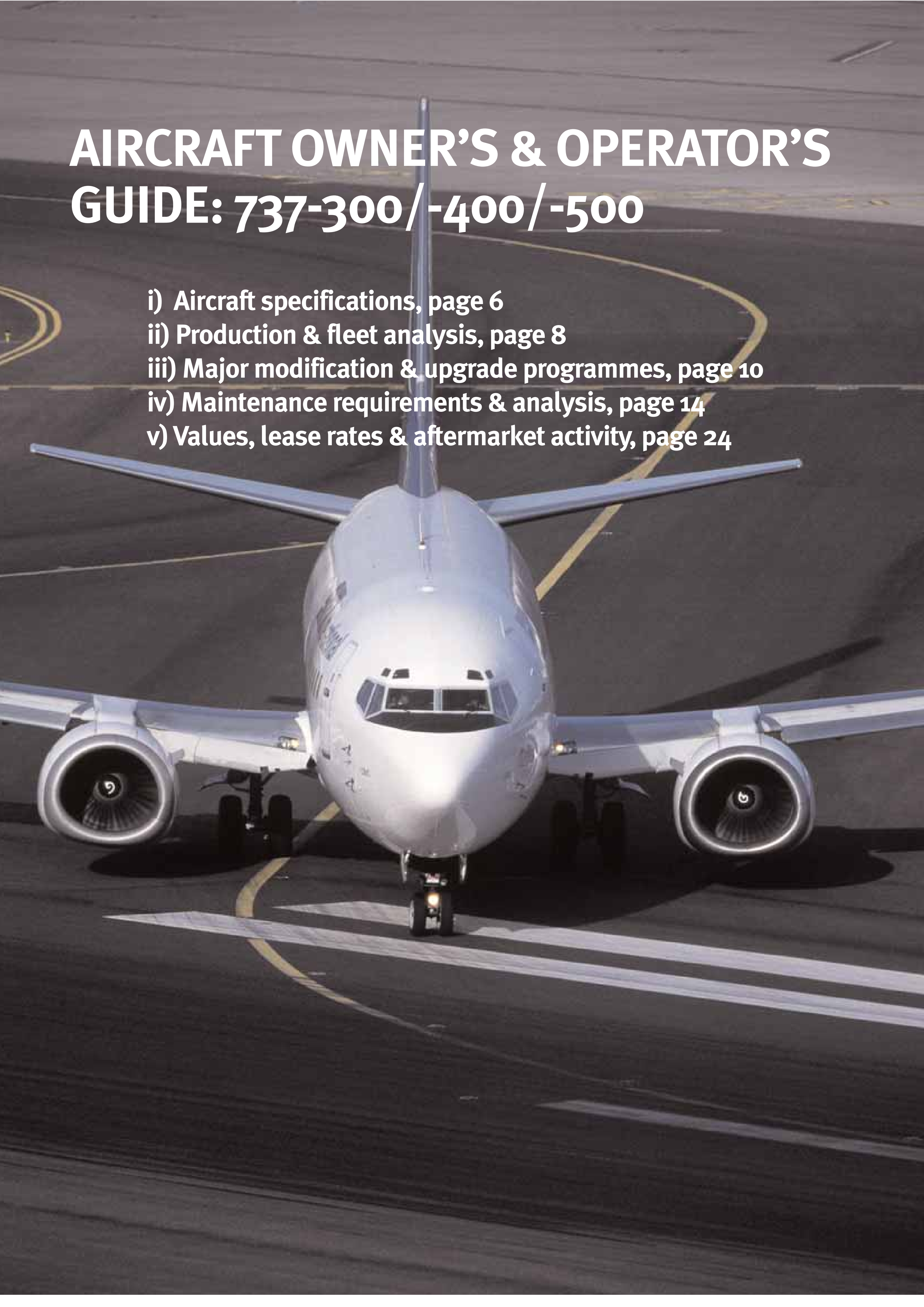
AIRCRAFT OWNER'S & OPERATOR'S GUIDE: 737-300/-400/-500



737-300/-400/-500 specifications

The 737-300/-400/-500 is available with three different engine variants and multiple MTOW & fuel tank options.

The second generation 737-300/-400/-500 family is one of the most popular short-haul workhorses, particularly for the growing number of low-cost carriers. The various combinations of gross weight, range and engines of the 737 –300, -400 and –500 are detailed in this section.

In total, 1,988 737-300/-400/–500s were built between January 1984 and December 1999. Of these, 1,113 were the –300 variant, 486 were the larger –400 and the remaining 389 were the smallest –500. The last aircraft built was a -400 for CSA Czech Airlines.

The family was launched with entry into service (EIS) in November 1984 with a -300 for US Airways: line number 1001. The airframe shares 80% commonality of spare parts with the earlier 737-200. Other internal changes compared to the -200 include materials and systems improvements first developed for the 757 and 767, including an early generation EFIS flightdeck (with four colour CRT screens). Soon demand for a larger capacity aircraft, partly as a 727 replacement with family commonality with the 737–300, led to the introduction into service in January 1988 of the stretched –400, which added ten feet accommodating three extra seat rows. This increased capacity by 19 seats.

The –500 was launched by Southwest and entered service in 1990 to serve some of its less dense point-to-point routes. It had almost the same fuselage length as the -200, which gave it three seat rows and 18 seats fewer than the -300. The -500's main appeal is for operators of large 737-300 and -400 fleets. Although the -500 is a shortened development of the -300, the -500 still carries much of the structural weight needed for the larger models. This makes the -500 less efficient than if it was designed specifically for its size category. The -500's extensive commonality benefits more than compensate for this, however.

A variety of engine options were introduced by CFMI for the -300/-400/-500. The CFM56-3 was launched on the 737-300 in its –3B1 variant, initially rated at 18,500 lbs thrust. It had the characteristic "squashed" engine cowl to accommodate the fact that it was a high-bypass ratio engine, with a significantly larger fan diameter compared with the Pratt & Whitney JT8D on the earlier 737-100 and –200. Two other main CFM56-3 variants are available at various thrust ratings: the –3B2 and the –3C1. There is a degree of interchangeability across the family.

There is also an option to install integral forward airstairs on all 737-300/-400/-500 models.

Specifications

-300 series

The –300 model can accommodate 140 passengers in an all-economy six-abreast configuration at a 32-inch seat pitch. This increases to 149 at a higher density 30-inch pitch. Major US operators, like the launch-customer US Airways, configured the aircraft with a two-class cabin, with eight first class four-abreast seats and 120 six-abreast economy seats, totalling 128 passengers.

The initial –300 model has a maximum take-off weight (MTOW) of 124,500lbs and fuel capacity of 5,311 USG *(see table, page 6)*. This is powered by the CFM56-3B1 rated at 20,000 lbs thrust. There are two other MTOW variants for this engine variant. These are the 130,000lbs MTOW with fuel capacity of 5,701USG (which is achieved with a 390USG Boeing-installed auxiliary fuel tank in the aft cargo compartment) and the 135,000lbs MTOW with fuel capacity of 6,121USG (using an 810USG Boeing-installed auxiliary tank in the aft cargo compartment).

With the CFM56-3B2 engine variant, rated at 22,000lbs thrust, MTOWs increase as do fuel capacities, again using auxiliary fuel tanks in the aft cargo hold. These are MTOWs of 137,000lbs, 138,500lbs and 139,500lbs with fuel capacity of 5,803USG (500USG Rogerson-installed auxiliary tank), and 6,295USG (1000USG Rogerson-installed auxiliary tank) for the two higher weights *(see table, page 6)*. A derated CFM56-3C1 was also introduced with these MTOWs in 1988 after the -400 was made available.

Range with 128 passengers and standard fuel is 1,815nm, while range with 128 passengers and maximum fuel is 2,685nm. The high gross weight version has maximum range of 3,400nm with 140 passengers.

There are three main variants. Each can be powered by engines with two different thrust ratings. More than 1,100 aircraft are the -300 variant, and nearly 500 are the largest -400 variant.

737-300/-400/-500 SERIES SPECIFICATIONS

Variant	-300	-300	-300	-300	-300	-300
MTOW lbs	124,500	130,000	135,000	137,000	138,500	139,500
Fuel volume USG	5,311	5,701	6,121	5,803	6,295	6,295
Engine	CFM56-3B1	CFM56-3B1	CFM56-3B1	CFM56-3B2 /-3C1	CFM56-3B2 /-3C1	CFM56-3B2 /-3C1
Engine thrust rating lbs	20,000	20,000	20,000	22,000	22,000	22,000
Seats	128/140	128/140	128/140	128/140	128/140	128/140
Variant	**-400**	**-400**	**-400**	**-400**	**-400**	**-400**
MTOW lbs	138,500	142,400	150,000	142,500	143,500	150,000
Fuel volume USG	5,311	5,701	6,121	5,803	6,295	6,295
Engine	CFM56-3B2	CFM56-3B2	CFM56-3B2	CFM56-3C1	CFM56-3C1	CFM56-3C1
Engine thrust rating lbs	22,000	22,000	22,000	23,500	23,500	23,500
Seats	138/159	138/159	138/159	138/159	138/159	138/159
Variant		**-500**	**-500**	**-500**	**-500**	**-500**
MTOW lbs		115,500	124,500	133,500	124,500	133,500
Fuel volume USG		5,311	5,701	6,121	5,803	6,295
Engine		CFM56-3B1	CFM56-3B1	CFM56-3B1	CFM56-3B1	CFM56-3B1
Engine thrust rating lbs		18,500	18,500	18,500	20,000	20,000
Seats		108/122	108/122	108/122	108/122	108/122

-400 series

The larger –400 model can accommodate 159 passengers in an all-economy layout at a 32-inch seat pitch. This is achieved with a six-feet fuselage plug insertion forward and another four-feet plug insertion rear of the wing. Seat capacity increases to 168 at a higher density 30-inch pitch. Some major US airlines operate with a two-class cabin layout, with eight first class four-abreast seats and 138 six-abreast economy seats.

The initial basic –400 model has an MTOW of 138,500 lbs and fuel capacity of 5,311 USG. This is powered by the CFM56-3B2 rated at 22,000lbs thrust, the same engine as the high weight -300.

There are two other MTOW variants for this particular 22,000lbs engine variant. These are the 142,500lbs MTOW with fuel capacity of 5,701USG (which is achieved with a 390USG Boeing-installed auxiliary fuel tank in the aft cargo compartment) and the 150,000lbs MTOW with fuel capacity of 6,121USG (using a 810USG Boeing-installed auxiliary tank in the aft cargo compartment). The higher gross weight aircraft have strengthened undercarriages.

The higher thrust CFM56-3C1 engine variant, which entered service in September 1988, and is rated at 23,500lbs thrust, allows MTOWs and fuel capacities to increase. Higher fuel capacity is again achieved using auxiliary fuel tanks in the aft cargo hold. The different versions are MTOWs of 142,500lbs, 143,500lbs and 150,000lbs. The first has a fuel capacity of 5,803USG (500USG Rogerson-installed auxiliary tank), and the two higher weights have a 6,295USG fuel capacity (Rogerson-installed 1,000USG auxiliary tank).

The CFM56-3C1 can also be de-rated for use on the 737-300 and –500. The –3C1 is the most numerous of the CFM56-3 family and superseded the –3B2 and –3B1.

The -400's standard range with maximum payload is 2,160nm, while typical range with 146 passengers is 1,960nm. Their range of the high gross weight option with 146 passengers is 2,080nm. Its transcontinental US range made it an ideal 727 replacement.

-500 series

Originally designated as the 737-1000, the smaller –500 model is a direct replacement for the 737-200 and can accommodate 122 passengers in an all-economy configuration at 32-inch seat pitch. This increases to 132 at a higher density 30-inch pitch. In a two-class cabin layout, with eight first class four-abreast seats and 100 six-abreast economy seats, but airlines rarely use this aircraft in this configuration.

The initial basic –500 model has an MTOW of 115,500lbs and fuel capacity of 5,311USG. This is powered by the CFM56-3B1 rated at 18,500 lbs thrust, the same engine as the low weight 737-300. There are two other MTOW variants for this thrust rating of the –3B1. These are the 124,500lbs MTOW with fuel capacity of 5,701USG (which is achieved with a 390USG Boeing-installed auxiliary fuel tank in the aft cargo compartment), and the 133,500lbs MTOW with fuel capacity of 6,121USG (using an 810USG Boeing-installed auxiliary tank in the aft cargo compartment).

With the same CFM56-3B1 engine, up-rated at 20,000lbs thrust, there are two further MTOWs available. The 124,500lbs MTOW has a fuel capacity of 5,803USG with the 500USG Rogerson-installed auxiliary tank, and the 133,500lbs MTOW has a fuel capacity of 6295USG with the 1,000USG Rogerson-installed auxiliary tank.

Standard range with maximum passengers is 1,520nm, while the higher gross weight option has a range of 2,400nm with maximum passengers. AC

737-300/-400/-500 fleet analysis

Most 737-300/-400/-500s remain in service. Aircraft are in operation with a wide variety of weight specifications & engine variants.

Of the 1,988 737-300s, -400s and –500s built, more than 1,872 are still in service. Analysis of the fleet shows that there are a good number of quality aircraft in operation.

Of the nearly two thousand aircraft built, 1,113 were the –300, 486 were the larger –400 and 389 were the smallest –500. There are 1,045 -300s active, 467 -400s active and 360 -500s active.

Of the stored aircraft, 50 are -300s, only five are -400s and 26 are -500s. Most of the stored -300s are United Airlines aircraft, with between 40,000 to 45,000 flight hours (FH) and 26,000 to 30,000 flight cycles (FC). They are all CFM56-3C1 powered and have a maximum take-off weight (MTOW) of 130,000lbs. The stored -400s have a total time of about 35,000FH and 20,000FC and are lessors' aircraft. The stored -500s are mainly United aircraft again, and are similarly CFM56-3C1 powered. They have an average time of 35,000FH and 25,000FC, and are the 123,500lbs MTOW variant.

The largest fleets of all variants (-300/-400/-500) belong to America West, China Southern Airlines, Continental Airlines, Delta, EasyJet, KLM, Lufthansa, Garuda, Southwest Airlines, THY Turkish Airlines, United Airlines, US Airways and Varig.

Some airlines have already begun to replace their 737-300/-400/500s with 737NGs or A320 family types, although the global 737-300/-400/500 fleet shows no real sign of decline overall. There is some activity in conversion of some older aircraft to freighters, but there has been a surge in demand for passenger-configured aircraft over the past year and supply has diminished.

-300 series

Of the 1,113 737-300 series aircraft built, 1,045 remain in service. Fifth of the remainder are stored. Most are ex-United Airlines aircraft.

The first -300 built was line number 1001, built for USAir, in January 1984. The last to be manufactured was for Air New Zealand in November 1999: line number 3130.

Southwest Airlines has the largest fleet, with 194 aircraft built between 1984 (line number 1037) and 1997 (line number 2932). The fleet is predominantly powered by the CFM56-3B1 and has a 130,000lbs MTOW and 6,291 US Gallons (USG) fuel capacity. About half of these have accumulated more than 40,000FH, with the oldest at 65,140FH and 63,612FC. The remainder average about 30,000FH and 29,000FC. They are all configured with 137 seats in an economy layout.

Half of all active -300s are powered by the CFM-3B1, with 23% (256 aircraft) equipped with the -3B2 and just 27% (294 aircraft) with the higher rated -3C1. In terms of seat configurations, 576 are in a two-class 120- plus eight-seat configuration. Another 288 are in normal economy 134- to 140-seat configuration, and 186 are in ultra-high density 148-seat layout.

The 67 highest gross weight aircraft at 139,500lbs MTOW, powered by -3C1s, are operated largely by Aegean, Air New Zealand, America West, EasyJet, Southwest and Garuda. These aircraft were mainly produced after 1990 and include some of the first -300QC conversions. Most -300s have lower MTOW of 130,000lbs to 135,000lbs.

There are large fleet operators and mid-sized secondary operators like Airasia, bmiBaby, Comair, DBA, Frontier Airlines, GOL, Hainan, Jetconnect, Norwegian Air Shuttle, Pace Airlines, PIA, Philippine Airlines, Rio Sul, Shangdong Airlines and Shenzhen Airlines. There is also a plethora of small scheduled airlines and charter operators, or airlines with small sub-fleets.

-300 Freighter

By 2005, 52 737-300s had been converted to freighters, but the number being converted is increasing. The youngest aircraft converted was built in 1997, and operates with Air Austral.

Pemco completed conversion of the first quick change 737-300QC in 2003. Pemco also converts to pure freighters as the 737-300SF. One major operator is Europe Airpost. Other freighter operators include Bluebird Cargo (IAI Bedek and Pemco -300SF), Channel Express (-300SF from IAI Bedek), China Southern/China Post (Pemco -300QC), TNT Airways (-300SF from IAI Bedek) and Yangtze River Express Airlines (Pemco -300QC).

Kitty Hawk became the first 737-300SF operator in North America, taking delivery in early 2005.

The majority of 737s are -300s. Half of these are powered by the CFM56-3B1, while just less than 300 are equipped with the -3C1 engine. Many -300s have now reached mature age.

There are almost 500 active -400s, and most of these are powered with the -3C1 engine. The -400 is the variant in highest demand on the used market.

-400 series

Of the 486 737-400 series aircraft built, 467 are still active. Five of the remainder are stored. The first -400 aircraft built was for the now defunct Piedmont Airlines (line number 1487) in January 1988. The last was built almost 12 years later in December 1999 for CSA Czech Airlines, and remains with it in service.

USAirways has the largest fleet of -400s. All 46 of these aircraft are CFM56-3B2-powered, have the lower MTOW of 142,500lbs, and are equipped with 144 seats in a two-class configuration. These aircraft represent some of the older -400s with total time exceeding 40,000FH and 20,000FC. Malaysian is close behind with 38 aircraft, all with an average total time of 27,000FH and 27,000FC.

Other major -400 operators are Air One, Alaska Airlines, British Airways, CSA Czech Airlines, Garuda, Japan Transocean Air, KLM, Malaysian Air System, Olympic, Qantas and THY Turkish. Most of the -400 fleet are 'middle aged', with two-thirds of the fleet having a total time of up to 40,000FH and 20,000FC. About a third of the fleet is the high gross weight 150,000lbs MTOW variant, with the other three lower weight variants being equally represented.

Most -400s are powered by the CFM56-3C1. In detail, 383 -400s have the CFM56-3C1, and 65 have the -3B2. Only 18 have the -3B1 variant, all of which are operated by Alaska Airlines. Most 737-400s are configured in a two-class 144- to 150-seat layout. Only 50 are in the high-density 170 seat, all-economy layout.

Secondary -400 operators include Aegean Airlines, Aerosvit Airlines, Air Algerie, Air Europa, Air Gabon, Blue Panorama Airlines, China Xinhua Airlines, Hainan Airlines, JAL Express, JAT Airways, Lion Airlines, MNG Airlines, TUI Airlines Belgium, and Virgin Express.

Some carriers have started to phase the -400. Lufthansa has disposed of all its -400s. BA has phased out six relatively young aircraft. Aer Lingus has two of its original six, both of which are aircraft with less than 35,000FH and 25,000FC. Malaysian Airlines has reduced its fleet by three aircraft. Its remaining aircraft have interesting potential for acquisition.

Alaska Airlines is to have four of its 737-400s converted to a fixed 70-passenger/four pallet configuration. One aircraft will be retrofitted to full cargo configuration. The aircraft will replace the airline's retiring 737-200s.

-500 series

The smallest of the classic 737s, the -500, was introduced as the last member of the family. Of the 389 737-500 series aircraft built, 360 are still active. Of the remainder, 26 are stored or inactive.

The first -500 aircraft built was for Southwest Airlines, line number 1718, in May 1989. The last was line number 3116, built in June 1999. Most -500s have stayed with their original operator.

Because it is a shrink of the original -300, the trip costs of the -500 are the lowest for the family. These make it an attractive aircraft for small operators, or start-ups, which wish to take a lower risk on filling aircraft on new or thin routes. It is also a good aircraft to serve point-to-point routes in markets like the US.

The largest fleet of -500s by far is Continental Airlines with 64, all of which are currently active. Half are fitted with the lower rated CFM56-3B1 engine and the remainder have the newer, higher rated CFM56-3C1. They are all the low gross weight basic version with a MTOW of 115,500lbs, and have a 5,307USG fuel capacity and 104-seat, two-class configuration.

They were all built after December 1993 and have an average total time of about 30,000FH/23,000FC. Aircraft range from 16,000FH/9,000FC up to 31,500FH/16,500FC.

United has the next largest fleet, with 38 of the heavier 123,501lbs MTOW -3C1 powered variant, again with a 104-seat, two-class layout. These all have a total time of about 37,000FH/27,000 FC, and six are in storage. Four of United's aircraft have been sold to Canjet Airlines.

Other large -500 fleets are with Air France, All Nippon Airways (ANA), BA (all used), China Southern Airlines, CSA Czech Airlines, Lufthansa, SAS Norway (Braathens) and Southwest Airlines.

Airlines that have phased them out, or are beginning to phase them out, are SAS Norway (Braathens), Maersk and Malaysian.

There are 111 aircraft with the lowest MTOWs between 108,000lbs and 115,500lbs. Another 211 aircraft have intermediate MTOWs between 116,500lbs and 124,500lbs. There are another 62 aircraft with highest MTOWs between 127,500lbs and 133,500lbs.

One-third of the -500 fleet are equipped with the lowest thrust CFM56-3B1, and two-thirds with the highest thrust -3C1 variant. Only three ANA aircraft have the CFM56-3B2.

Secondary -500 operators include small regional carriers and some start-up low-cost carriers in Europe. The -500 also forms a small part of larger mixed 737 fleets. Operators include Aerolineas Argentinas, Air Baltic, Bmibaby, Britannia Airways, DBA, Estonian Air, Garuda Indonesian Airways, Hapag-Lloyd Express, LOT Polish Airlines, Luxair, Maersk Air, Royal Air Maroc, VARIG and Xiamen Airlines.

While not many are readily available, there are a number of low- to middle-aged aircraft that would be interesting for start-up or small airlines increasing aircraft size. CFM56-3C1-powered aircraft are most attractive. AC

737-300/-400/-500 modification programmes

The 737-300/-400/-500 remains viable for passenger operations. A range of performance modifications & engine upgrades are available, in addition to mandatory avionic upgrades and freighter conversion programmes.

There is a wide range of mandatory and voluntary upgrades and modifications for the 737-300/-400/-500 that enhances their operatibility and allows continued operation. These modifications include several passenger-to-freighter conversions for the -300 and -400.

Besides conversion to freighter, the main modification and upgrade programmes for the 737-300/-400/-500 family include: performance enhancement kits; auxiliary fuel tank installations; CFM56-3 engine upgrades; and avionics installations.

Performance enhancement

Aviation Partners Boeing

Some of the design work that has been done for the 737NG family (-BBJ/-600/-700/-800/-900) has benefited the classic family. Aviation Partners Boeing (APB) has certified the Blended Winglet modification, originally developed for the 737-BBJ business jet and the 737-700/-800, for the 737-300. It is not yet available for the -400 or -500.

Aircraft modified with Blended Winglets carry the SP suffix on their variant number to designate for special performance. Launched by AirPlus Comet on the 737-300 programme, the Blended Winglet received FAA certification on May 30th 2003. "We anticipate extensive market penetration with our Blended Winglets for the 737-300 and -400," says Sheldon Best, vice president of sales at Aviation Partners Boeing. "Blended Winglets pay off in fuel savings, performance improvements and environmental benefits."

"The total block fuel saving benefit of a 737-300SP is up to 4.5%, about half a per cent better than we've achieved with 737NGs," says Mike Marino, chief executive officer at APB. "The average 737-300, flying 2,900 flight hours (FH) per year with an average flight cycle (FC) time of 1.5FH, will save over 65,000 US gallons (USG) of fuel per year."

The environmental benefits of Blended Winglets include reduced noise on take-off and landing, decreased engine emissions, and reduced engine maintenance requirements. Installation requires a revision to the avionics and flightdeck to install the Load Alleviation System (LAS) controller and LAS speedbrake auto-Stow mechanism. LAS is not required for aircraft with an MTOW of less than 125,000lbs. A full suite of manual supplements is delivered with the Blended Winglet modification.

The modification is estimated to take 2,260-2,360 manhours (MH) and has a span time of eight to 10 days. The list price is $450,000 for the 737-300.

Operators look at the winglet modification for a number of economic reasons, but it also improves performance from airports with operating limitations. Another benefit comes from reduced engine maintenance costs. Lower thrust levels extend on-wing life and reduce EGT margin degradation. Take-off thrust levels typically are reduced by about 3% and cruise thrust levels by about 4%. The final benefit is higher residual value for the aircraft, since its operational life is longer than an un-modified aircraft's.

The main purpose of the Blended Winglet is to reduce wingtip vortice drag, which reduces fuel burn on all phases of flight. The largest fuel savings are made with the longest stage lengths. Fleet studies show that average sector lengths for the 737- 300 and -400 are 750-980nm. In both cases, the average reduction in block fuel is about 3.2%. Fuel burn reduction for longer routes is up to 5%. The 737-300's fuel burn of about 1,550USG for a 750nm trip length will be reduced by about 55USG. Annual utilisations for many US and European and other similar operations generate 1,800 flight cycles (FC) each year. At these rates of utilisation, total fuel burn saved will be about 100,000USG, equal to $121,000 per aircraft annually *(see table, page 11)*. This will allow operators to realise a payback from installation of the kit in five to six years, based on acquiring the kit at list price.

There are three performance modifications available for the 737-300. These all reduce drag with the consequence of reducing fuel burn by 3-5%, depending on modification. At current fuel prices, the cost of these upgrades are paid for within 18-60 months.

AvAero

Performance enhancement modifications do not all involve major structural changes. One provider of enhancements for the 737 classic family is AvAero from Florida, which offers its FuelMizer modification. Based upon enhancing the aerodynamic effectiveness of the wing, FuelMizer is an FAA-approved modification for the 737 classics, including the freighter version of the aircraft. AvAero claims the FuelMizer is the only wing modification for the 737 -200, -300, -400, & -500 series designed to improve lift and aerodynamic performance without costly structural modifications. FuelMizer enhances the aerodynamic efficiency of the wing by increasing the aircraft's lift-to-drag ratio. By reducing induced drag, a by-product of lift, the FuelMizer modification is able to deliver typical fuel savings of up to 4%. The aft segments of the trailing edge flaps are relocated aft and below their standard locations when in the retracted position. These changes result in increased wing area, and airfoil camber, and a lengthened wing chord. AvAero calculates typical fuel savings of between 50 and 80 USG per flight, depending on stage length. A 90 minute flight time and annual utilisation of 1,800FC would save about 90,000USG and $107,000 per year *(see table, this page)*. The AvAero kit has a list price of $135,000.

Importantly there is no change to operational or flight procedures. One recent customer is Kitty Hawk, which has chosen to install the AvAero FuelMizer solution for its 737-300SFs in conjunction with a passenger-to-freighter conversion from Bedek.

Based on test flights with other airlines, Kitty Hawk expects to realise as much as a 4% fuel saving. In typical use, the modification can reduce jet fuel consumption by thousands of gallons per year per aircraft.

Quiet Wing Technologies

Quiet Wing Technologies Inc has developed a new noise reduction and performance kit for the 737-200 and 737-300/-400/-500 series. Customers have the option of installing just the wing configuration changes for added performance (performance kit) or the acoustic treatments and wing configuration changes (noise and performance kit), with the additional option of adding winglets to either configuration for further performance and fuel savings. The overall effect is improved operating performance and reduced fuel burn, plus a reduction in aircraft noise, which helps the aircraft achieve Stage 4 compliance.

Total list price for the noise, performance and winglet kit ranges between $295,000 and $645,000, depending on options and the original configuration of the aircraft being modified. An additional cost is installation. The performance kit alone requires about 1,200MH, which adds $60,000. Installation of the winglets requires a further 600MH, adding another $30,000.

The reduction in drag relates to a reduction in fuel burn through all phases of flight. Savings in fuel burn are 2-3% for modified aircraft without winglets and 5-6% with winglets installed.

At an annual utilisation of 1,800FC, the performance kit will save about 67,000USG of fuel and about $81,000, while adding the winglets will increase the savings to 112,000USG of fuel and $134,000 *(see table, this page)*.

It is not yet clear what operating performance and payload enhancements the 737-300/-400/-500 will gain from the kit, but the additional available payload and revenue generated will reduce the payback period for investing in the kit. Kits for 737 classics will be available after FAA flight testing and receiving STC.

PERFORMANCE UPGRADE PROGRAMMES FOR THE 737-300

Modification programme	APB Blended Winglet	AvAero FuelMizer	QuietWing Performance	QuietWing Performance & Winglet
Kit list price	$450,000	$135,000	$400,000	$550,000
Install MH	2,000	250	1,200	1,800
Install cost	$100,000	$12,500	$60,000	$90,000
Annual FC	1,800	1,800	1,800	1,800
Fuel burn improvement	4.50%	4.00%	3.00%	5.00%
Annual fuel saving USG (Average 90 minute flight time)	100,800	89,600	67,200	112,000
Annual fuel saving (Fuel at $1.2 per USG)	120,960	107,520	80,640	134,400

Engine upgrades

The initial variant of the CFM56-3 was the -3B1, which was rated at 20,000lbs thrust and 18,500lbs thrust. The -3B2 was introduced and rated at 22,000lbs thrust, and the -3C1 was rated at 23,500lbs thrust. These could also be de-rated to lower thrusts, and so the -3C1 could be rated at all four thrust ratings.

There are three main upgrade kits available on the CFM56-3 series, all of which improve reliability: a major Time-On-Wing (TOW) extension; an Enhanced Performance kit; and an Enhanced Durability kit. These kits improve reliability.

Younger CFM56-3C1s reach more than 25,000 engine flight hours (EFH) before their first shop visit. Expected first-run life of more than 16,000EFH make these one of the most durable engines in operation. Older -3C1s, and -3B2s and -3B1s achieve shorter on-wing intervals than the youngest -3C1s.

The first major modification CFMI offers is the TOW; this is a core upgrade, based on CFM56-7B technology, which CFMI claims will save up to 1% specific fuel consumption. The kit also increases exhaust gas temperature (EGT) margins by about 15 degrees centigrade, thereby giving the engine about 1,500-2,500EFH. The TOW package costs about $1.2 million.

The kit features the same advanced three-dimensional high pressure compressor aerodynamics (3-D aero) and new high pressure turbine hardware as the CFM56-7B. The TOW modification was launched by Southwest Airlines in 2001 with an order for 300 kits.

Earlier build engines had problems with the HPT nozzle guide vane and other parts like C-clips. Some earlier build engines used X40 material for the high pressure turbine (HPT) nozzles of which the nozzle areas tended to open during operation, causing EGT margin to erode. A new material, DSR142, released in 1990, made the nozzles more stable so that EGT margin deterioration was not as rapid. As earlier build engines have gone through shop visits, their older hardware has been replaced with younger material, thereby improving their reliability and EGT margin deterioration rates.

Operations, average flight cycle time, route network, and ambient temperatures all have an impact on the rate of EGT

PAYLOAD CHARACTERISTICS 737-300SF/-400SF

Aircraft type	Bedek 737-300SF	Pemco 737-300SF	Boeing 737-300SF	Boeing 737-400SF
MZFW-lbs	109,600	109,600	109,600	113,000
OEW-lbs	66,500	68,298	68,100	71,050
Gross structural payload-lbs	43,100	40,802	41,500	41,950
Crew weight-lbs	500	500	500	500
Number maindeck containers	8 +1	8 + 1	8	9
Type maindeck containers	82/88/125	82/88/125	82/88/125	82/88/125
Unit tare weight maindeck containers-lbs	476/230	476/230	476	476
Unit volume maindeck containers-cu ft	440/152	440/152	440	440
Total tare weight maindeck containers-lbs	4,038	4,038	3,808	4,284
Total volume maindeck containers-cu ft	3,672	3,672	3,520	3,960
Lowerdeck volume-cu ft	1,068	1,068	1,068	1,376
Net structural payload-lbs	38,562	36,264	37,192	37,166
Total volume-cu ft	4,740	4,740	4,588	5,336
Maximum packing density-lbs/cu ft	8.24	7.65	8.10	7.00
Volumetric payload @ 7.0lbs/cu ft	33,180	33,180	32,116	37,352

margin deterioration and time on-wing between removals.

The need for performance and life improvement modifications on CFM56-3s therefore depends on the engine variant and build date, type of HPT nozzle guide vanes, and style of operation.

Earlier in 2004, CFMI launched two more upgrade kits: the Enhanced Performance kit and the Enhanced Durability kit, giving customers more flexibility in managing maintenance costs.

The Enhanced Performance kit includes the 3-D aero HPC blades and vanes, and provides increased exhaust gas temperature (EGT) margin that translates to as much as 40% longer on-wing life, depending on airline operations.

The Enhanced Durability kit reduces part scrap rates by 50%, thereby reducing maintenance costs. This kit is available now and CFMI has received four orders to date. KLM has ordered 31 Advanced Upgrades and Air China five.

Freighter conversion

The 737-300SF/-400SF (Special Freighter) and QC (Quick Change) are ideal successors for the 727-100 and 737-200. The 737-300SF/-400SF have an identical fuselage cross-section to the 727-100/-200, allowing them to use the same pallets and containers. There are three main freighter conversion programmes for the 737-300/-400. There is no freighter conversion available for the -500. Conversions are offered by Bedek Aviation in Israel, by Pemco, Alabama in the US, and by Boeing Airplane Services with the aircraft modified either by Goodrich in the US or InterContinental Aircraft Services (ICAS) in Taiwan.

Bedek Aviation

Bedek launched its conversion programmes for the 737-300 in June 2001, with a launch order from GE Capital Aviation Services (GECAS) to convert 15 aircraft to a Special Freighter (-300SF) configuration. Bedek's additional 737-300 conversion program is the 737–300QC (Quick Change).

The conversions have received their STCs from the leading aviation authorities (FAA, EASA, UK CAA and others). The 737-300SF received its STC in September 2003, and the 737-300QC ('Quick Change') received its STC in April 2004. The 737-400SF/QC STC is expected in the last quarter of 2006. The price for standard 737-300 conversion from Bedek is less than $3 million.

The 737SF conversion requires a 60-day cycle, and Bedek operates more than one conversion line. The conversion consists of removing all passenger-related interior items and associated wiring, and installing of freighter liners.

Floor beams are fitted as required to meet cargo load requirements, including the additional pallet (60.4-inch X 79-inch X 64-inch or 60.4-inch X 96-inch X 64-inch) in the rear position.

There are three standard 737-300SF maindeck cargo configurations. One main option is eight 88-inch X 125-inch X 82-inch containers plus one 60.4-inch X 96-inch X 64-inch container *(see table, this page)*. Each of the main containers has a tare weight of 476lbs and internal volume of 440 cubic feet. The nine containers therefore have a total tare weight of 4,308lbs and volume of 3,672 cubic feet *(see table, this page)*.

The specification weights are: maximum take-off weight (MTOW) 139,500lbs; maximum zero fuel weight (MZFW) 109,600lbs; maximum landing weight (MLW) 113,600lbs; and operating empty weight (OEW) 66,500lbs. Exact weights will differ for each customised configuration. This gives the aircraft a gross structural payload of 43,100lbs. An allowance of 500lbs for crew weight should be given.

The aircraft also has a lower deck volume of 1,068 cubic feet, taking total volume for freight to 4,740 cubic feet *(see table, this page)*. The crew weight and tare weight of containers give the aircraft a net structural payload of 38,562lbs.

This volume allows a maximum packing density of 8.2lbs per cubic foot. With freight packed at 7.0lbs per cubic foot, the aircraft has a volumetric payload of 33,180lbs.

Pemco

Pemco World Air Services is the other main provider of 737-300 passenger-to-freighter modification.

Following Pemco's modification, the aircraft will have an MZFW of 109,600lbs. OEW varies with conversion, with an average weight of 68,298lbs. This gives the aircraft a gross structural payload of 40,802lbs *(see table, this page)*.

The maindeck has capacity for eight standard containers and a smaller ninth container, with an internal volume of 152 cubic feet and tare weight of 230lbs. Total maindeck volume is therefore 3,672 cubic feet *(see table, this page)*. These nine containers have a combined tare weight of 4,038lbs, which takes the net structural payload to 36,264lbs *(see table, this page)*. The aircraft also has 1,068 cubic feet of space below the maindeck, taking total freight volume to

A small number of 737-300s have been converted to freighter. STCs will be available for -400 conversions from late 2006. Market forecasts predict about 250 737-300/-400s will be converted to freighter over the next 20 years.

4,740 cubic feet. The aircraft can thus have a maximum packing density of 7.65lbs per cubic foot. Freight packed at 7.0lbs per cubic foot generates a volumetric payload of 33,180lbs.

In October 2003 Pemco completed conversion of the first 737-300QC. "The QC aircraft is designed to provide maximum utilisation and revenue by allowing passenger use during the day and cargo operations at night," comments Hal Chrisman at Pemco World Air Services. "China Southern is a major customer for the QC. The first two 737-300 aircraft being delivered to China Southern will be QCs and the next two will be all-cargo aircraft. All four 737-300s are leased from GECAS."

Passenger seats in the 737-300QC aircraft can be removed within 45 minutes, so that the aircraft can be available for freight operations. Seats can be quickly locked back into place and ready for passenger service.

"Converted aircraft will be equipped with all of Pemco's latest upgrades, including the Pemco redesigned main cargo door," says Chrisman. "These features are unique to Pemco, and increase aircraft dispatch reliability and reduce maintenance costs." Each QC can accommodate eight cargo containers with a payload of about 38,000lbs, while the 737-300SF can carry nine cargo containers with a capacity of up to 40,000lbs.

Boeing Airplane Services

Boeing has entered the conversion market in a teaming agreement with Goodrich and ICAS, offering modifications for the -300SF and -400SF.

Under the agreement, all three companies worked together in a partnership to develop a 737 passenger-to-freighter conversion program. ICAS is an alliance of major Taiwanese companies, including Air Asia, China Airlines (25%), Evergreen Aviation Technologies, and Aerospace Industrial Development Corp. They are also members of Boeing Airplane Services' international network of modification and engineering facilities. A QC option is also being evaluated.

Under the agreement, the partnership is led by Boeing Airplane Services, which will provide proprietary data and technical expertise. The STC is owned by Boeing, ensuring that customers can obtain round-the-clock support from the Boeing global network of Field Service representatives.

ICAS and Goodrich perform aircraft modifications at their facilities in Taiwan and in Everett in the US.

The -300SF modification carries eight maindeck 88-inch x 125-inch pallets, providing 3,520 cubic feet of maindeck palletised volume and 1,068 cubic feet of bulk volume in the lower cargo hold. This takes total available volume to 4,588 cubic feet *(see table, page 12)*.

The specification weights are: MTOW 139,500lbs; MLW 116,600lbs; MZFW 109,600lbs; and OEW 68,100lbs. Maximum structural payload is 41,500lbs. Deducting tare and crew weight, the aircraft has a net structural payload of 37,192lbs *(see table, page 12)*. This gives the aircraft a maximum packing density of 8.10lbs per cubic foot.

For the -400SF, there are nine maindeck pallets providing a volume of 3,960 cubic feet. Combined with 1,376 cubic feet of bulk volume in the lower cargo hold, the aircraft's total available volume is 5,336 cubic feet. The specification weights are: MTOW 143,500lbs; MLW 121,000lbs; MZFW 113,000lbs; and OEW of 71,050lbs. Maximum structural payload is 41,950lbs. The container tare weight gives the aircraft a net structural payload of 37, 166lbs *(see table, page 12)*.

Avionic upgrades

There are various avionics upgrades that 737 -300/-400/-500 owners and operators need to consider.

The following modifications are mandatory on all aircraft in Europe. Two sets of VHF communication transceivers must be installed an operational with 8.33kHz frequency spacing above FL245.

Traffic collision avoidance systems (TCAS) have already been mandated. Terrain awareness and warning systems are also mandatory, currently known as enhanced ground proximity warning systems (EGPWS), but this requirement is expected to expand with technology.

Reduced vertical separation minima (RVSM) is mandatory in Europe and Atlantic ocean areas to support higher traffic densities.

The basic form of area navigation requirements (B-RNAV) is mandatory in Europe, with precision (P-RNAV) optional for now, but will soon be required to fly into major airports in the near future with preferential slots.

Mode-S transponders are also mandatory, with the Elementary and Enhanced Surveillance becoming mandatory in 2007.

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

Requirements vary widely outside Europe and North America, making it difficult to generalise. Radio spacing, TCAS and EGPWS are either mandatory already or in progress.

Typical costs for mandatory avionics modifications per aircraft are as follows: VHF radio spacing requires parts and wiring modification and costs about $110,000 and uses about 50 man-hours (MH), RVSM is typically $30,000 and 30MH, EGPWS/TAWS is about $80,000 and 100MH, and TCAS and Mode-S is $250,000 and 800MH. AC

737-300/-400/-500 maintenance analysis

The 737-300/-400/-500 have competitive maintenance costs for aircraft in their size class. Careful management of maintenance costs will ensure the aircraft remain economic.

The 737-300/-400/-500 was developed with a maintenance steering group 2 (MSG2) maintenance programme. Some airlines have bridged the aircraft on to an MSG3 maintenance programme. The 737's maintenance requirements include line maintenance, base airframe checks, heavy component repair and overhaul, line replaceable unit (LRU) rotable components, engine maintenance and spare engine support.

This analysis considers the 737-300/-400/-500's maintenance requirements and overall maintenance cost budget for aircraft operated at an average flight cycle (FC) time of 1.25 flight hours (FH) and a typical utilisation of 2,500FH and 2,000FC per year.

Maintenance programme

The 737-300/-400/-500's line maintenance programme is standard with all other aircraft types. It has a pre-flight check performed before the first flight of each day, a transit check prior to all subsequent flights during the day and a daily check performed every 24 hours. Most 737s are operated on short-haul operations during the day and so daily checks are performed overnight in most cases.

The 737-300/-400/-500 has a basic A check interval of 250FH, and four A check multiples of 1A, 2A, 4A and 8A items. These can be grouped into block checks or equalised.

When grouped into block checks the A8 check is the heaviest and completes the cycle at an interval of 2,000FH. The A1, A3, A5 and A7 checks have just the 1A tasks, while the A2 and A6 checks have the 1A and 2A tasks. The A4 check has the 1A, 2A and 4A tasks, while the A8 has all four multiples.

Air New Zealand Engineering Services (ANZES) has a system under which it performs its A checks as equalised checks, which are further split to allow checks to be fitted into overnight maintenance slots.

The 737-300/-400/-500's maintenance planning document also has a similar block check system for C check tasks. The basic C check interval is 4,000FH, and so two A check cycles are completed every C check interval.

The C check items are packaged into the 1C, 2C, 4C, 6C and 8C items, as well as the structural inspection (SI) tasks. "There are two ways these tasks can be grouped into a system of checks," explains Li Qiang, manager of engineering subdivision at Ameco Beijing. "There can be a system of eight checks in the C check cycle, with the 6C and SI tasks being performed in the C6 check, and the 8C items in the C8 check. This makes two heavy checks. The 1C, 2C and 4C tasks are performed at their appropriate intervals, so that the C1, C3, C5 and C7 checks have the 1C tasks, the C2 check has the 1C and 2C items, and the C4 has the 1C, 2C and 4C tasks. This way the 6C and SI items get out of phase with all the other tasks, since the 6C and SI items will be performed again at the twelfth C check, or the fourth C check in the next C check cycle.

"The other system that can be followed is that 7C and 8C tasks are brought forward to the C6 check and the cycle is completed at this check," continues Qiang. "This sixth check would have all the heavy tasks and is termed the 'D' check."

ANZES operates the system of completing the C check cycle with the heaviest check at the C6 check. "Our C check has a basic interval of 4,500FH, 4,000FC and 15 months, whichever is reached first," explains Viv de Beus, customer support manager for ANZES. "Considering that most aircraft achieve about 2,500FH per year, about 3,000FH are accumulated in the 15-month interval. This means the full C check cycle is completed about once every 85-90 months (about seven years) and every 18,000-19,000FH, rather than the maximum interval of 27,000FH that is allowed by the basic C check's FH interval. We operate a block check system, so the checks vary in size, with the C4 and C6/D checks being the largest. The C1, C3 and C5 checks just have the 1C items and so are the smallest."

Some operators have modified their maintenance programmes, and even bridged to an MSG3 system. KLM operates 14 737-300s and 13 -400s. "We changed our fleet to an MSG3 in 2004," says Ton de Geest, project engineer maintenance programs at KLM Engineering & Maintenance. "We did

The 737-300/-400/-500's line maintenance programme results in labour and material costs in the region of $290-355 per FH, not including supply of LRUs.

While most operators have retained an MSG2 maintenance programme for the 737, KLM has recently bridged its fleet to an MSG3 programme. This effectively rearranges tasks and the total number in the programme has overall been reduced. The system is expected to make the work content of base checks more predictable, and result in less man-hours consumed.

this in conjunction with a Boeing working group. The main difference to an MSG2 programme is that an MSG3 system allows the operator to group each task into checks that suit its operation. This means tasks with escalated intervals can keep their escalations, while others can be re-grouped into new checks. We have pre-flight, transit and overnight checks in our line maintenance programme like all other operators, as well as out-of-phase tasks that are either added to overnight checks or performed separately. We have an A check interval of 550FH, and basic C check interval of 4,000FH, 4,000FC and 18 months."

"The new MSG3 programme has effectively re-arranged tasks, deleted some and added others. The MSG2 programme had separate structural items and corrosion prevention and control programme (CPCP) items, as well as others," explains de Geest. "These have been re-arranged and an enhanced zonal programme has been added to the MSG3 system. The number of tasks overall has been reduced. In the meantime we have transferred the fleet to a new schedule in the MSG2 system where we have a base check cycle of six C checks. We had a problem in that some structural tasks had different initial and repeat intervals, which got more frequent as the aircraft got older. This meant checks were gradually getting heavier and less predictable in terms of content. The new system has all structural items concentrated in the 3C and 6C checks, and the 1C, 2C, 4C and 5C checks are light. These four are all similar in content, while all the structural tasks have the same intervals. The system means that every third check is a heavy check, with an interval of 54 months (four and a half years). This system should result in less overall MH per heavy-check cycle than the previous block-check system which was more complicated. This is because repetition of access required during lighter checks is avoided, and is only required during heavy checks. The 3C group of tasks, however, actually has some CPCP items that have an interval of 48 months. We therefore adjusted the C3 interval to 48 months, and the C6 interval to 96 months (eight years)."

The 737-300/-400/-500 fleet was built between 1984 and 1999, and so aircraft are now between six and 21 years old. The base check interval of about seven years means that most aircraft will not have had more than two D checks and will be in either their first or second base check cycle.

Line maintenance

On the basis of an aircraft operating for 350 days per year and completing about 2,000FC, about 350 pre-flight and 350 daily checks will be performed each year. A further 1,650 transit checks will be completed annually, and if weekly checks are included in the maintenance schedule then about 50 will be performed each year.

The number of MH used and consumption of materials and consumables for all of these checks can be totalled and compared to annual utilisation to provide a cost per FH for ramp checks.

MH and material consumption for A checks can also be analysed on the same basis. The length of the A check cycle in terms of calendar time will depend on the A check interval and number in the cycle.

As an example, ANZES has a phased A check interval of 250FH. Because of a daily utilisation of about 7FC, the actual interval it achieves between A checks is likely to be about 125FC. On this basis the number of ramp and line checks performed in the complete A check cycle is similar to the number completed in a year.

Estimations of MH used during ramp checks vary widely between operators. This is due to variations in how line mechanics' hours are recorded, how extensively the aircraft are cleaned and how defects are addressed. The MH used to have the most influence on the total number of MH consumed in the complete A check cycle. "Pre-flight and transit checks consume a similar number of MH, which total about 2.0," says de Beus. "This is enough for 1.0MH for routine items and another 1.0MH to cover defaults arising during operation. Also included in these MH are general servicing requirements. The cost of materials and consumables covers items such as oil and water." An amount which can be used for budgeting purposes is about $15 per check.

"A daily check requires 2.0-3.0MH for engineering items, and again general servicing requirements. This is the evaluation of dealing with technical log items. Cleaning and cabin work will add MH, although this can be done by a third party," continues de Beus.

Michael Keller, manager of production of engineering and planning at Ameco Beijing estimates that a daily check can consume up to an average of 13.5MH. Again, the cost for materials and consumables will be relatively light. Operators can use $50 per check as a budget for material and consumable consumption for daily checks.

Keller says that material and consumable cost overall for pre-flight, transit and daily checks can total about $7 per FH.

Some operators include weekly checks in their line maintenance schedules to complete out-of-phase tasks. These tasks can also be added to the content of daily checks.

Over the course of a year, a 737-300/-400/-500 will consume 8,000-10,000MH for the 2,300-2,400 ramp checks completed. This will be equal to a consumption of 3.2-4.0MH per FH. With labour for line maintenance charged at an industry standard of $70 per MH, this is equal to a cost of $220-275 per FH. Consumption of materials and consumables adds $7-20 per FH, taking total cost to $230-295 per FH *(see table, page 22)*.

A checks vary in size and so does the use of MH and materials. "The block check system we operate has MH consumptions of about 85MH for A1, A3, A5 and A7 checks," says Keller. "The larger A2 and A6 checks use about 125MH, the A4 check consumes about 235MH and the largest A8 uses about 325MH."

Ameco's schedule of an A check cycle of eight checks has an interval of 2,000FH, although the actual interval achieved is likely to be close to 1,600FH considering the utilisation of the A check interval achieved by most operators. MH consumption for all eight checks totals about 1,150. This is equal to about 0.7MH per FH. A labour rate of $70 per MH takes labour cost per FH to $50. Keller estimates the average material and consumable cost for A checks at about $1,500, totalling $12,000 for the cycle and equal to another $8 per FH. This takes total cost per FH for cost of A checks to about $60 per FH *(see table, page 22)*.

de Beus explains that under ANZES's 1/2 A check system, each half uses an average of about 40MH and about $200-500 in materials and consumables.

Although line replaceable units (LRUs) are exchanged during line maintenance, the capital cost of these parts and additional charges for repairs and management are accounted for as a separate item.

Base maintenance checks

As described, there are several ways a base maintenance programme can be organised. ANZES follows the system of block checks, with the cycle being completed at the C6 check. "The total number of MH used in each check in the series depends on how the programme is structured, as well as the content," explains de Beus. "Besides routine inspections and non-routine tasks that arise as a consequence, several other items have to be added. These are airworthiness directives (ADs), service bulletins (SBs), modifications and engineering orders (EOs), component changes such as landing gear or thrust reversers, non-routine repairs to components, interior work, and the supplemental structural inspection document (SSID) and CPCP. The heavier checks towards the end of the cycle will have a higher level of interior work for refurbishment of panels, lavatories and galleys. They will also include stripping and painting."

ANZES manages Air New Zealand's fleet of 12 737-300, as well as Freedomair's four aircraft, and Jetconnect's domestic fleet of nine aircraft in New Zealand. "These are aircraft built between the late 1980s and 1999, many of which are still in or have completed their first C check cycle, but have not got to their second D check," says de Beus.

Based on a review of several maintenance providers, the industry average for C1, C3 and C5 checks is about 5,000MH for the whole content. Only about 1,200-1,500MH of this is used for the MPD element and interior work. The remainder is used for ADs, SBs, modifications, EOs and component changes and all non-routine maintenance. The check uses about $125,000 for materials, consumables and some component repair activity.

A C2 check is slightly heavier and uses about 6,500MH when all items are considered and in the region of $150,000 or materials, consumables and some component repair activity. The C4 check is one of the heavier checks experienced by operators, and consumes an average of 8,000MH when all items are considered, plus about $200,000 in materials, consumables and component repairs.

Depending on the operator, the C6/C7 or D check is the largest check, and can include some significant modification packages. A lot of SBs and ADs are often completed in these checks so that the aircraft is clear until the next C check. Average consumption for a first D check is about 13,000MH plus another 1,500MH for stripping and re-painting. The cost of materials, consumables and some component repairs can vary widely, since the degree to which interior parts and items in the interior are either refurbished or replaced also varies widely. The cost of component repairs is also highest in this check, since items such as flap tracks are repaired during these checks. A typical range is $300,000-800,000, with an average of $550,000. These checks are also often required for aircraft at the end of a lease agreement, when bridging maintenance and changes to avionics and components are required.

Total MH consumption for base checks over the first C check cycle is about 45,000. Charged at an industry average labour rate of $50 per MH, total labour cost is $2.3 million. Total cost of materials, consumables and component repairs is about $1.3 million. This total cost for labour and materials amortised over the interval of 18,600-20,000FH works out at an average of 2.4MH per FH, and total cost for base maintenance

The base checks in an MSG2 programme consume in the region of 50,000 man-hours for the second base check cycle. This, and material costs, result in an overall cost in the region of $210 per FH.

checks is $180-195 per FH *(see table, page 22).*

Ameco Beijing's C check programme is similar to that of ANZES. "A total of about 15,000MH are consumed for the first D check, which includes labour for MPD tasks, engineering orders and modifications and component repairs," says Torsten Kurznack, manager subdivision of aircraft overhaul at Ameco Beijing. "Material consumption for the check is about $300,000 which is for materials and consumables, but does not include the cost of component repairs. The MH consumed for the second D check will rise over the first, mainly because of an increase in the non-routine ratio. About 8,000MH will be required for routine and CPCP tasks, about another 5,000MH for non-routine tasks, about 4,000 for EOs and modifications, 2,300MH for component repairs and another 1,600MH for stripping and re-painting. This would be a total of about 21,000MH. Total material cost for these heavier checks has averaged about $550,000."

Total MH for the second base check cycle is about 52,000, depending on the non-routine ratio. This increase, plus a rise of total material costs to about $1.6 million over the cycle will take total charge for the base maintenance cycle to about $3.9 million. This will be equal to about $210 per FH.

Heavy components

Heavy components fall into four categories: landing gear, thrust reverser, wheels and brakes, and auxiliary power unit (APU). These four component types have independent maintenance schedules. Apart from the landing gear, all are maintained on an on-condition basis.

Most operators now opt for exchange programmes for landing gears, which will have to be used for small airlines acquiring used aircraft. Maintenance intervals are 8-10 years and up to 32,000FC, and exchange programmes are a single cost to cover exchange fee and overhaul cost. "Exchange costs vary widely depending upon availability, but they normally include a fixed cost of overhaul, " explains Steve Hodgkiss, managing director of FlyerTech. "An overhaul fee of $150,000 is reasonable depending on condition of the landing gear. Exchange fee will be about $40,000."

A total cost of $190,000 incurred every eight years will be equal to a cost of $10 per FH *(see table, page 22).*

Costs for wheels and brakes are related to FC intervals. Wheels require tyre remoulds and replacement, as well as wheel rim inspections. Tyre removal and re-tread intervals will be affected by landing weight, which will vary by aircraft variant. Average intervals of 250FC for main wheels and 200FC for nose wheels can be expected, and tyres are remoulded an average of three times before being replaced at the fourth removal. This would make the total life cycle of main and nose tyres 1,000FC and 1,200FC

Re-tread of main wheel tyres has an average cost of $400, while nose tyres will be about $350. New main and nose tyres cost about $1,400 and $800. Total cost for remould and replacement for a complete shipset of four main wheel tyres would be about $10,400, and about $3,700 for a shipset of two nose wheel tyres. Amortised over the replacement interval, this results in a rate of $13 per FC *(see table, page 22).*

Wheel inspections are made at tyre removal and have an average cost of $650 for main wheels and $600 for nose wheels. This results in a cost of $12 per FC *(see table, page 22).*

Brake repairs are made on average every three wheel removals, and so about every 900FC. The average cost for a brake repair is about $11,000, and the cost per FC for all four main wheel brake units is $49 *(see table, page 22).*

Thrust reversers for mature aircraft have an average removal interval of about 8,000FC. A cost of $190,000 for an average shop visit can be used for a thrust reverser shipset. The total cost for both reverser shipsets amortised over the removal interval is about $48 per FC *(see table, page 22).*

The 737-300/-400/-500 uses the GTCP 85-129 auxiliary power unit (APU). Many operators will use the APU while taxiing to the gate before connecting to a ground power unit, and then use the APU again during engine start. The APU thus gets used twice in each FC for an average of 45 minutes, and will therefore accumulate about 1,500 hours per year. The average time between shop visits is about 3,500 APU hours, equal to more than two years of aircraft operation. An average shop visit cost of $150,000 is equal to $32 per FC *(see table, page 22).*

Line replaceable components

The 737-300/-400/-500 is now widespread in the global fleet, and there is a plentiful supply of rotable LRUs on the used market. Prospective operators of 737-300/-400/-500s have several choices for sourcing LRUs. Many maintenance providers offer LRUs, as do specialist component providers.

The standard practice would be for an operator to be supplied with a home-base stock and given access to a component pool for the remainder of the items once it had established the confidence level it required in its operation, what the failure rates of the components are likely to be, as well as the structure of its operation.

Ralf Aljes, manager subdivision component services at Ameco Beijing says a small operator can be supplied with an LRU contract at a rate of $110-120/FH to cover the cost of repair and management of the parts, and a further $40-50/FH for access or lease costs of the material. "Total cost is $180-220 per FH for the airline if it joins the access pool *(see table, page 22)*. This cost includes the repair and management of parts and access to all LRUs. This compares to a probable cost of $300/FH if an airline were to lease its own stock and manage the repair by itself," says Aljes.

Every rotable supply contract is different, and Hodgkiss says it is possible to get a contract for about $110 per FH. "This would be the rate for the supply and repair of all LRUs, without including wheels and brakes, interior parts and large insurance items. It does not include the cost of shipping all items sent for repair. The $110 per FH rate includes the supply of a minimal home-base stock worth about $500,000 for one or two aircraft," says Hodgkiss. "Another $50 per FH could be added to cover all miscellaneous and unknown items, such as cabin items, oil and unscheduled problems and accidents."

Engine maintenance

There are three variants of the CFM56-3: the -3B1, -3B2 and -3C1. The -3B1 is rated at 18,500lbs and 20,000lbs, and powers the 737-300 and -500. The -3B2 can be rated at 22,000lbs and powers all three family members. The -3C1 is the most numerous and can be rated at 23,500lbs and all lower thrust ratings for all three 737 variants.

The lower-rated engines have installed exhaust gas temperature (EGT) margins in the region of 135-140 degrees centigrade, while those rated at 20,000lbs have margins of about 110 degrees, those rated at 22,000lbs rated at 70 degrees and the highest powered models have margins of about 50 degrees.

These margins and the rate of EGT margin erosion generally allow long removal intervals between shop visits. Most CFM56-3s built have been through their first shop visit and are on their second or subsequent on-wing runs. The lowest maintenance cost per engine flight hour (EFH) contributes to lower overall aircraft maintenance costs. Low rates per EFH are achieved by optimising removal intervals, shop visit workscopes and LLP replacement timing. LLPs can generally be divided into three groups: in the high pressure (HP) section, the low pressure turbine (LPT); and fan and booster section. Most HP system LLPs have lives of about 20,000EFC, although a few are restricted at 15,000-17,000EFC. The list price for LLPs in this section is about $650,000. LPT LLPs have lives of 25,000EFC, and have a list price of about $410,000. Fan/booster LLPs have lives of 30,000EFC and list price of $263,000.

The high EGT margins of the lowest rated engines allow on-wing intervals to average about 18,500 engine flight cycles (EFC). This compares to an annual rate of utilisation of about 2,000EFC, and so is equal to about nine years of operation. HP and LPT LLPs should be replaced at this stage, since the restored EGT margin after the shop visit will allow a second removal interval of 11,000-12,000EFC. Besides HP LLP replacement, the engine should require a performance restoration on the core engine and a workscope on the LPT. This will have an approximate cost of $1.1 million, not including LLPs.

The second run of about 11,000EFC will be followed by another core engine performance restoration and workscope on the fan and booster section, as well as replacement of fan and booster LLPs. This will incur a cost in the region of $950,000, not including LLP replacement. The third removal interval will be 500-1,000EFC less than the second and will be followed by a shop visit workscope similar to the first at which HP and LPT LLPs would be replaced. This would have a cost of about $1 million, not including LLPs. By this stage the engine will have accumulated about 40,000EFC on-wing, equal to about 20 years of operation. Maintenance reserves, including LLP amortisation, up to the first removal will be in the region of $90 per EFH. This will increase to $110-115 per EFH for the

DIRECT MAINTENANCE COSTS FOR 737-300/-400/-500

Maintenance Item	Cycle cost $	Cycle interval	Cost per FC-$	Cost per FH-$
Ramp checks	$600,000-700,000	1 year		230-295
A check	$60,000-90,000	1,300-1,600FH		60
C & D checks	$3,600,000	18,500-20,000FH		180-195
Heavy components:				
Landing gear	$190,000	16,000FC	13	10
Tyre remould & replacement	$12,000	800FC/1,400FC	13	10
Wheel inspections	$3,800	200FC/250FC	12	10
Brake inspections	$44,000	900	49	39
Thrust reverser overhauls	$340,000	8,000	48	38
APU	$150,000	4,700	32	26
Total heavy components			167	133
LRU component support				180-220
Total airframe & component maintenance				**$785-910/FH**
Engine maintenance:				
High rated (mature)				$180/EFH X 2
Mid rated (mature)				$135-150/EFH X 2
Low rated (mature)				$130-145/EFH X 2
Total direct maintenance costs:				
Aircraft with high rated engines				**$1,145-1,270/FH**
Aircraft with medium rated engines				**$1,055-1,210/FH**
Aircraft with low rated engines				**$1,045-1,200/FH**

Annual utilisation:
2,500FH
2,000FC
FH:FC ratio of 1.25FH:1.0FC

second removal intervals *(see table, this page)* and increases again to about $130 per EFH for the period up to the third removal. Subsequent intervals are expected to be in the region of 9,000-11,000EFC, given the high EGT margin, and $130-145 per EFH should be allowed for maintenance reserves.

Mid-rated engines have planned first-run removal intervals of about 11,000EFC, and can be expected to have a subsequent on-wing time of 9,000EFC. It is therefore not necessary to replace any LLPs at the first shop visit. The first shop visit workscope is usually a core performance restoration, since the LPT and fan/booster sections can remain on-wing until the second removal. The cost of this first workscope will be in the region of $900,000.

The second removal interval of 9,000EFC takes total time to about 20,000EFC, equal to about 10 years of operation, at which point HP and LPT LLPs should be replaced. The shop visit workscope at this stage is a core refurbishment and LPT workscope. The cost for this shop visit, not including LLPs, is about $1 million. The third and subsequent on-wing intervals will be in the region of 8,500EFC.

Maintenance reserves, including LLP amortisation, are in the region of $105 per EFH up to the first removal, $125 per EFH up to the second removal, and $135 per EFH up to the third removal and a similar rate thereafter *(see table, this page)*.

The highest-rated engines naturally have the shortest on-wing removal intervals, which are about 8,500EFC for the first interval. At this point the engine has a core engine performance restoration workscope, but no LLPs are replaced since the engine is capable of a second removal interval of about 6,500EFC. The first shop visit workscope is a core performance restoration, which will cost about $900,000 not including LLPs.

The second removal interval will be about 6,500EFC and the engine will have a heavy core workscope, since accumulated time on-wing will not necessitate work on the fan/booster or LPT sections. Total accumulated time at this stage will be about 15,000EFC, and so HP LLPs should be replaced, although fan/booster and LPT LLPs can remain for the third on-wing run. The second shop visit will cost about $950,000, not including LLPs.

Mature intervals to subsequent shop visits will be 6,000-6,500EFC. Total time to the third shop visit will be about 21,500EFC and the engine will require a full workscope on the core engine and LPT section, as well as LPT LLP replacement. The cost of this workscope will be in the region of $1.1 million, not including LLPs. Maintenance reserves to the first shop visit will be about $135 per EFH, climbing to about $180 per EFH at maturity *(see table, this page)*.

Maintenance cost summary

The total direct maintenance costs for the 737-300/-400/-500 vary between $1,050 and $1,270 per FH *(see table, this page)*. The actual cost per FH is influenced by all elements of maintenance cost, but ramp and line checks, repair of heavy components, LRU rotable component support and engine maintenance vary widely. Despite their magnitude and attention they attract, the costs of base airframe checks are relatively predictable.

The eventual cost per FH for ramp checks will be affected by efficiency of labour, but also how labour for line maintenance is recorded and allocated, as well as an airline's maintenance practices.

This goes partly in-hand with the cost of LRU rotable support, which is also highly variable. The ultimate cost per FH for this element can vary by more than $100 per FH. Engine maintenance costs will be most affected by thrust rating, and consequently by aircraft variant and gross weight.

The 737-300/-400/-500 are still popular, and many are operated by original users, although more aircraft are now being acquired by secondary users and are becoming mature. The last manufactured aircraft is now six years old, and most engines are mature, having been through their first and second shop visits. Tight control of all these elements can keep maintenance costs stable.

Spare engine support

Operators also have to consider the costs of spare engine provisioning. Removal intervals for mature engines are in the 7,500-12,000EFH range, depending on thrust rating and style of operation. This is equal to three to five years of operation in most airlines' cases, but will be 30-55 months once unscheduled removals are taken into account. Typical shop turn times of three to four months mean that one spare engine will support 10-15 installed engines, or a fleet of five to seven aircraft.

This is a small fleet, and airlines with at least this number of aircraft would find it economic to own a spare engine that had full utilisation in covering for removed units going through shop visits. Demand for the 737-300/-400/-500 has increased over the past year to 18 months, following a surplus. A number of aircraft were repossessed from United Airlines and USAirways. Some were broken for parts and engines, which temporarily brought down values of aircraft and the CFM56-3s. "The last peak in CFM56-3 values was in 1998, and they then reached a trough in 2000-2002," says Tom MacAleavey, senior vice president of sales and marketing at Willis Lease Finance Corporation. "CFM56-3 values have gone up by 20-25% and there is now a shortage of them. The engine is also no longer built and this has exacerbated the problem. Values mainly depend on the maintenance status. It can cost nearly $3 million to put an engine through a heavy shop visit and replace a complete set of LLPs. Core values of completely run-out engines are $600,000-700,000. Values of -3C1s fresh from an overhaul that have LLPs with at least 10,000EFC remaining have a value of $3.5-4.0 million. Values of -3B2s are slightly less at about $3.2 million."

Andrew Pearce, director at Macquarie Aviation Capital puts values for -3C1s and -3B2s in a good maintenance condition at a similar level. "A -3B2 fresh from a shop visit and with fairly good LLP status has a market value of $3.2-3.45 million. A -3C1 in the same condition has a value of about $4.0 million."

These values have to be considered in relation to long-term lease rates that airlines would alternatively have to pay if they did not own spare engines. Maintenance reserves would also have to be paid with lease rentals. "More airlines are now taking engines on long-term leases," says MacAleavey. "Long-term lease rentals have now risen to $40,000-44,000 per month for -3C1s, and are slightly lower for -3B2s."

Pearce confirms that lease rates have firmed up to this level over the past 12 months. "Maintenance reserves also have to be paid, and these are about $120 per EFH and $70-80 per EFC," says Pearce. This equates to a total reserve of $184 per EFH for an engine operated at an average EFC time of 1.25EFH.

MacAleavey puts reserves at $115 per EFH and $71 per EFC for -3C1s, $84 per EFH and $62 per EFC for -3B2s, and $98 per EFH and $62 per EFC for -3B1s.

Most airlines also have to consider short-term leases for coverage in the event of unscheduled failures and engine removals, and emergency requirements. "Short-term lease rentals are in the range of $1,800-2,000 per day, plus maintenance reserves, although they do drop by about $400 per day in off-peak seasons when airlines are not so busy, " comments Pearce.

Technical support

Besides direct maintenance costs, airlines have to consider having the infrastructure in place for the technical management of their aircraft. "This will be expensive for small and start-up operators to consider," says Hodgkiss at Flyertech. "We specialise in providing this technical management and can source maintenance providers, set a maintenance control department, and manage the whole range of technical management aspects for airlines. This includes managing the aircraft's maintenance programme, determining maintenance task workscopes, deciding which ADs and SBs to perform, monitoring reliability data, keeping maintenance records, and a whole range of other tasks. The cost for providing all of these services for a small fleet will be in the region of $2,500-3,500 per aircraft month, and will reduce with fleet growth." AC

737-300/-400/-500 values, lease rates & the aftermarket

Values of 737-300/-400/-500s have rebounded following a surge in demand.

The 737-300/-400/-500 are too technologically advanced to enter a state of decline. The aircraft are simple to operate and have been used by the majority of airlines around the world. There is also the fact that there are more than 1,000 MD-80s in service that will decline prior to the 737, as well as the overriding factor that there are few good quality aircraft in storage.

The age of the 737-300/-400/-500 fleet ranges between six and 20 years. The majority of aircraft would thus be considered to be at a 'mature' age. The median age of the fleet and their accumulated flight hours and flight cycles, and the presence of the more advanced 737NG and A320 families, has put pressure on the market values of 737-300/-400/-500s. Most aircraft have entered the phase where values have begun to decline more rapidly.

Values of 737-300/-400/-500s dropped after 9/11 with the ensuing glut of aircraft. "While the values of older aircraft types have dropped through the floor, values of good quality 737 classics have gone up by 30-40% since the post-9/11 trough," says Doug Jaffe, chief executive officer at Jetran International. There was a surplus of 737-300/-400s after 9/11, mainly because a large number of ex-United and ex-USAirways aircraft were parked.

"The supply of 737-300/-400/-500s is now tight. This is because airlines are swapping out older aircraft, like the 737-200 and MD-80, for younger types. This process has been intensified because of the rise in fuel prices. The price of fuel has driven 737-300/-400/-500 values up because they are the most fuel efficient of older generation aircraft," continues Jaffe. "The 737-300/-400/-500 is also much easier to trade worldwide than some types. It is hard to get an air operator's certificate (AOC) for the MD-80 in Romania, for example. There are still problems when trading 737-300/-400/-500s across continents, however. Some avionics are mandatory in Europe, but not in the US. This can result in some expensive modifications being required."

Jaffe makes the point that if a major operator, for example USAirways, were to cease operations or merge with another carrier, it might release 40-50 aircraft onto the market. "It would still not be too difficult to place these aircraft with airlines, given the demand for them, although it would pull values down again," he comments.

The problem with 737-300/-400/-500 values is that the CFM56-3 is an expensive engine to overhaul. "This is mainly because of the price of parts. An overhaul can go to as high as $1.5 million, which compares to about $1.0 million for a JT8D. The maintenance status of the engines therefore has the most influence over values of 737-300/-400/-500s. Older -300s, which are mid-life in maintenance terms, have values of about $7 million, while younger aircraft built between 1990 and 1999 have values in the $9-11 million range," says Jaffe. This compares to engine values, which are $3-4 million each, depending on maintenance status and lives of life limited parts. Engines can thus account for up to 90% of an older aircraft's value, and up to 80% of a mid-life aircraft's.

"Values of -400s are not much higher, with older aircraft being in the $7-8.5 million range and mid-age aircraft being $9-12 million," continues Jaffe. "The -500s are not that popular, but values are nevertheless close to the -300/-400 at $8-10 million. Lease rates are also close for the three variants, and are $85,000-105,000 per month for earlier build aircraft and $110,000-140,000 for younger aircraft."

While the supply of aircraft has been soaked up, values have not increased as much as lease rates. There are few cash buyers of aircraft, and most airlines prefer to lease when liquidity is low.

The 737-300/-400/-500 benefits from the fact that the CFM-56s have predictable on-wing intervals, and although they are expensive to maintain they make the aircraft's overall maintenance costs stable.

The rise in values will cause uncertainty in the freight conversion market. The accepted market lease rate for a 737-300SF is in the region of $100,000-110,000, and a lease rate factor of 1.25% puts the total cost for acquisition and conversion to freighter at no more than $9 million. "This means the market for an aircraft can be no more than about $6 million for someone buying a used machine and speculatively converting it," says Jaffe. "A lessor that has fully or nearly depreciated its aircraft can justify conversion, however." AC

Demand for 737-300/-400/-500s has lifted market values by as much as 40%. Supply of aircraft is now tight and values are in the region of $7-11 million, depending on age, variant and maintenance status.