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