28A, the six light C checks in the base-check cycle will include routine inspections and non-routine work arising as a result, cabin cleaning, modifications and service bulletins (SBs).

The two heavy checks, the C4 and C8 checks, will include these items, as well as interior refurbishment and stripping and re-painting. The extended interval of the full base-check cycle means that some airlines decide to strip and re-paint at every heavy check.

Since no operators have experience of an aircraft completing a base-check cycle under Revision 28A, all MH and materials cost inputs are drawn from aircraft operating under earlier MPDs.

Light C1, C3, C5 and C7 checks include the C1 tasks and require about 800MH for routine tasks. In the first base-check cycle, they experience a non-routine ratio of 20-30%, which adds about 200MH. Ignacio Diez-Barturen, commercial director at Iberia technical division, explains that it records a non-routine ratio of 20-30% for C1 and C3 checks. This takes the number of routine and non-routine MH for the C1 check to 1,250-1,500, and to between 1,600 and 1,750 for the C3 check.

The number of MH required to complete modifications, SBs and out-of-phase items varies, but an average of 700MH can be used for lighter C checks on aircraft in their first base-check cycle. Airlines will also have to add about 100MH for interior cleaning and cabin work, taking the total to about 1,800MH. Base maintenance labour charged at $50 per MH takes this cost to about $90,000.

Diez-Barturen adds that the totals for C1 and C3 checks vary. The total MH for C1 checks will be about 1,700MH, but up to 3,000MH for C3 checks.

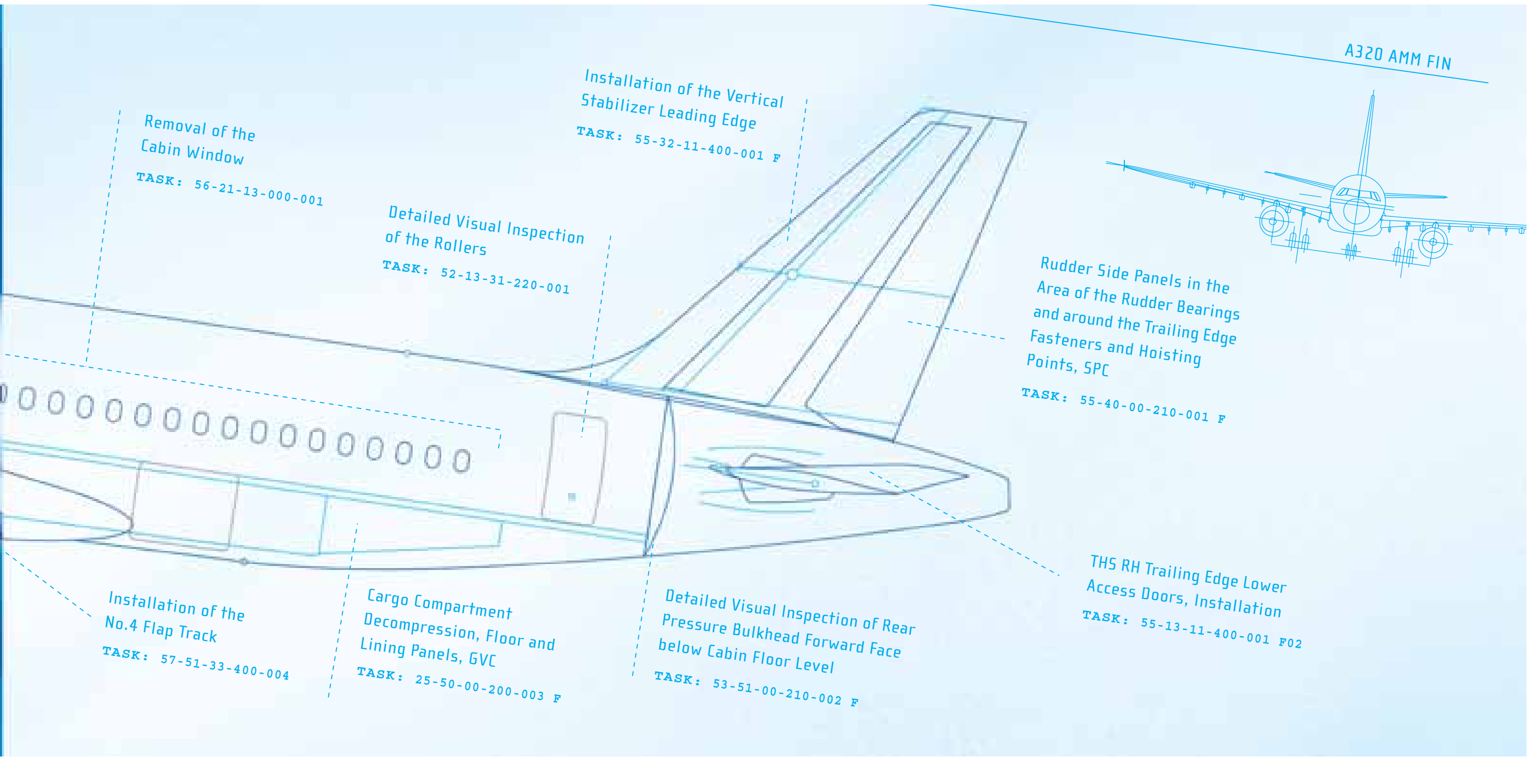
Consumption of materials and consumables is at $20 per MH, so $36,000 should be budgeted for these checks. The total check cost will be about $126,000.

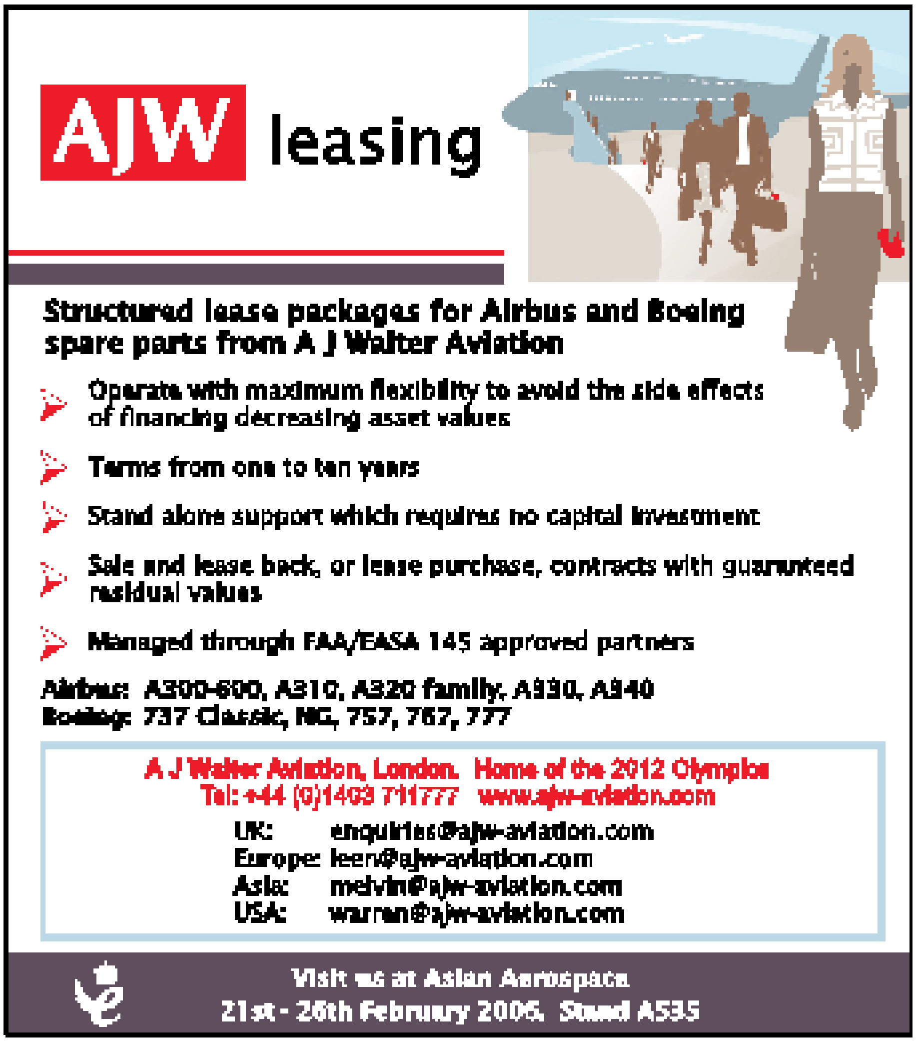
C2 and C6 checks include the C1 and and C2 task items. This increases the number of routine MH to about 950, while a non-routine ratio of about 30% adds a further 300MH. Diez-Barturen says that Iberia uses about 1,250MH for routine work, with a non-routine ratio of 25-40% adding about another 650MH.

Modifications, SBs and interior works add another 800MH, taking the total to 2,050-2,500MH, equal to $102,500.

Materials and consumables will be about $41,000, taking the total cost for the check to $143,500.

The C4 check includes routine items for C4 tasks and five- or six-year structural inspection, and so requires a lot of access. MH for routine tasks and access will total in the region of 4,500. A non-routine ratio of 55% will add another 2,500MH, and modifications another 1,800MH. A further 4,000MH will be used for interior refurbishment





and in the region of 1,500MH for stripping and painting. Diez-Barturen estimates that stripping and painting during this check will add about 1,200MH and a further $14,000 for the cost of the paint. This takes the total for the check to about 14,300MH. Aircraft that have lower non-routine ratios, and use fewer MH for interior work, will have lower total MH consumptions of about 12,500MH. The labour portion will have a cost of about $625,000-715,000.

Materials and consumables will total $250,000-285,000. An additional cost of about $50,000 can be expected for the repair of soft-time or on-condition components removed during the check, as well as another $60,000 for materials used in cabin refurbishment. The total for materials and component repairs will therefore be $360,000-395,000.

The composition of C8 checks is similar to C4 checks. MH for routine items and access have been in the region of 7,500MH for aircraft in their first cycle. Defect ratios of 50-60% increase this to 11,500-12,000. An additional 2,000MH should be allowed for modifications and SBs, 5,000MH for cabin and interior refurbishment, and 1,500MH for stripping and painting. This will take the total MH to about 20,000. The total expenditure for many aircraft drops when MH used for modifications, SBs, and routine, non-routine and interior work are reduced. This has taken labour down to 18,000MH, equal to charge of $900,000.

Consumption of materials will be at a rate of about $25 per MH, so equal to about $450,000. Additional materials for interior refurbishment will be in the region of $100,000, while the cost of on-condition and soft-time component repairs will be about $60,000. This will take the total cost for the check to about $1.5 million.

A total of 43,500MH are used for the first base-check cycle. The total labour and material cost for the full base-check cycle will be $3.3-3.5 million. When amortised over the interval of 26,000FH that is achieved by most airlines over a nine-year period, the total reserve for these base checks is $128 per FH *(see table, page 31)*. If the MH and material consumption are the same for an aircraft completing 34,000FH in its base-check cycle, when operating under a Revision 28A MPD, this reserve will fall to $98 per FH.

There are, however, small differences between the A320, and the smaller A319 and the large A321. While many tasks are the same irrespective of aircraft type, Diez-Barturen estimates that on average there is a difference of about 5% between the A320 and its two smaller counterparts.

Aircraft that have been through their second base-check cycle will experience an increase in MH, due to more routine tasks, higher non-routine ratios and a higher level of modifications and SBs. Total MH for the base-check cycle can reach 48,500. The consumption of materials will also rise with MH, and as more components are removed for repair. Total material expenditure will reach up to $1.5 million. This will take total cost for the eight base checks to about $3.9 million, which will increase the base-check reserve to about $150 per FH. This could be kept down to about $115 per FH for aircraft operating under a Revision 28A MPA and with a base-check interval of 34,000FH.

Heavy components

Heavy components comprise four groups: wheels, tyres and brakes; landing gears; thrust reversers; and the auxiliary power unit (APU). These are sometimes referred to as 'off-aircraft components', because they have independent maintenance programmes.

The maintenance of these four groups of components is FC related, and their costs are summarised *(see table, page 26)* by repair intervals, factors affecting the number and cost of repairs, the total cost for repairs and replacement over the repair cycle, and the resulting cost per FC. This is $15 per FC for the retreading and replacement of tyres, $9 per FC for wheel inspections, $64 per FC for brake repairs, $19 per FC for landing gear exchange and repair, $29 per FC for thrust reverser repairs and overhaul, $44 per FC for APU maintenance. This totals $180 per FC for all heavy components, and equals $120 per FH for the aircraft operated at an FC time of 1.5FH *(see table, page 31)*.

Rotable support

The majority of the A320's rotable and repairable components are on-condition. While some will be inspected and may be removed during base checks, the majority can be removed relatively easily during line, ramp and A checks. Few airlines have their own repair shops and complete inventories to be self-sufficient in rotable and repairable component support.

Rotable support contracts can be provided on the basis of the airline leasing a homebase stock from the rotable support provider. This usually includes high-failure-rate and 'no-go' components. "The value of stock for a fleet of 20 A320s each operating at about

A320 FAMILY HEAVY COMPONENT MAINTENANCE COSTS

Tyre retreads & replacement	**Number**	**Removal FC**	**Number retreads**	**Total life FC**	**Retread cost/tyre**	**Shipset retread $**	**Total all retreads $**	**New tyre $**	**Shipset new tyre $**	**Total cost $/FC**
Main wheels	4	300	4	1,500	600	2,400	9,600	1,600	6,400	11
Nose wheels	2	200	4	1,000	300	600	2,400	400	800	4

Wheel inspections	**Number**	**Removal FC**	**Repair $**	**Shipset repair $**	**Repair $/FC**
Main wheels	4	300	450	1,800	6
Nose wheels	2	200	250	500	3

Brake repairs	Number	Heat pack life FC	Repair $	Repair $/FC	Shipset repair $/FC
	4	2,100	33,000	16	64

Landing gear	**Interval**	**FH interval**	**FC interval**	**$ exchange**	**$/FC**
	10	28,000	18,350	340,000	19

Thrust reversers	**Number**	**FC interval**	**Workscope**	**Repair $**	**Total $**	**$/FC**
	2	12,000	Intermediate	170,000	340,000	29

APU : GTCP 331-250	**APU hours SV interval**	**APU hours/FC**	**FC interval**	**Shop visit $**	**$/FC**
	5,500	1.2	4,600	200,000	44

2,600-2,800FH per year will be $10 million, and will have a lease rate of $120,000 per month," says Joerg Asbrand, manager aircraft component services at Lufthansa Technik. "This equates to about $28 per FH for each aircraft."

Rotable support providers also give airlines access to serviceable units of all other types of components as they fail and need to be removed. These are provided within an agreed time limit and on an exchange basis.

Asbrand says the cost for this element of the contract will be about $30 per FH. The largest element, however, will be the fee for the repair and management of the failed components. "This will be $110-115 per FH for an airline that has reasonable transport time and customs costs when considering the location of the support provider," continues Asbrand. This results in an overall cost of $170-180 per FH. The SB and modification status of the components must also be considered.

Engine maintenance

As described, the A320 family is dominated by aircraft powered by the CFM56-5B series and V.2500-A5 series *(see A320 family fleet analysis, page 9)*. These two engine types provide the aircraft with similar levels of operational performance, and so their maintenance cost is an important issue in influencing engine selection.

The information here applies to the CFM56-5B/P and V.2500-A5 engines, under a generic operation with an FH:FC ratio of 1.5. Actual figures obviously vary with specific operating conditions.

CFM56-5B series

The CFM56-5B series can be split into three main groups that power the A319, A320 and A321. The majority of A319s are powered by the CFM56-5B5 and -5B6. These are rated at 22,000lbs and 23,500lbs thrust and have high initial production exhaust gas temperature (EGT) margins of 110-165 degrees centigrade. Most A320s are powered by the CFM56-5B4 rated at 27,000lbs thrust, which has an initial production EGT margin of about 110 degrees centigrade. The majority of A321s are powered by the CFM56-5B3 rated at 33,000lbs thrust, which has an initial production EGT margin of about 66 degrees centigrade.

"The initial rate of EGT margin loss is about 15 degrees in the first 1,000 engine flight cycles (EFC)," says Russell Jones, programme manager at Total Engine Support. "This then falls to about five degrees per 1,000EFC thereafter." This implies that the -5B3 could theoretically remain on-wing for up to about 11,000EFC before losing all EGT margin. Lower-rated engines with higher margins can remain on-wing for longer.

Actual rates of EGT margin vary with the engine flight hour (EFH) to EFC ratio. "After the initial loss, EGT margin will deteriorate by 2.0-2.5 degrees per 1,000EFH at an average EFC time of 1.5EFH," says Pierre-Emmanuel Gires, vice president of customer operations at Snecma Services. This is equal to 3-5 degrees per 1,000EFC.

First removal intervals for the lower-rated engines powering the A319 can therefore be up to about 16,000EFC. "The -5B series will have first on-wing intervals of 10,000-15,000EFC in most cases when operating in average conditions with a take-off temperature of 64 degrees fahrenheit, a 10% de-rate and an average EFC time of 1.5EFH," says Gires.

"Most first on-wing intervals for the -5B5 and -5B6 engines on the A319 are 10,000-16,000EFC in average conditions," says Jones. "The -5B7 powering the A320 averages about 10,000EFC for its first interval in the same circumstances, while the -5B3 powering the A321 will have intervals in the region of 7,000EFC."

All engines usually require a hot-section restoration at their first shop visit. "The amount of EGT margin that engines recover depends on their shop visit workscope, but will be about 60% of initial margin following a hot-section restoration or inspection, and 80% following a full performance restoration or overhaul," explains Jones, "A hot-section restoration will result in margins of about 40 degrees centigrade for the highest-rated engines that power the

The latest revision to the A320's MPD has extended the basic C check interval to 6,000FH, and the C8 to 48,000FH. The structural checks have had their intervals increased to 6 and 12 years. Considering planning and operational constraints, this will allow the base check cycle to be completed about every 12 years, the C8 and 12-year check combined.

A321." This implies that the engine could have a second on-wing run of up to 6,000EFC. Lower-rated engines will be capable of longer intervals of about 7,500EFC, but other limiting factors have to be considered. One factor concerns the remaining lives of life limited parts (LLPs). The lives of some LLPs can be completely used during the second on-wing run, depending on engine thrust rating, and so force removals. Some lower-thrust-rated engines achieve longer intervals in friendly environments, and a core performance restoration is likely to be more suitable.

The CFM56-5B series has 19 LLPs with varying lives. Jones explains that the three parts in the fan section have lives of 25,000EFC when powering the A319 and A320, and 20,000EFC when powering the A321, with a list price of $380,000.

The high-pressure compressor (HPC) LLPs have lives of 18,200EFC for engines powering the A319 and A320, and lives of 17,200EFC for higher-rated engines powering the A321. They have a list price of $440,000.

LLPs in the high-pressure turbine (HPT) have a list price of $450,000, and lives of 17,600EFC when powering the A319 and A320. They have shorter lives of 14,300EFC when powering the A321.

LLPs in the low-pressure turbine (LPT) have lives of 25,000EFC when powering all A320 variants, and a list price of $610,000 (including LPT case).

The engines powering the A321 are likely to have accumulated a total of 12,000-13,000EFC by the second removal, with only a little over 1,000EFC remaining on their HPT LLP lives. These LLPs certainly have to be replaced at the second shop visit, but careful consideration must be given to HPC LLPs. These will have about 5,200EFC remaining, which is about equal to the expected interval following the second shop visit, and so could be left in the engine and removed at next shop visit.

Lower-rated engines will have accumulated a total time of about 17,500EFC at their second shop visit, which will be forced by expiry of the HPT and HPC parts. LPT and fan LLPs will remain in the engine until the third shop visit after about another 7,500EFC and a total time of 25,000EFC. At this stage the engines will have accumulated a total time of about 25,000EFC, equal to the life limits of the fan and LPT parts.

Probable on-wing intervals and timing of LLP replacement have to be considered together with shop visit workscopes. "While all engines will have a hot-section restoration at their first shop visit, the level of parts replacement or repair will depend on engine rating, with higher-rated engines requiring heavier restorations," says Jones. "The lower-rated engines powering the A319 and A320 will require a full performance restoration as well as the replacement of HPT and HPC LLP limits after accumulating about 17,500EFC. Their LPT and fan LLPs would be replaced at the third shop visit, after a total time of 22,000-25,000EFC. The engine powering the A321 will have accumulated a shorter time of about 12,000EFC at the second visit, and so only require a full core performance restoration. HPT LLPs should be replaced at this stage, but HPC LLPs could be left in. Engine management would probably be simpler if all core LLPs were replaced, with a stub life of 5,000-6,000EFC, and sold on the aftermarket." In this scenario, and with probable mature on-wing intervals of about 5,000EFC, fan and LPT LLPs would be replaced at the fourth shop visit. While the varying lives of LLPs in the CFM56-5B require careful management with respect to on-wing intervals and shop visit workscopes, many of the LLPs can be used in other variants. Parts with stub lives can probably be used on other CFM56 engines, such as the CFM56-5C, due to its low cycle usage of only a few hundred EFC per year.

"Most engines will follow a shop visit pattern of alternating core restorations and full overhauls, with on-wing intervals for mature engines on the A321 being in the region of 5,000EFC, and 7,000-8,000EFC for engines on the A319 and A320," says Gires.

Depending on thrust rating, first shop-visit core restorations require 2,700-3,100MH, and a total of $625,000-700,000 in materials and sub-contract repairs. A labour rate of $70 per MH would take the total shop visit cost to $800,000-920,000, depending on engine rating.

This equals a reserve of $49 per EFH for the engine powering the A319, $56 per EFH for the engine powering the A320 and $87 per EFH for the engine powering the A321.

Second shop visits, which comprise an overhaul, require higher labour inputs of 3,700-4,500MH and $775,000-975,000 in materials and sub-contract repairs. This takes the cost of these heavier visits to about $1.05 million for engines powering the A319, $1.15 million for engines powering the A320 and $1.3 million for engines powering the A321.

This is equal to a reserve of $106 per EFH for engines powering the A319 and A320, and $172 per EFH for engines powering the A321.

Reserves for LLPs have to be added. While LLPs have different lives depending on thrust rating, engines powering the A319 and A320 can generally be expected to replace core LLPs at every second shop visit and every 15,000EFC, while fan and LPT LLPs would be replaced at every third shop visit and every 22,500EFC. Without assuming any remaining value for stub LLPs, reserves would be about $105 per EFC.

In the case of A321 engines, HPT and HPC LLPs would be replaced about every third shop visit, fan LLPs replaced every

The A320's total maintenance costs are influenced most by the cost of line and ramp checks, base checks, rotables, and engines. Bridging to the latest MPD can allow operators to save about $30 per FH on the cost of base check reserves. Increasing average FC time from 1.5FH to 2.0FH reduces total cost per FH by about $110.

fourth, and LPT parts every fourth or fifth. These replacement intervals result in an LLP reserve of about $110 per EFC.

When shop visit and LLP reserves are combined, the lower-rated engines on the A319 and A320 will have a total reserve of $120-126 per EFH for the first interval, and reserves varying between $157 and $176 per EFH for the second and third interval *(see table, page 31)*. The engine powering the A321 will have a reserve of $161 per EFH during the first interval, and then $215-245 per EFH during the second and third interval *(see table, page 31)*.

V.2500-A5 maintenance

Like the CFM56-5B, the V2.500-A5 series has a high EGT margin. "The production margin for new engines is 90-115 degrees centigrade for the V.2522/24-A5 powering the A319, 70-80 degrees for the V.2527-A5 powering the A320, and 40-60 degrees centigrade for the V.2530/33-A5 powering the A321," says Phillip Stott, programme manager at Total Engine Support. Most A319s are powered by V.2522-A5 and V.2524-A5 engines, most A320s by the V.2527-A5, and most A321s by the V.2533-A5.

After initial EGT margin loss, deterioration rates are about 4 degrees per 1,000EFC for low-rated engines, 4.5 degrees per 1,000EFC for medium-rated engines, and about 6 degrees per 1,000EFH for high-rated engines when operating at an average FC time of 1.5FH.

The EGT margin on the higher-thrust V.2530/33-A5 can be low enough for it to limit the on-wing interval achieved by the engine. Typically, however, this will coincide with the third shop visit and LLP replacement. Lower-rated engines are not limited by EGT margin, and removals are forced by distress or replacement of LLPs.

"The V2527-A5 on the A320 will typically run for about 10,000EFC until the first shop visit," says Stott. "The V.2530/33 engines powering the A321 run for 7,000EFC until the first shop visit." It is not unusual to see engines staying on-wing longer.

All engines will go through a hot-section refurbishment at their first shop visit. At this stage probable second on-wing intervals and the remaining life of LLPs should be considered. The V.2500-A5 benefits from having a set of 25 LLPs with uniform lives of 20,000EFC for current part numbers. This simplifies engine management. LLPs removed with more than 3,000EFC remaining can often be sold on the aftermarket to operators that have a long average EFC time.

"The V.2500-A5 has a reputation for being able to recover up to 90% of its initial EGT margin. Lower-rated engines for the A319 and A320 can achieve intervals of about 7,500EFC after their first shop visit, taking total time at the second removal to about 17,500EFC," explains Stott. "These engines can be expected to conform to a pattern of shop visits that alternate between a core restoration and full refurbishment. The total time at the second removal and similar third run of 7,500EFC means the LLPs would have to be removed at this shop visit, with a stub life of about 2,500EFC."

"Higher-rated engines will remain on-wing for about 5,000EFC during the run to the second shop visit, and so will have a total accumulated time of about 12,000EFC at the second removal," continues Stott. "These engines are more likely to go through a pattern of two consecutive hot-section refurbishments, followed by a full refurbishment every third shop visit. The workscope of the second hot-section refurbishment may be a little heavier than the first. Total time at the third shop visit would be about 17,000EFC, making it appropriate for LLPs to be replaced."

Under this pattern of management LLPs in most engines would be replaced after a total time of 17,000-18,000EFC. The shipset list price of $1.9 million means that LLP reserves will be in the region of $105-110 per EFC.

A hot-section refurbishment shop visit will consume 3,500-3,750MH, about $100,000 in sub-contract repairs, and $450,000-475,000 in parts and materials. A labour rate of $70 per MH would take total cost for this shop visit to $795,000-840,000. This results in a reserve rate of $53-56 per EFH when amortised over the first on-wing interval of 15,000EFH. When combined with LLP reserves, total reserve for engine maintenance is $126-130 per EFH for these lower-rated engines on their first on-wing run.

The following refurbishment workscope at the second shop visit will use 4,750-5,000MH, $200,000-250,000 in sub-contract repairs, and $670,000-700,000 in parts and materials. This takes the total cost of this refurbishment to $1.2-1.3 million. Amortised over the shorter interval of about 11,500EFH, this results in a reserve of about $108-116 per EFH. The addition of LLPs takes this to a total of $180-188 per EFH *(see table, page 31)*.

The initial workscope of the high-rated engine powering the A321 will consume about 4,000MH, $100,000 in sub-contract repairs, and $500,000 in parts and materials, resulting in a shop visit with a cost of about $880,000. This has a reserve of about $84 per EFH. The total reserve will increase to $158 per EFH when reserves for LLPs are added.

The second workscope, a heavier hot-section refurbishment with limited HPC work, will consume about another 500MH and $250,000 in materials, parts and sub-contract repairs, resulting in a total shop visit cost of about $1.15 million. This will have a higher reserve of $155 per EFH. Additional reserves for LLPs will take total reserves to about $230 per EFH *(see table, page 31)*.

The third visit, a full refurbishment, will use up to about 5,000MH and about $1 million in parts and repairs. The higher shop visit cost of about $1.35 million will have a reserve of $180 per EFH, and will total $255 per EFH when LLPs are added *(see table, this page)*.

DIRECT MAINTENANCE COSTS FOR A319/A320/A321

Maintenance Item	Cycle cost $	Cycle interval	Cost per FC-$	Cost per FH-$
Line & ramp checks	595,000	2,800		212
A check	77,000	2,800		28
Base checks	3,500,000	26,000		128
Heavy components:			180	120
LRU component support				180
Total airframe & component maintenance				**635-700***
*** ±5% variation about $668 per FH for A319 and A321**				
Engine maintenance:				
2 X CFM56-5B5/-5B6 (A319)				314-352
2X CFM56-5B4 (A320)				314-352
2X CFM56-5B1/-5B2/-5B3 (A321)				430-490
2 X V.2522/24-A5 (A319)				360
2 X V.2527-A5 (A320)				380
2 X V.2530/33-A5 (A321)				460
Total direct maintenance costs:				
A319 (CFM56-5B5/-5B6)				950-987
A320 (CFM56-5B4)				982-1,020
A321 (CFM56-5B1/-5B2/-5B3)				1,130-1,190
A319 (V.2522/24-A5)				995
A320 (V.2527-A5)				1,048
A321 (V.2530/33-A5)				1,160

Annual utilisation:
2,800FH
1,830FC
FH:FC ratio of 1.5:1.0

Engine inventory

Operators must also consider engine inventory. Airlines have the choice of engine ownership and long- or short-term leasing. Engines that are constantly being utilised will always be owned, although the major engine lessors are available for sale and leaseback transactions if operators want to release the cash value of their assets. The supply of V.2500 and CFM56-5A/B engines is tight, and has reduced as the average engine shop-visit rate across the fleet has increased. "V.2500-A5s are effectively at list price, which for a bare engine is about $7.5 million for a V.2527," says Tom MacAleavey, senior vice president of sales and marketing at Willis Lease Finance. "The value increases to about $8.0 million for a V.2530 and is $6.0 million for a V.2522. There are few or no engines available in the market to buy, and values only decrease by an amount equal to the cost of accrued maintenance."

This shortage has also strengthened lease rates. "While there is a shortage of engines to buy, the lease market is strong," says Richard Hough, vice president technical at Engine Lease Finance. "Long-term lease rates are competitive, and lease rate factors are about 0.8% per month of market value. Long-term lease rates for V.2500-A5 engines will therefore be between $48,000-64,000 per month, depending on variant."

The long-term lease market for the CFM56 is similar. "More CFM56-5Bs are available than V.2500-A5s," says MacAleavey. "A CFM56-5B4 for the A320 has a bare engine value of $7.2 million, and $8.7 million when equipped with a quick engine change (QEC)."

Hough estimates similar values for the CFM56-5B, with the -5B3 at $9.1 million for an engine with a QEC, and about $7.2 million for a -5B5 with a QEC. "These values would put long-term lease rates for the CFM56-5B at $58,000-73,000 per month, depending on thrust rating."

Values for CFM56-5As have come under pressure in recent years with a large number of aircraft on the market, but have increased again to about $5 million.

Short-term lease rates also have to be considered, and are relatively high, but Hough explains that few engines are available. "Short-term rates for engines like the V.2500-A5 can be in the region of $4,000 per day, equal to $120,000 per month, due to lack of supply," says MacAleavey. "Short-term rates for the CFM56-5B are lower, with more engines available on the market, and rates are in the region of $2,500-2,800 per day. Daily rates for the CFM56-5A are in the region of $2,300."

Summary

There is a variation of $160-240 per FH in the total maintenance costs of the A319, A320 and A310 *(see table, this page)*. The main factor in this difference is due to engine-related maintenance costs. The total of airframe- and component-related costs varies between $635 and $700 per FH for aircraft in their first base-check cycle. These can be reduced by about $30 per FH if aircraft are changed to a maintenance programme base on Revision 28A of the MPD. Base check reserves increase by about $20 to $150 per FH for aircraft in their second cycle, but would be about $115 per FH if operating under Revision 28A.

Engines account for up to 40% of total costs. Other main constituents are line and ramp checks, base checks, and LRU component support.

The effect of increased FH:FC ratio to 2.0 would reduce the number of line and ramp checks performed, with a corresponding drop in cost per FH. This would be mainly due to fewer TR checks being required over a given period, and would reduce costs by about $10 per FH.

The same change would also result in a drop in engine reserves. The amortisation of LLPs would be reduced from their current level of about $75 per FH (when the rate of $105-110 per EFC is amortised over 1.5EFH) to about $55 per EFH; reducing total aircraft maintenance costs by about $40 per FH.

Engine reserves would also be reduced by about $30-40 per EFH, and so maintenance costs for both engines would be reduced by about $65 per EFH.

The change of maintenance programmes to one based on Revision 28A of the MPD could also reduce reserves for base-related checks by about $30 per FH.

It is therefore possible for aircraft to have total maintenance costs in the order of $110 per FH less than shown if an average FC time of 2.0FH is flown.

A320 family values & aftermarket activity

The availability of A320 family aircraft has dried up, and values and lease rates have strengthened as a consequence. Values and lease rates are analysed.

The large number of A319s, A320s and A321s built, and their popularity with lessors, mean that they are often offered for lease or sale. Recent US airline bankruptcies have made additional aircraft available. But they remain much in demand and, in today's strong market, lease rates and trading values continue to firm. Values for the newest, smaller A318 remain relatively strong as sales grow.

The A320 family is one of the most successful commercial jet programmes. Its 918 orders in 2005 exceeded the previous annual sales record for any jet airliner family. The next industry downturn may affect delivery of A320 family aircraft ordered in 2005, but it is still more popular now than any other type.

Although the 11 initial-model A320-100s had CFM56-5A1 engines, from the outset the A320-200 (1988), the A321 (1994) and A319 (1996) were offered with either the CFM56 or V.2500.

At first airlines found the -A1, the initial V.2500 variant, less reliable than the CFM56-5A, but John Leech, Orix Aviation Systems' head of marketing, says that things have changed. IAE V.2500-A1 engines now have mean times between removals (MTBRs) of 12,000-14,000 flight hours (FH), while Mexicana even achieved 17,000FH with one of its -A1s.

Sales of CFM56-powered A320s exceeded those of aircraft powered by the V.2500. IAE improved the reliability of its engines, and the A320 market split evenly with the introduction of the CFM56-5B/P series and V.2500-A5 series. Slightly more operators use IAE engines, while slightly more aircraft are powered by CFM engines. While Leech says that there remains a small lease rate premium for CFM56-5A versus V.2500 power on the oldest A320-200s, Bryson Monteleone, managing director of global sales and marketing for Morten Beyer & Agnew (MBA), says that there is "no measurable difference" in lease rates between aircraft with CFM56-5B or V.2500-A5 power.

The market for A320-family aircraft is always active. "Aircraft are constantly being leased and placed," says Doug Kelly, vice president of asset valuation for Avitas. Airclaims currently lists 27 A319s, 18 A320s and four A321s in storage, but it is clear that many are undergoing maintenance checks and repainting before shortly going to new lessees.

The failure of Independence Air and Flyi, and the Chapter 11 bankruptcy of Northwest Airlines, have put at least 22 A319s on the market. CIT Aerospace has placed its four ex-Independence Air aircraft with the new Mexican low-cost carrier Volaris, however, and ILFC is believed to have secured new lessees, including Turkey's Izmir Airlines, for at least some of the eight ex-Flyi A319s that it has parked at Lake Charles, Louisiana. However, the rejection by Northwest of leases on 10 A319s and three A320s close to heavy checks, and now parked at Marana, Arizona, has created a surplus.

These surplus aircraft and 25 A320s advertised in January, prompt Kelly to suggest that "some softness may still exist in the A320-family leasing market". Yet the number available is a reflection of the number built, and A320s and A319s undoubtedly continue to find operators.

Monteleone says that, since 2005, leasing prospects for the A320 family have improved. As industry demand for capacity increases and airlines worldwide bolster or launch operations with A320-family aircraft, lease rates on the oldest A320-200s have strengthened by at least $30,000 a month. New or recent-build A320s are achieving lease rates close to those of comparable 737-800s, which did not suffer as much in the downturn.

Early production A320s

"An average airline credit should be able to negotiate a rental of $155,000-$179,000 for a five-year lease on a half-life, 1989, IAE-powered A320-200," says Leech, whose company Orix owns several older V.2500-A1-powered aircraft.

"The current market value (CMV) of a 1988 A320-200 powered by a CFM56-5A is $13.5 million," comments Owen Geach of Bureau Veritas, "but a 1988 V.2500-A1-powered aircraft may sell for $2 million less. The CMV of a 1989, CFM-powered A320 is $14.5 million and for a 1990 aircraft it is $15.1 million."

Geach continues that the CFM-powered 1989 A320 should attract a monthly lease rate of $150,000-$169,000, and a 1988 aircraft $143,000-$160,000. Northwest Airlines recently renegotiated its lease rates on 1992 and 1993 A320s to $165,000, but these were probably aircraft nearing heavy checks.

Meanwhile, lease rates for the oldest A320-200s still appear to be rising. A rental of $200,000 is being sought for a 1989, CFM-powered A320 available from summer 2006, according to one lessor. "Even CMVs for 1987-88 A320-100s are holding up surprisingly well at about $8.3 million today," says Geach.

Mid production A320s

The A320's production mid-point was in 1996 and 1997. No rental premium is evident for a CFM56-powered A320 compared with a V.2500-powered aircraft of this age. A 1996, half-life A320 on a five-year lease to an average credit will now attract a monthly rental of $225,000-$249,000, a 1997 A320 a rental of $235,000-$260,000 and a 1998 aircraft a rental of $245,000-$270,000.

The CMV of a 1997 A320 is $24.9 million, so the value loss for aircraft in that age band is $1.3 million for each preceding year of build. Both the top and bottom values in the monthly rental ranges for A320s built in the mid-production period are falling by $10,000 for each year of age. Monthly rental values are falling by only $5,000-$7,000 per year of age for much older A320s, but by nearly $20,000 for newer ones.

Today a brand-new A320 entering a five-year lease should have a rental in the $357,000-$395,000 range. Aer Lingus was recently quoted a $375,000 rate, according to one executive. "However, a 2005 aircraft would now lease for $340,000-$378,000," says Geach.

"The actual price paid for new aircraft cannot be taken in isolation," says Leech. "Customers and appraisers, must take into account not only the manufacturer's net pricing, but also the after-sales support on offer, the airframe and engine warranties available, the residual value and/or first-loss deficiency guarantees that the maker is willing to provide, and the relationship between the manufacturer and the customer."

As a result, while Airbus is known to have priced new A320s at $36 million net, and Leech says it is still cutting deals for $38-$40 million, CMVs for new A320s delivered under smaller orders, or for sale/leasebacks of new aircraft are now in about $44 million. This is close to (and in some cases even higher than) Boeing's net prices for 737-800s. A 2005 A320 now has a CMV of $42.3 million.

"Although the -A5 is now IAE's standard V.2500 engine variant, the V.2500-A1 was available for new A320s until 2003. A 2003 A320 powered by -A1 engines now has a CMV of $33.8

million," says Geach. "An A320 built in either year and powered by the later V.2500-A5 should be more expensive."

A319s

The oldest A319 is eight years younger than the oldest A320-200. Monteleone says that A319s' youth and continuing attractiveness to operators mean that they were retained by airlines throughout the downturn, and fell less in value than A320s. A319 values mirrored those of 737-700s too. "Today, a five-year lease of a 1996, half-life A319 to an average credit should attract a monthly rate of $204,000-$219,000," says Geach. The A319's mid-production point is 2000-2002: a 2000 A319 should attract a rental of $231,000-$253,000; a 2001 aircraft $240,000-$260,000; and a 2002 A319 $252,000-$276,000. A 2005 A319 will achieve a lease rate of $290,000-$325,000 and a 2006 A319 a little more.

The CMV for a new A319 delivered now is $38 million, for a late-2005 model $37.3 million, and for an early-2005 one below $37 million. However, net prices of $33-$34 million have recently been realised. Today, the CMV for a mid-production 2002 A319 is $29.5 million, for a 2001 aircraft $27.6 million and for a 2000 A319 $25.8 million. The CMV of aircraft built in the downturn falls by nearly $2 million for each additional year of age. The CMVs of the oldest A319s, built early in 1994, will be $16 million.

A321s

The A321 was first delivered in 1994. For a year only the shorter-range A321-100 was built, but Airbus then offered an A321-200 version whose maximum gross take-off weight (MTOW) could be upgraded to provide additional range or payload if necessary. While both the A321-100 and the A321-200 feature the same 2,200nm basic range with typical payload, the A321-200's fuel capacity can be upgraded to operate 3,000nm sectors. Airbus still offers both variants, but the A321-200 has become more popular.

"In today's market a 2005 A321-100 should realise a lease rate of $361,000-$387,000, and a 2005 A321-200 $369,000-$409,000," says Geach. Some net prices may be lower, particularly for lessors or carriers buying in volume, but the CMV of a new A321-200 is near its theoretical book value of $48 million. The same goes for a new A321-100, whose book value is $47 million. Since A321 deliveries began in 1994, the mid-production point is currently 2000. An A321-100 delivered in 2000 will lease for $281,000-$306,000 and an A321-200 for $293,000-$330,000. A 1997, early-production A321-200 will lease for $260,000-$300,000, while a A321-100 from 1994, the first year of build, has a CMV of $22.5 million and will lease for $220,000-$245,000.

A318s

Airbus's newest A320-family variant, the A318, has been dismissed as a niche type with limited market appeal, but sales have been galvanised by the A318 Elite corporate jet, 10 of which were sold immediately after launch. The 26 already in service are being joined by 22 in 2006, and 18 in 2007. The first was delivered in 2003. The orderbook totals almost 100, but Air Cairo's order for six has become an order for four A320s. ILFC's order may also be changed to A320s or A319s.

"A318 CMVs and lease rates remain theoretical, as there have been no trading transactions and leases, but for an aircraft delivered now the CMV would be $32.2 million," says Geach. "A 2005 A318 has a CMV of $30.6 million and a lease rate of $214,000-$238,000. A 2004 A318's CMV will be $27.9 million and its lease $206,000-$226,000. A 2003, first-year-build A319's CMV will be $25.75 million and its rental $195,000-$214,000." AC