AIRCRAFT OWNER'S & OPERATOR'S GUIDE: 757 FAMILY

757-200/-300 specifications

The 757 family has three main variants. The fleet is also divided between two main engine types; resulting in six main types of the aircraft.

The development of the 757 was relatively simple compared to other jetliner types. The fleet can be sub-divided in two ways, between the three main variants (the -200 passenger model, the -200PF factory freighter model, and the -300 passenger model), and between those aircraft that are powered by the RB211-535 series engines and those that are powered by the PW2000 series engines. This splits the 757 fleet into six main groups.

757-200 series

The -200 variant comprised the majority of 757s built. This was one of the largest narrowbodies, and was principally aimed at replacing the smaller 727, retaining the same fuselage cross-section and six-abreast seat layout as the 727 and 737 families.

Seating configuration varies from 178 for a mixed first- and economy-class layout up to 228 for the highest density all-economy seating at 28/29-inch seat pitch.

The weight specification development of the 757-200 was relatively simple. Fuel capacity of the aircraft was unchanged for all different models of the -200 at 11,276 US Gallons (USG). Range performance was only improved through increases in the aircraft's maximum take-off weight (MTOW).

The first -200s were powered by the Rolls-Royce (RR) RB211-535C and PW2037. Derived from the The RB211-524, the RB211-535C used fewer stages and was rated at 37,400lbs thrust. The PW2037 was rated at 37,500lbs thrust. The initial models equipped with RB211-535C engines had a MTOW of 220,000lbs *(see first table, page 7)*. Only a few aircraft with this engine had a higher MTOW of 240,000lbs. Production of aircraft with the RB211-535C was limited, with only 40 built. This aircraft has a range of about 2,000nm with a full load of passengers.

The RB211-535C was soon followed by the RB211-535E4. Although this engine had the same basic turbomachinery configuration, it was the first RR engine to use wide-chord fan blades that improved fuel burn efficiency, as well as using a range of other improved materials. The engine was also rated at 40,100lbs thrust, which allowed higher performance. The 757-200 was developed with higher MTOWs of up to 255,000lbs. Aircraft equipped with the -535E4 have MTOWs up to this level.

The first main customers for the 757-200, with RB211-535C-powered aircraft, were British Airways (BA) and Eastern Airlines. Eastern Airlines had its earlier built aircraft re-engined with the RB211-535E4, and the -535C engines that were subsequently removed were subsequently installed on aircraft destined for BA at Boeing's production line. The earliest aircraft to be powered with the RB211-535E4 were line number 2, built in 1982.

The original bill of materials used for the RB211-535E4 included a Phase II combustor, which was later changed after the introduction of the -535E4-B, rated at 43,100lbs thrust. The -535E4-B's higher thrust rating improves the aircraft's field and climb performance.

The -535E4-B was first built in 1989 and went into production with a Phase II combustor, but had other materials that were different to the -535E4. The -535E4-B also required different turbine materials that were resistant to higher temperatures as a result of the higher thrust rating.

The materials in the -535E4 and -535E4-B were then commonised. The Phase V combustor was introduced at this stage to comply with more stringent NOx emissions standards. The introduction of the Phase V combustor resulted in changes to the fuel nozzles, high pressure compressor guide vane casing, and other hot section parts. Following this the only differences between the -535E4 and -535E4-B are changes to the engine control software.

The PW2037 was not introduced until 1984, two years after 757-200 production had started. The most notable feature of the PW2037 was its lightness, because of its two-shaft design, compared to the RB211-535. The difference in operating empty weight (OEW) between PW2037-powered and RB211-535-powered aircraft is about 600lbs. The PW2037 was followed by the PW2040 rated at 40,900lbs thrust, but since 1991 the engines have used the same bill of material, and thrust rating is controlled by the data entry plug.

The PW2037 is utilised on all MTOW variants of the 757-200, and powers the largest group of 757s. The PW2040 was introduced in 1990, but was selected to power a small number of aircraft.

Higher MTOWs increased the aircraft's range performance, with the highest MTOW of 255,000lbs giving it a range of about 3,750-4,000nm with about 190 passengers *(see first & second tables, page 7)* depending on the engine type installed, although fuel capacity remained unchanged. These higher MTOW models also had higher landing weights. Maximum zero fuel weight (MZFW) remained the same at 184,000lbs for all MTOW variants, except the highest of 255,000lbs which had an MZFW of 188,000lbs.

With the ability to operate non-stop for more than 3,500nm came the requirement to operate the aircraft unrestricted for long distances over water, so extended range twin engine operations (Etops) were developed.

Aircraft also have to be fitted with additional equipment for Etops missions, including an auxiliary fan for electronic cooling, an additional hydraulic motor, and revised engine indicating and crew alerting system (EICAS) screen on the flightdeck. Not all aircraft are equipped with Etops equipment, however, which increases the OEW.

The 757's seat capacity is affected by its fuselage configuration. Boeing offered the 757-200 in two options. The first was with three type I doors on each side of the fuselage and a pair of type III overwing exits, which was specified by many US operators, but few other carriers. The second and most popular option is the use of four similar-sized type I exits on each side of the fuselage. This option requires more seat pitch for emergency evacuation at the third door, and so results in marginally fewer seats than the first option.

A typical two-class layout of 16 first class and economy seats results in a total of 178 to 186 seat, about 10 seats more than the A321 in a similar configuration.

The 757-200 also has about 1,790 cubic feet of underfloor capacity that is used for carrying passenger baggage and freight.

757-200PF

Since the 757 shares the same fuselage cross-section as the popular 727 freighter, it made sense to develop a freighter version of the 757.

The position of the first door on the original 757-200 passenger fuselage is adjacent to position of the first freight position, which prevents its use. The 757-200PF therefore has a crew entry door forward of the position of the number one door on the passenger aircraft to allow 15 125-inch wide X 88-inch long contoured containers to be carried. These are the same containers utilised by 727 and 737 freighters, and are contoured to make maximum use of the aircraft's fuselage.

These containers each have a capacity of 440 cubic feet, giving the 757-200PF a main deck volume of 6,600 cubic feet. The aircraft also has a lower deck volume of 1,830 cubic feet, giving the aircraft a total volume of 8,430 cubic feet.

The 757-200PF was built with a MTOW of 250,000lbs, and also has an MZFW of 200,000lbs and OEW of 114,000lbs, thereby giving it a maximum structural payload of 86,000lbs. The tare weight of each main deck container is 476lbs, and so the aircraft has a net structural payload of 78,860lbs *(see fourth table, this page)*. This allows a maximum packing density of 9.35lbs per cubic foot. The aircraft can carry a full payload up to about 2,450nm.

In addition to the -200PF, there are now several passenger-to-freighter conversion programmes for the 757-200 *(see 757 modification & upgrade programmes, page 10)*. The first of these was developed by Boeing and allows the aircraft to carry 14 main containers and a half-container. This is being followed by a new programme being developed by ST Aero and Israel Aircraft Industries for an aircraft that will carry 15 containers, which will come available in 2007. Precision Conversions is the first of three modifications to have its supplemental type certificate, and the modification allows 15 full containers to be carried. Alcoa-SIE is developing a modification that will allow the aircraft to carry 14 main and one demi container.

757-200 SERIES GROSS WEIGHT & ENGINE CONFIGURATIONS

Variant	-200	-200
MTOW lbs	220,000	255,000
OEW lbs	134,090	136,940
Structural payload lbs	49,910	51,060
Fuel volume USG	11,276	11,276
Dual-class seats	178/186	178/186
Range nm	2,000/1,950	3,600/3,550
Belly freight capacity cu ft	1,790	1,790
Engine options	RB211-535C/E4	RB211-535E4/-535E4-B
Engine thrust	37,400	40,100/43,100

757-200 SERIES GROSS WEIGHT & ENGINE CONFIGURATIONS

Variant	-200	-200
MTOW lbs	220,000	255,000
OEW lbs	128,380	130,875
Structural payload lbs	55,620	55,125
Fuel volume USG	11,276	11,276
Dual-class seats	178/186	178/186
Range nm	3,850/3,750	4,050/4,000
Belly freight capacity cu ft	1,790	1,790
Engine options	PW2037	PW2037/PW2040
Engine thrust	37,500	37,500/40,900

757-300 SERIES GROSS WEIGHT & ENGINE CONFIGURATIONS

Variant	-300	-300
MTOW lbs	270,000	270,000
OEW lbs	142,350	141,800
Structural payload lbs	67,650	68,200
Fuel volume USG	11,490	11,490
Dual-class seats	243	243
Range nm	3,200	3,200
Belly freight capacity cu ft	2,382	2,382
Engine options	RB211-535E4-B/C	PW2043
Engine thrust	43,100	43,100

757-200PF GROSS WEIGHT & ENGINE CONFIGURATIONS

Variant	-200PF
MTOW lbs	250,000
MZFW lbs	200,000
OEW lbs	114,000
Structural payload lbs	86,000
Fuel volume USG	11,276
15 main deck containers-cu ft	6,600
Container tare weight-lbs	7,140
Belly volume-cu ft	1,830
Total volume-cu ft	8,430
Net structural payload	78,860
Packing density-lbs/cu ft	9.35

757-300 series

The 757-300 was a stretch development of the -200 fuselage, which increased seat capacity by about 60 seats to 243 in a mixed configuration and 279 in an all-economy layout. This gives the 757-300 a seat capacity between the 767-200 and the 767-300, and makes the 757-300 the largest narrowbody aircraft ever built. Despite the economic advantages, the aircraft's long fuselage had inherent problems with loading times.

Besides the fuselage stretch, the 757-300 was developed by increasing MTOW to 270,000lbs and fuel capacity slightly to 11,490USG.

The RB211-535E4-B already offered on the 757-200 was offered, and the -535E4-C with the same rating of 43,100lbs thrust was also offered. The only difference between the two variants is that the -535E4-C has a number of performance enhancement modifications.

The PW2043 rated at 43,000lbs was also offered, with some physical differences with the PW2037 and PW2040.

The 757-300 can carry a load of 240 passengers about 3,200nm. The aircraft also has an underfloor freight capacity of 2,382 cubic feet.

Freighter conversions

There are three passenger-to-freighter modification programmes being developed for the 757-200 *(see 757 modification & upgrade programmes, page 10)*. These aircraft have a MZFW and available payloads 12,000lbs less than the -200PF.

757-200/-300 fleet analysis

The 757 fleet can be divided into six main groups. The two most numerous types are RB211- & PW2037-powered -200s.

There were 1,039 757s built over the 22-year period between 1982 and 2004. Out of this number 998 aircraft are still in civil operation and another 27 are in storage or are temporarily inactive, taking the total available fleet to 1,025. A small number of civilian aircraft has been destroyed, and a few others are operated by Boeing, NASA, and various governments and air forces.

The 757 can generally be subdivided in two ways: between the two major engines types (the Rolls-Royce (RR) RB211-535 series and the Pratt & Whitney (PW) PW2000 series); and between -200 series passenger-configured aircraft, -200 series freighter-configured aircraft, and -300 series passenger-configured aircraft.

This means that there are six main groups of aircraft, with the total available fleet is divided between 600 RB211-powered aircraft *(see table, page 9)*, and 425 PW2000-powered aircraft.

There are 826 -200 series passenger-configured aircraft in service, of which 466 are RB211-powered and 360 are PW2000-powered. A further 14 RB211-powered aircraft and 13 PW2000-powered aircraft are in storage or temporarily inactive, and include one Alcoa-SIE aircraft that is being converted to freighter.

The 480-RB211-powered passenger-configured aircraft form the largest group of the global 757 fleet. The 373 PW2000-powered aircraft are the second largest group of aircraft.

There are 127 active aircraft in freighter configuration. These are split between 79 factory-built 757-200PFs and 38 aircraft that have been converted to freighter. The factory-built freighters are mainly operated by UPS. Most of the 38 converted aircraft were converted by Boeing. Only three have been modified by Precision Conversions.

While the 757-200 series was successful, only 55 757-300s were produced, all of which are still in operation.

757 production

Production of 757s ceased in October 2004, after 22 years. Production rates peaked between 1989 and 1994, and then again in 1998 and 1999, averaging 47 units per year.

SUMMARY OF 757-200/-300 PRODUCTION & IN-SERVICE AIRCRAFT

Aircraft variant	-200	-300	-200CF	-200PF	TOTAL
ACTIVE FLEET					
RB211-535C	3		34		37
RB211-535E4	288		4	43	335
RB211-535E4-B	175	27			202
RB211-535E4-C		12			12
PW2037	320				320
PW2040	40			36	76
PW2043		16			16
TOTAL	**826**	**55**	**38**	**79**	**998**
STORED FLEET					
RB211-535C	1				1
RB211-535E4	8				8
RB211-535E4-B	5				5
PW2037	12				12
PW2040	1				1
Total	**27**				**27**

The 757 sold well to US majors, with American Airlines placing one of the largest orders for the 757 in 1988 for 75 units. Many of these aircraft were delivered in the early and mid-1990s. A surge in aircraft orders in the late 1990s from American, Continental, Delta and United accounted for the second wave of peak production.

The majority of aircraft built in the last four to five years of production were -300 series aircraft.

The 757 is operated in large numbers by American, Delta, Northwest and United. The fleets of Continental, USAirways, America West and American Trans Air (ATA) were medium sized, but collectively account for a large number of aircraft. Iberia and several Chinese airlines also operated medium-size fleets. The remainder of 757s in operation are small fleets operated by a variety of carriers.

-535C-powered -200s

The RB211-535C was the initial RB211-535 variant used on the 757. This was quickly followed by the higher thrust rated and more fuel efficient -535E4 that contributed to the aircraft operating at higher weights and on long-haul missions. Most RB211 customers selected the -535E4, and British Airways (BA) was the only main customer for the -535C since it only used the aircraft on short-haul services. A few other carriers took a small number of -535C-powered aircraft.

All 34 of BA's -535C-powered fleet have been converted to freighter using Boeing's passenger-to-freighter modification. These aircraft are all now operated for DHL's European subsidiary European Air Transport.

The only other remaining -535C-powered aircraft in passenger configuration are two ex-Europe and one ex-Lufftrans-Sud aircraft, being operated for Pace Airlines and Orient Thai. A third ex-Air Europe aircraft is in storage, and is owned by Pegasus.

-535E4-powered -200s

There are 288 -535E4-powered aircraft in operation, which form the second largest single sub-fleet of all types of 757. The first of these was built in March 1982, just one month after the first 757 produced, and production continued throughout the 22 years of 757 manufacture.

The -535E4 is rated at 40,100lbs thrust. A higher rated variant, the -535E4-B, was launched by Rolls-Royce. This is rated at 43,100lbs thrust. The main difference over the earlier variant was that the initial -535E4-Bs built had

The fleet of PW2037-powered 757-200s is the largest sub-fleet of the world's 757s. This group of 320 aircraft is dominated by the three fleets of United, Delta and Northwest; which have 265 aircraft between them.

different turbine materials to withstand higher temperatures. The two engines were then later built with a common bill of materials, which included a Phase V combustor. The only difference between the -535E4 and -535E4-B in this case is engine control software. This means that later built -535E4s, with a Phase V combustor, can be upgraded to the -535E4-B, while earlier -535E4s cannot be upgraded.

Virtually all -535E4-powered aircraft have a fuel capacity of 11,483 US Gallons (USG). The fleet contains several large fleets, the majority of which are leased, but no large US fleets with the exception of USAirways' fleet of 31 aircraft.

There are several other major fleets, some of which are owned and others that are leased. BA owns 13 aircraft and Monarch seven; some of Iberia's 10 and Icelandair's 10 aircraft are owned. Most of America West's 13 aircraft, First Choice's 18, Britannia's 19 and Thomas Cook's 15 aircraft are leased.

There are several large fleets in China, including 13 aircraft with Air China, nine aircraft with China Xinjiang, 20 aircraft with China Southern and nine with Xiamen Air. Most of these aircraft are owned by their operators.

The majority of the remainder of the fleet is operated in small fleets of up to six or seven aircraft by a large number of different operators. This includes Air Astana, Air Atlanta Icelandic, Air Finland, Arkia, Astraeus, Avianca, Belair, MyTravel, Ryan Airlines, Skyservice Airlines and VARIG. Most of these aircraft are leased from the major lessors that include Aerfi, ILFC, GECAS, CIT, AWAS, Babcock & Brown, GATX and Aviation Capital.

-535E4-B-powered -200s

This fleet of 175 active and five stored aircraft is dominated by American Airlines which accounts for 124 units. Most of these are owned by American and come from two order batches for 75 and 50.

The next largest fleet is 41 aircraft operated by Continental. This is a mixture of owned aircraft, units leased from GECAS and others owned by various financial institutions.

The remainder of the fleet is split between just three operators: Air Horizons (3 aircraft), American Trans Air (6 aircraft) and Vulcan Aircraft (1 aircraft). There are also five stored aircraft, four of which are ex-ATA units.

PW2037-powered -200s

This is the largest 757 sub-fleet, with 320 units, although the RB211-535E4 and -535E4-B fleets may be considered as a single group. The PW2037-powered fleet is dominated by a few carriers.

The largest fleets are operated by Delta (121), United (96), and Northwest (48). American also has 17 ex-TWA aircraft, and Shanghai Airlines has 13. Two Shanghai airlines aircraft, which are owned by ILFC, are being converted to freighter by Precision Conversions. The remaining 23 aircraft are operated in small fleets by airlines that include Royal Air Maroc, Mexicana, Fischer Air, Far Eastern Air Transport, Aeromexico, Blue Panorama, and Uzbekistan Airways.

Delta, United and Northwest own many of their aircraft, which have uniform specifications and so represent good opportunities for possible freighter conversion.

PW2040-powered -200s

Aircraft with PW2040s are limited in number, comprising 40, mostly used and re-leased aircraft, aircraft obviously with the advantage of higher thrust rated engines. A large number are ex-Condor aircraft which are now operated by Mexicana, Air Italy and Russian carrier Vim Airlines. Ethiopian Airlines also has four passenger-configured aircraft, while Uzbekistan Airways has three. ILFC has 16 aircraft which are leased to Finnair, Eos Airlines, Fisher Air, Mexicana, and American Airlines. There is one aircraft in storage.

-535E4-B/C-powered -300s

The RB211-535E4-B and -535E4-C dominate the 757-300 fleet. There are 27 -535E4-B aircraft. Condor accounts for 13 and Continental another nine aircraft. The remainder are operated by Arkia, Thomas Cook, and Icelandair.

There are 12 -535E4-C-powered aircraft, which are split between three Continental aircraft and nine ATA aircraft.

PW2043-powered -300s

Northwest is the only customer for the PW2000-powered 757-300, with a fleet of 16 owned aircraft.

757-200 freighters

The fleet of 38 converted freighters includes 34 ex-BA RB211-535C aircraft converted by Boeing for DHL.

The other four include three RB211-535E4-powered aircraft that have been converted converted by Precision Conversions, two of which are now operating for Icelandair, and a third for DHL.

Out of 79 factory-built freighters, 75 were built for UPS. The first 35 were equipped with PW2040 engines, and the later 40 with the RB211-535E4.

One PW2040-powered aircraft was built for Ethiopian. Three RB211-535E4-powered aircraft are operated by Icelandair, Pacific Airlines and Royal Nepal. AC

757 modification & upgrade programmes

The 757 requires few of the avionic or noise reduction programmes that older aircraft do. There is a blended winglet programme to reduce fuel burn & performance enhancement, but the most prominent modification programmes for the 757-200 are the passenger-to-freighter conversions.

There are several categories of modifications and upgrades for the 757, including weight upgrades, performance enhancement modifications, passenger-to-freighter modifications, and avionic upgrades.

Weight upgrades

The weight specifications of the 757-200 are simpler than for other aircraft types. There are five different maximum take-off weight (MTOW) variants *(see 757 specifications, page 12)*, and all of which have the same fuel capacity. There are also only two maximum zero fuel weight (MZFW) options; all MTOW options have an MZFW of 184,000lbs, except the 255,000lbs MTOW variant which has an MZFW of 188,000lbs, therefore offering only a few possibilities for specification weight increases.

Most aircraft have MTOWs of 240,000lbs or higher *(see 757 specifications, page 12)*, so the majority are only likely to require small increases in MTOW capability. Most airlines are unlikely to require any weight increases, and changes are only likely to be made during conversion to freighter. Aircraft with MTOWs up to 250,000lbs are permitted an MZFW of 188,000lbs, while aircraft with an MTOW of 255,000lbs will have their MZFW capped at 186,000lbs, thereby reducing structural payload by 2,000lbs. Many aircraft may therefore need to have their MTOWs downgraded during conversion to make full use of payload potential. Many aircraft, however, are also likely to require an increase in MZFW from 184,000lbs to 188,000lbs, which must be done via Boeing at a cost of $150,000-170,000, providing aircraft are eligible.

Noise compliance

The 757-200 with the highest MTOW of 255,000lbs and powered by all four main engine types (the PW2037, PW2040, RB211-535E4 and RB211-535E4-B) is compliant with Stage 3 noise requirements.

The highest gross weight variant of the 757-200 is permitted a cumulative noise emission of 293.4 EPNdB, compared to actual cumulative noise readings of between 283.2 EPNdB for the PW2037-powered aircraft and 275.0 EPNdB for the RB211-535E4-B-powered aircraft. This provides the four variants with a Stage 3 compliance margin of 10.2 to 18.4 EPNdB.

Stage 4 noise rules are that aircraft manufactured/certified after 1st January 2006 should have a cumulative noise reading 10 EPNdB lower their permitted Stage 3 cumulative noise emissions. Aircraft certified prior to this date, such as the 757, are not required to be Stage 4 compliant, although there may be legislation in the future that requires older aircraft to be. The Stage 3 compliant margins of the four different variants of the high gross weight 757-200 are sufficient for the aircraft to meet Stage 4 compliance without any requirement for noise reduction modifications, since their Stage 3 compliant margins are all at least 10 EPNdB. There is therefore no need for noise reduction kits, or modifications.

Performance enhancement

Although the 757 meets Stage 3 and Stage 4 noise emissions requirements, there is a performance improvement programme from Aviation Partners Boeing which primarily reduces fuel burn. The modification features installation of blended winglets to reduce induced drag, and so lower fuel burn. Block fuel burn reduction varies from about 2% for a 500nm sector up to about 4.7% for a 3,500nm sector. The benefits of the blended winglets are: increased payload-range performance; improved take-off field performance; lower noise emissions; and reduced throttle settings and consequent reduced engine deterioration.

The annual savings in fuel costs are substantial at current fuel prices of about $1.50-1.65 per US Gallon (USG).

The majority of 757-200s are used on average sectors of about 1,000nm, with an average time of 2.7 flight hours (FH), and generate about 1,050 flight cycles (FC) per year. On this sector length aircraft burn in the region of 2,700-3,000USG, depending on engine type and operating conditions *(see 757 in service & operations, page 15)*. The blended winglets reduce fuel burn by about 3.1% on this sector length: equal to 84-93USG per flight or 88,000-97,000USG per year. At current fuel prices this provides a saving of up to $161,000 per year, against a list price of $1.05 million for the winglets, which will therefore pay for themselves in about six years.

Larger fuel burn reductions are realised with longer sector lengths. Continental Airlines, for example, uses some of its 757-200s on its thinner transatlantic routes. Fuel burn on a 3,000nm route is about 8,500-9,000USG, depending on engine type and operating conditions *(see 757 in service & operations, page 15)*. Blended winglets will reduce fuel burn by about 4.5% and 405USG on this route length.

These sectors have flight times of about 7.2FH, and the aircraft will generate about 4,500FH and 625FC per year. Annual fuel burn reduction is thus about 253,000USG, equal to an annual saving of up to $415,000. Payback is realised in less than three years in this scenario.

Freighter conversion

There are four different passenger-to-freighter modification programmes for the 757-200, offered by Boeing, Precision Conversions, Alcoa-SIE (ASCC) and Bedek Aviation/ST Aero.

The modification offered by Boeing is the oldest, but its only customer to to date has been DHL. The modification, designated the 757-200SF, provides an aircraft that accommodates 14 125-inch wide by 88-inch long containers that are standard for narrowbody freighters. The containers each have an internal volume of 440 cubic feet, giving the main deck a total freight volume of 6,160 cubic feet. Added to the belly capacity of 1,790 cubic feet, total aircraft freight volume is 7,950 cubic feet.

757-200PCF PAYLOAD CHARACTERISTICS-PRECISION CONVERSIONS

Aircraft variant	757-200	757-200	757-200	757-200
Engine type	RB211-535E4	RB211-535E4	PW2000	PW2000
Etops equipped	Yes	No	Yes	No
MTOW lbs	250,000	250,000	250,000	250,000
MZFW lbs	188,000	188,000	188,000	188,000
OEW lbs	116,041	115,541	115,441	115,041
Gross structural payload lbs	71,959	72,459	72,559	72,959
main deck containers				
Number of containers	15	15	15	15
Container tare weight lbs	7,140	7,140	7,140	7,140
Container volume cu ft	8,390	8,390	8,390	8,390
Net structural payload lbs	64,819	65,319	65,419	65,819
Maximum packing density (lbs/cu ft)	7.73	7.79	7.80	7.84
Volumetric payload lbs	58,730	58,730	58,730	58,730

757-200ASF PAYLOAD CHARACTERISTICS-ALCOA-SIE

Aircraft variant	757-200	757-200	757-200	757-200
Engine type	RB211-535E4	RB211-535E4	PW2000	PW2000
Etops equipped	Yes	No	Yes	No
MTOW lbs	250,000	250,000	250,000	250,000
MZFW lbs	188,000	188,000	188,000	188,000
OEW lbs	117,864	117,364	117,264	116,764
Gross structural payload lbs	70,136	70,636	70,736	71,236
main deck containers				
Number of containers	14 + 1/2	14 + 1/2	14 + 1/2	14 + 1/2
Container tare weight lbs	6,964	6,964	6,964	6,964
Container volume cu ft	8,170	8,170	8,170	8,170
Net structural payload lbs	63,172	63,672	63,772	64,272
Maximum packing density (lbs/cu ft)	7.73	7.79	7.81	7.87
Volumetric payload lbs	57,190	57,190	57,190	57,190

The list price of $8.5 million is viewed as high, especially compared to other conversions that accommodate more containers at lower prices.

Precision Conversions is the first independent passenger-to-freighter modification to receive its supplemental type certificate (STC), for RB211-powered aircraft. It will receive an amended STC for PW2000-powered aircraft when the first is converted at the end of 2005. The designation for aircraft converted by Precision Conversions is 757-200PCF. The modification has a list price of $4.65 million, including the cargo handling system which is supplied by Ancra.

This modification seals the first door on the passenger aircraft and installs a new crew door further forward, allowing 15 standard 88-inch long containers to be accommodated, providing 6,600 cubic feet of freight capacity. When added to the underfloor space of 1,790 cubic feet, the aircraft has a total freight volume of 8,390 cubic feet.

One important criterion following conversion is the aircraft's MZFW. This will be 184,000lbs or 188,000lbs for aircraft that have an MTOW of up to 250,000lbs. For MZFW to be upgraded to 188,000lbs, owners and operators have to get the aircraft upgraded by Boeing, provided the aircraft is eligible.

Aircraft with an MTOW of 255,000lbs will have their MZFW capped by Boeing at 186,000lbs, thus taking out nearly one ton of payload capability from the aircraft. It is therefore preferable for operators to have MTOWs downgraded to 250,000lbs. The MTOW reduction of 500lbs reduces range performance by only about 200nm when the aircraft is carrying high payloads.

Precision Conversions' converted aircraft, with RB211-535E4 engines, has a basic empty weight of about 115,541lbs. This is the weight of an Etops-equipped aircraft without crew or tare weight of containers. The actual weight will vary between individual aircraft. Precision Conversions estimates a non Etops-equipped aircraft will be about 500lbs lighter. About 500lbs should be added for crew, taking operating empty weight (OEW) to 116,041lbs for an Etops-equipped aircraft and 115,541 for a non-Etops equipped aircraft.

These weights allow a gross structural payload of 71,959-72,459lbs *(see first table, this page)* for aircraft that have an MZFW of 188,000lbs.

The basic empty weight (BEW) of PW2000-powered aircraft, however, is expected to be about 600lbs less than their RB211-powered counterparts. With crew weight considered, these aircraft will have gross structural payloads of 72,559-72,959lbs *(see first table, this page)*.

The tare weight of a standard 125-inch wide X 88-inch long container is 476lbs, making total tare weight 7,140lbs for the 15 containers.

This takes net structural payload down to 64,819-65,319lbs for RB211-powered aircraft, and down to 65,419-65,819lbs for PW2000-powered aircraft *(see first table, this page)*.

These allow maximum packing densities of 7.75-7.85lbs per cubic foot. When freight is packed at 7.0lbs per cubic foot, the aircraft's volumetric payload is 58,730lbs *(see first table, this page)*.

Alcoa-SIE (ASCC) is developing a passenger-to-freighter modification for the 757-200 that accommodates 14 full containers plus a half-sized container in the fifteenth position at the rear of the fuselage. ASCC has developed this modification by retaining the first door of the passenger-configured aircraft so that the first cargo position is aft of the position for the first container on the Precision Conversions modification. For this reason, the ASCC conversion accommodates 14 full containers plus a demi container in the 15th position. This gives the aircraft similar freight volume to the Boeing conversion.

ASCC's conversion is designated the 757-200ASF and has a list price of $3.75 million, $0.9 million less than Precision Conversions' 15-container modification.

ASCC is still in the process of developing the modification for the RB211-powered aircraft, and says it expects to receive its STC by the end of 2005. As with all other modifications, MZFW will be either 184,000lbs or 188,000lbs, depending on the aircraft converted. MZFW can be raised from 184,000lbs to 188,000lbs for eligible

All 757s will be compliant with some mandatory avionic requirements, such as B-RNAV. Other avionic modifications, like 8.33KHz radio spacing, are only mandatory in Europe. The consequence of this is that aircraft may require several expensive modifications when they change operators and move from one part of the world to another.

aircraft by the owner or operator by paying Boeing for a weight increase.

The BEW of an Etops-equipped aircraft is 117,364lbs, and OEW including crew is 117,864lbs. This gives the aircraft a gross structural payload of 70,136lbs. This will be about 500lbs more for a non-Etops equipped aircraft *(see second table, page 12)*. The equivalent PW2000-powered aircraft will be about 600lbs lighter, and so have structural payloads of 70,736lbs and 71,236lbs.

The tare weight of each of the 14 main containers is 476lbs, while the 15th demi container has a tare of 300lbs. Total tare is thus 6,964lbs. This gives the RB211-535E4-powered, Etops aircraft a net structural payload of 63,172lbs *(see second table, page 12)*. Net structural payloads for the PW2000-powered aircraft are adjusted relative to their difference in BEW.

The volume of the 14 main containers, demi container and underfloor space totals 8,170 cubic feet, which is 220 cubic feet less than an aircraft converted by Precision Conversions. This volume allows a maximum packing density of 7.73lbs per cubic foot. Volumetric payload for freight packed at 7.0lbs per cubic foot is 57,190lbs *(see second table, page 12)*.

The third conversion is being developed by Israel Aircraft Industries (IAI) and ST Aero, which have obtained a licence from Boeing for a programme to follow Boeing's first conversion, which accommodated 14 and a half containers. IAI and ST Aero will be the two conversion facilities. This conversion will provide an aircraft that can accommodate 15 full-sized containers. STC is not expected until mid 2007. The conversion will have a list price of $5.5million, but will not include the cargo handling system. After sales support and weight upgrades will be provided by Boeing, and the STC is not expected until mid 2007.

The conversion will have the same MZFW as modifications offered by Precision Conversions and ASCC, and the the aircraft will have a gross structural payload of 68,500-72,500lbs depending on engine type and MZFW. Boeing is currently conducting a feasibility study for an upgrade of MZFW beyond 188,000lbs that would allow higher structural payloads.

Avionic upgrades

As with all other aircraft types, there are a series of avionic upgrades that only apply to operations in certain parts of the world. This means some aircraft will have been modified, while others will have to be if they change operators and fly in an area of the world where these modifications and mandatory.

The first of these is 8.33KHz radio spacing which is mandatory in Europe. The cost of components for this is about $30,000.

Installation of a traffic collision avoidance system (TCAS) and Mode S air traffic control (ATC) transponder was required worldwide by the end of 1991. The upgraded ATC transponder was installed on the 757 production line from line number 300 onwards. The transponders have gone through several upgrades, one of which was to comply with European requirements for enhanced surveillance. TCAS was mandatory for all aircraft from 1993.

Aircraft built before ATC Mode S and TCAS requirements may need avionic upgrades. Jacob Barak, manager of avionics at El Al Engineering estimates that the cost of new TCAS components is about $80,000.

Enhanced ground proximity warning systems (EGPWS) or terrain awareness systems (TAWS) are required by the Federal Aviation Administration (FAA), the Joint Airworthiness Authority (JAA) and the International Civil Aviation Organisation (ICAO) for worldwide application. The FAA required that EGPWS/TAWS be installed on new production aircraft from March 2002, and that previously built aircraft be retrofitted by March 2005. The JAA required the equipment to be installed on new production aircraft from October 2001 and retrofitted to previously built aircraft by January 2005. ICAO's dates were January 2001 for new production aircraft and January 2003 for previously built aircraft. Boeing actually started installing TAWS/EGPWS equipment on the 757 production line in May 1998.

Barak estimates the cost of TCAS/EGPWS components at $80,000 for any aircraft that still need to be retrofitted.

Reduced vertical separation minima (RVSM) are only mandatory in Europe and the Atlantic Ocean area, and are related to the calibration of pitot tubes to ensure that accurate altimeter readings are given. They do not require installation of new avionics.

Basic area navigation (B-RNAV) requirements have to be met in Europe. These require the aircraft not to deviate more than five miles of the planned track only 5% of the time. "All 757s are B-RNAV compliant since they have an FMS,"explains Barak. "Precision area navigation requirement (P-RNAV) is optional in most areas, but required in a few. This requires a deviation of no more than 300 feet from the planned track, and that waypoints for standard instrument departures (SIDs) and standard terminal arrival routes (STARs) be shown on a navigation screen. P-RNAV therefore requires the installation of a flat screen on the flightdeck. This does not have to be installed on the 757, but P-RNAV also requires that the navigation database fed into the flight management computer is P-RNAV compliant."

757 in service & operations

Most 757s are the -200 model and operate as passenger aircraft. Their operating & fuel burn performance on sample routes is analysed.

Out of the 998 757s in operation, 826 are passenger-configured -200s and 55 are passenger-configured 757-300s. The majority of the remainder are factory-built freighters flying for UPS.

The fleet of 757-200s is dominated by a small number of large fleets operated by US carriers, the largest by American Airlines (141) and Delta (121). The major US airlines operate a total of 501 757-200s, which account for 60% of the passenger fleet. Another 33 are operated by European scheduled carriers and 64 by major Chinese airlines. The operations of airlines in these three continents are similar, with most aircraft being operated on average flight times of 2.0-3.0 flight hours (FH) and at annual utilisation of 2,500-3,000FH per year. Many other 757-200s operated in smaller fleets by other carriers are utilised in a similar way.

The 757 is a reliable workhorse, operated by airlines such as Finnair and Iberia. Finnair uses the 757 for leisure routes and has an average flight time of 6FH for operations from Helsinki to the Mediterranean. The aircraft average 14FH per day and 4,000FH and 950FC per year. The fleet of six PW2000-powered aircraft achieve this with a technical despatch reliability of 99%.

Iberia's operation is for an average route length of 930nm for flights with its fleet of 10 757-200s. These generate an average of 3,800FH per year, and manage this operation with an average turn time between flights of 45 minutes.

Fuel burn performance

To illustrate the fuel burn performance of the different 757-200 variants and the RB211-535E4-B-powered 757-300 on different routes of varying length, three sample city-pairs have been used. These have sector lengths of between 881nm and 3,225nm *(see first table, page 16)*.

Four different 757 variants have been analysed, including three 757-200 models. These three have a maximum take-off weight (MTOW) of 255,000lbs, fuel capacity of 11,276lbs, and are powered by the RB211-535E4, PW2037 and PW2040. The fourth variant analysed is a 757-300, powered by RB211-535E4-B engines.

The fuel burn calculations have been made using a maximum passenger load of 190 and a conservative average weight of 220lbs. The 757-300 has been analysed with a passenger payload of up to 245.

The fuel burns in US Gallons, flight times, distance tracked, equivalent still air distance (ESAD) flown, wind component factor, and number of passengers carried for each aircraft type on each route in both directions are summarised.

The results also show the average fuel burn per passenger carried, illustrating the difference in fuel burn efficiency between the engine types.

The data for the three 757-200s first show that the aircraft is not payload-limited on the longest and most challenging route: Lima to New York. This is because it is able to carry a full passenger load, and the aircraft takes off at its MTOW of 255,000lbs.

The fuel burns of the three -200 variants illustrate the fuel efficiency of the PW2000-powered aircraft over the RB211-535E4-powered aircraft. In most cases the RB211-535E4-powered aircraft burns 5-8% more fuel. The PW2040-powered aircraft is marginally more fuel efficient than PW2037-powered aircraft in most cases, although few operators specified the PW2040. The difference in fuel burn between the RB211-powered and PW2000-powered aircraft is in the region of 0.6-0.8USG per passenger: equal to about additional $1.2 in fuel cost on a 800-1,000nm route.

The 757-300 experiences a payload limitation on the Lima-New York route. This city-pair has an ESAD of about 3,200nm when wing direction and speed are considered. This compares to a range of about 3,050nm with 245 passengers at an average weight of 220lbs. A payload reduction therefore has to be made on this route. Analysis on other routes with shorter ESADs in the region of 2,700nm shows that the 757-300 can operate with a full payload. One example of this is JFK-Birmingham, UK where the reverse trip has an ESAD of 3,300nm, forcing the aircraft to have a payload reduction. Bahrain-Brussels, with an ESAD of 2,814nm, allows the aircraft to operate with a full passenger load. This indicates that the aircraft can operate on routes with an ESAD of up to 2,900nm, and a flight time of about 6 hours and 25 minutes, without payload restrictions.

In terms of fuel burn efficiency, the 757-300 burns 6.2-10% less than PW2000-powered -200s and 13-15% less than RB211-535-powered -200s, mainly because of the aircraft's larger size, carrying 29% more passengers.

Freighter performance

Since a large number of 757-200s are likely to be converted to freighter, an analysis of their fuel burn performance on a few routes has been analysed.

Because of the large number of different -200 variants and the three conversion programmes available, the analysis has been simplified by taking two variants converted under one modification programme. The two variants are the RB211-535E4-B-powered and PW2037-powered -200 aircraft. These are the most numerous of -200 variants and the fuel burn difference between them and the other two variants is only 1-2%.

The conversion programme used here is the Precision Conversions modification, which results in the -200PCF aircraft. For the same engine type, MZFW, aircraft fuel capacity and payload carried; the only other factor that will affect the fuel burn between this and aircraft converted under another programme is the operating empty weight (OEW). The difference in OEW between -200PCF and the same aircraft converted by ASCC is 1,823lbs in favour of the -200PCF. The -200ACF will have a 1.0-1.1% higher fuel burn. The fuel burn data shown *(see second table, page 16)* can thus be increased by about 1% for an aircraft converted by ASCC: the -200ACF.

The three routes used to illustrate the fuel burn performance of the freighter are Cincinnati-New York JFK, Miami-Bogota and Miami-Manaus. These routes have still air distances of about 500nm to 2,140nm and so are representative of how many 757 freighters may be used in the future.

The weight specifications of the -200PCF aircraft are: MTOW of 250,000lbs; MZFW of 188,000lbs; and OEW of 116,041lbs for the RB211-535E4-B-powered aircraft and 115,541lbs for the PW2037-powered aircraft. In all cases, the aircraft carries a gross payload of 53,100lbs; which includes a tare of 7,100lbs, leaving a net payload of 46,000lbs.

There were no take-off weight restrictions, and so no payload limitations on any route. The shortest sector is completed in about 77 minutes. The RB211-535E4-B-powered aircraft burns 1,445USG of fuel *(see second table, page 16)*. This is 82USG and about 6%

FUEL BURN PERFORMANCE OF 757-200 & 757-300

City-pair	Aircraft variant	Engine model	Fuel USG	Flight time	Passenger payload	Fuel USG per passenger	Tracked distance-nm	ESAD nm	Wind speed factor
Chengdu-Beijing	757-200	RB211-535E4	2,313	1:58	190	12.2	881	799	43
	757-200	PW2037	2,171	1:57	190	11.4	881	800	43
	757-200	PW2040	2,208	1:59	190	11.6	881	804	40
	757-300	RB211-535E4-B	2,562	1:56	245	10.5	881	802	42
Beijing-Chengdu	757-200	RB211-535E4	2,795	2:23	190	14.7	884	1,000	-50
	757-200	PW2037	2,643	2:22	190	13.9	884	998	-49
	757-200	PW2040	2,637	2:27	190	13.9	884	1,012	-53
	757-300	RB211-535E4-B	3,072	2:22	245	12.5	884	998	-49
Miami-Lima	757-200	RB211-535E4	6,318	5:06	190	33.3	2,303	2,303	0
	757-200	PW2037	6,003	5:08	190	31.6	2,303	2,303	0
	757-200	PW2040	5,870	5:15	190	30.9	2,303	2,303	-1
	757-300	RB211-535E4-B	7,099	5:09	245	29.0	2,303	2,303	0
Lima-Miami	757-200	RB211-535E4	6,325	5:09	190	33.3	2,320	2,320	0
	757-200	PW2037	5,983	5:12	190	31.5	2,320	2,320	1
	757-200	PW2040	5,929	5:18	190	31.2	2,320	2,314	1
	757-300	RB211-535E4-B	7,097	5:10	245	29.0	2,320	2,320	0
New York-Lima	757-200	RB211-535E4	9,058	7:12	190	47.7	3,288	3,219	1
	757-200	PW2037	8,658	7:13	190	45.6	3,288	3,281	1
	757-200	PW2040	8,467	7:18	190	44.6	3,288	3,281	1
	757-300	RB211-535E4-B	9,830	7:13	220	44.8	3,288	3,181	1
Lima-New York	757-200	RB211-535E4	8,897	7:00	190	46.8	3,225	3,197	4
	757-200	PW2037	8,416	7:04	190	44.3	3,225	3,197	4
	757-200	PW2040	8,171	7:09	190	43.0	3,225	3,196	4
	757-300	RB211-535E4-B	9,633	7:02	229	42.0	3,225	3,197	4

Source: Navtech

FUEL BURN PERFORMANCE OF 757-200PCF

City-pair	Aircraft variant	Engine model	Fuel USG	Flight time	Freight payload lbs	Tracked distance-nm	ESAD nm	Wind speed factor
Cincinnati-New York	757-200	RB211-535E4-B	1,455	1:16	53,100	550	491	49
	757-200	PW2037	1,373	1:17	53,100	550	498	43
New York-Cincinnati	757-200	RB211-535E4-B	1,750	1:33	53,100	528	607	-53
	757-200	PW2037	1,648	1:33	53,100	528	600	-48
Miami-Bogota	757-200	RB211-535E4-B	3,511	3:04	53,100	1,336	1,333	1
	757-200	PW2037	3,349	3:07	53,100	1,336	1,333	1
Bogota-Miami	757-200	RB211-535E4-B	3,560	3:08	53,100	1,349	1,356	-2
	757-200	PW2037	3,416	3:11	53,100	1,349	1,356	-2
Miami-Manaus	757-200	RB211-535E4-B	5,408	4:40	53,100	2,095	2,077	4
	757-200	PW2037	5,114	4:42	53,100	2,095	2,077	4
Miami-Manaus	757-200	RB211-535E4-B	5,575	4:48	53,100	2,117	2,141	-5
	757-200	PW2037	5,287	4:53	53,100	2,117	2,141	-5

Source: Navtech

more than the PW2037-powered aircraft. This is equal to about $120 at current fuel prices, and has to be considered against all other cash operating costs and aircraft financing and lease charges.

The Miami-Bogota route is completed in just over three hours and uses about 3,500USG. Again, the RB211-powered aircraft has a higher fuel burn, in this case 4-5% more than the PW2037-powered aircraft depending on the direction of flight and the effects of en-route winds.

The Miami-Manaus route, with an ESAD of 2,080-2,140nm, depending on the direction travelled, is completed in 280-290 minutes. The RB211-powered aircraft burns 5,400-5,575USG, 5-6% more than the PW2037-powered aircraft.

757 maintenance analysis & budget

The 757 has reasonable total maintenance costs for its age. One of the largest and most variable elements of maintenance costs are engine reserves.

Most 757s are mature aircraft in maintenance terms, and only about 140 will still be in their first base check cycle. The oldest aircraft will have passed their fourth base check cycle and will now be in the ageing phase of their life. Although production of the 757 has ceased, the aircraft is in a class of its own and is therefore likely to remain popular, ensuring that the number of 757s in operation will not change significantly from the current number of about 1,000 for the next five to 10 years.

One major change in the 757 fleet could be the conversion of a large number to freighters. The 757 is in a size class that is forecast by many to experience a high rate of growth, and several hundred may be modified to freighter. The 757 will have a range capability of up to about 2,500nm with a full payload, and can therefore offer itself as a versatile freighter. The aircraft could thus operate in a variety of roles, with low and medium rates of utilisation being experienced across short- and medium-haul operations.

757 in operation

Most 757s operate medium-haul passenger services on sectors with average flight times of 2.7 flight hours (FH), and operate about 1,050 flight cycles (FC) per year. Aircraft therefore accumulate about 2,700FH and about 3,000 block hours (BH) per year.

This pattern of utilisation is relatively efficient for narrowbody aircraft, since most other types are operated on shorter average FC times, which have the effect of raising costs per FH. The 757's long average FC time will reduce maintenance costs per FH for items such as landing gears, thrust reversers, wheels and brakes, some elements of engine reserves and base checks, and line and ramp checks.

Most aircraft that will be converted to freighter are likely to operate shorter average FC times, with the effect of increasing many of the aircraft's FH maintenance costs. One particular issue of concern for future freighter operations is the effect on maintenance costs of RB211-535E4 and PW2000 engines changing to shorter average cycle times and lower rates of annual utilisation.

Maintenance programme

The 757's maintenance programme was developed in parallel with the 767's maintenance schedule under a maintenance steering group 3 (MSG3) programme. Ageing aircraft tasks are thus built into the maintenance programme. The initial thresholds for these are relatively high, and appear in the second or third base check cycles.

Separate maintenance programmes were developed for structural- and system-related tasks. System tasks were grouped into checks with FH intervals, while structural inspections were grouped into checks with FC intervals. These two groups of checks could then be performed together or separately at the operator's discretion.

The maintenance planning document (MPD) has an interval of 500FH for system-related A check items. There are also system-related tasks with multiples of this interval: the 2A, 3A, 4A and 6A tasks (the latter having an interval of 3,000FH).

The structural-related system 1SA tasks have an interval of 350FC. There are also 5SA tasks with an interval of 1,500FC.

The different groups of tasks will not be in phase until the A12 check, so the A check cycle terminates at this check, which has an interval of 6,000FH.

Downtime for maintenance is minimised if the structural tasks are combined with a multiple of the system tasks. That is, the 1SA could be combined in one check with the 1A, 2A or 3A tasks, depending on the average FH:FC ratio achieved during operation. An aircraft with an FH:FC ratio of 1.4:1 or less would combine the 1SA with the 1A tasks in order to utilise a high proportion of both check intervals.

An aircraft with an average FH:FC ratio of 1.4-2.8:1 would combine the 2A items with the 1SA tasks, while an aircraft with an FC time of more than 2.8FH would combine the 3A tasks with the 1SA tasks to best utilise check

Most 757s operate on average FC times of 2.0-2.7FH and achieve annual utilisations of 2,500-3,250FH. This has the beneficial effect of lowering the costs per FH of the many elements of maintenance that have cycle-related costs.

intervals. The majority of operators, however, combine 1A and 1SA tasks, irrespective of their FH:FC ratio, to simplify maintenance planning, which means most of the 1SA check interval is not utilised.

This also affects C check planning. The 1C system check tasks have an interval of 6,000FH and 18 months. There are 2C, 3C and 4C multiples, with intervals of 12,000FH/36 months, 18,000FH/54 months and 24,000FH/72 months.

The 1SC structural tasks have an interval of 3,000FC and 18 months. There are 2SC tasks with an interval of 6,000FC and 36 months, 3SC tasks with an interval of 9,000FC and 54 months, and 4SC tasks with an interval of 12,000FC and 72 months. Like A check items, most airlines combine 1C tasks with 1SC tasks to simplify maintenance planning.

Most operators arrange C checks into block checks. The C4 check therefore includes the 1C, 1SC, 2C, 2SC, 4C and 4SC tasks, forming the largest check in the cycle, and also terminating the cycle of C check items.

Maintenance planning

As described, most operators combine 1A and 1SA tasks and relevant multiples in the A checks, and combine 1C items with 1SC tasks and relevant C check multiples in the C checks for the ease of planning. This results in a low rate of utilisation for structural-related A and C task intervals.

Aircraft converted to freighter will still combine system and structural tasks in this way, and will use a high proportion of the structural check intervals because they are more likely to operate with shorter average cycle times.

Most operators also perform block checks. There are 1A, 2A, 3A, 4A and 6A tasks. The 1A tasks are performed every check, the 2A tasks every second check, the 3A tasks every third, the 4A tasks every fourth, and the 6A tasks every sixth. The tasks are therefore all in phase at the A12 check, at an interval of 6,000FH.

C checks are arranged in the same way, and block checks are formed with the C4 check being the largest, grouping the 1C, 1SC, 2C, 2SC, 4C and 4SC tasks together. In theory all task cycles will be in phase until the C12 check, because the 3C and 3SC tasks will have to be performed every third check. The cycle is completed by most operators, however, at the C4 check. The 3C and 3SC tasks comprise only a few items.

In addition to systems and structural tasks, operators and maintenance planners also include tasks that have intervals that are out of phase with the main tasks, including: cabin cleaning; cabin and interior refurbishment; performance of ageing aircraft tasks as they come due in later checks; performance of airworthiness directives (ADs) and service bulletins (SBs); removal and reinstallation of components and rotables; and strip and repaint when required. These tasks increase the content of checks, and can almost double the number of man-hours (MH) required to complete some of the heavier checks.

Check interval utilisation is an important issue. Airlines typically only utilise about 70% of their A check intervals, and so the 757 would have an A check about every 350FH. The A check would thus get completed about every 4,200FH or every 18 months when compared against typical annual utilisation.

Airlines utilise higher proportions of base check intervals, typically 85%. On this basis, a 757 would have a C check about every 5,100FH. The C check also has an 18-month calendar limit, which is unlikely to be fully utilised. A 15- or 16-month interval between checks is more likely. About 3,375-3,600FH will thus be accumulated between each C check, utilising only about 60% of the FH interval. The C4 check and base check

The 757's base maintenance programme has a cycle of four C checks and a C check interval of 18 months. The implication of this is to limit the cycle time to a maximum of six years, limiting the number of FH that can be accumulated in this time.

cycle, will therefore be completed about every 14,400FH and 62 months. Most 757s will therefore complete a base check cycle about every five years, and so the oldest aircraft will be in their fifth base check cycle.

Line & ramp checks

The line and ramp checks for 757 passenger operations are the pre-flight check prior to the first flight of each day, a transit check prior to all subsequent flights of an operating day, and a daily check performed overnight every 24 hours.

The content, MH and material inputs used, and the number of these checks performed every year or each A check cycle can account for a high proportion of maintenance costs. There will be a large number of pre-flight and transit checks in a given period for aircraft that have high cycle rates of utilisation.

The three line and ramp checks can be analysed over an A check cycle, and their inputs compared to the aircraft's annual utilisation. Taking into consideration downtime for base checks, the aircraft is likely to operate for 345-350 days per year. This means the same number of pre-flight and daily checks will be performed each year. The number of transit checks will therefore be about 700.

The actual interval between A checks will be in the region of 400FH, so the A check will be completed about every 4,800FH, which is equal to 21 months of operation. During this period the aircraft will go through about 600 pre-flight checks, 1,200 transit checks and 600 daily checks.

The MH used for each type of check vary widely between operators, and also depend on how the aircraft's technical defects are managed. Pre-flight checks consume about 5MH and $60 should be allowed for materials and consumables. Transit checks use about 1MH, and can sometimes be carried out by flightcrew. An allowance of $10 should be made for materials and consumables. A daily or overnight check, which will be used to clear most of the technical defects that arise during operation, will require a total input of up to 15MH from more than one mechanic, and a budget of $150 should be made for materials and consumables.

Over the duration of an A check cycle, a total of 13,000-14,000MH and $106,000 in materials and consumables will be consumed for these line and ramp checks. A labour rate of $70 per MH will take this to a total cost of about $1.05 million, which is equal to a rate of $220 per FH when amortised over the interval of 4,800FH *(see table, page 26)*.

Lighter A checks consume about 250MH, and two heavier checks in the A check cycle consume about 400MH each. Average material and consumable consumption is about $6,000 per check, taking total costs for the 12 checks in the cycle to about $300,000, and equal to a reserve of about $65 per FH *(see table, page 26)*.

Base checks

As previously described, the majority of 757s are now mature since they are in the second, third or fourth base check cycles. The 18-month calendar limit on C checks and typical levels of utilisation of check intervals means the four-check cycle gets completed about every five years. This is equal to about 13,500FH.

The majority of aircraft are in their second and third base check cycles, and the important issue is by how much the number of MH used to complete these checks increases with each base check cycle.

The content of base checks will include: routine inspections; corrosion prevention and control programme (CPCP) and sampling inspections; non-routine labour arising from routine inspections; cabin cleaning; ADs and other modifications; interior refurbishment; and stripping and re-painting. The total number of MH used for each of these checks will vary. First, the efficiency of maintenance planning will affect the number of MH required for routine inspections and, second, the initial thresholds of CPCP tasks occur late in the first base check cycle, and increase thereafter. The routine portion of base checks is therefore not only variable, but also increases with age.

The non-routine portion is determined by the age of the aircraft, its operating environment and how well the defects that arise during operation are managed. It is generally held that the non-routine ratio is relatively low during the 757's first base check cycle, and that it does not increase rapidly as the aircraft ages.

The content of the C1, C2 and C3 checks is relatively small, since they only include one or two groups of inspection tasks. The workscope for interior work and modifications is also relatively small. Routine and non-routine inspections therefore account for a high percentage of the total MH used in these checks.

The non-routine ratio for these first three checks is typically 40-50%. Routine MH for the C1 check are 1,500-1,650, and so the total routine and non-routine MH are 2,100-2,600.

MH used for modifications, ADs, SBs and engineering orders will vary between 300 and 550 according to how the operator manages its aircraft and what modifications are issued at the time. Interior cleaning consumes another 400-500MH, taking the total MH consumed for the check to 3,100-3,500.

The C3 check in the first cycle consumes a similar quantity of MH to the C1 check. The number of MH for routine inspections are marginally higher, while the non-routine ratio and MH used for modifications and cabin cleaning are about the same as the C1 check. This takes the total MH for the C3 check to 3,300-4,000.

The quantity of materials and consumables used for these two checks is is in the region of $65,000 for each visit.

The C2 check is a larger check, with the 2C and 2SC tasks being larger than the 3C and 3SC inspection items. Routine tasks consume 2,100-2,400MH, and the non-routine ratio can also be higher at 50-60%. This takes the labour used for non-routine tasks to 1,100-1,450MH and the sub-total for routine and non-routine inspections to 3,300-3,800MH. On average, a similar number of MH will be used for modifications and interior cleaning as consumed in the C1 and C3 checks, taking the total labour used in the check to 4,100-4,700MH. The cost of materials and consumables used in this check is about $80,000, but will vary according to modifications and defects found during routine inspections.

The C4 check, sometimes referred to as a 'D' check, has the largest workscope, because the initial CPCP items are included in the first C4/D check. The group of routine tasks is also about three times the size of the C1, C2 and C3 checks, while the non-routine ratio can also be 50-60%. Operators also normally have a higher inclusion of modifications, ADs and SBs. Most airlines also perform interior refurbishment during this check, which involves the refurbishment of galleys, toilets, overhead storage bins, sidewall panels, and seats and carpeting.

Routine inspections in the first C4/D check consume 5,000-6,000MH, and a non-routine ratio of 50-60%, take the sub-total for routine and non-routine to 7,500-9,500MH. A few operators experience higher non-routine ratios.

About 1,000-1,200MH can be used for modifications, ADs, SBs and EOs. Cleaning and a full interior refurbishment will consume up to 3,000MH. Stripping and painting will add another 2,000MH to the check's total. The overall total for the check will therefore reach 13,500-15,500MH, although it can be as high as 19,000MH where high non-routine ratios are experienced.

The cost of materials and consumables for this check will be $250,000-350,000, depending on the level of interior refurbishment and number of modifications included in the check.

The complete first base check cycle therefore consumes about 25,000MH and $460,000-560,000 in materials and consumables. A labour MH rate of $50 would take this to a total cost of $1.7-1.8 million. Amortised over an interval of 13,500FH, this would be equal to a cost of $125-135 per FH. Total MH expenditure can be as low as 19,000-20,000MH, however, if MH used for routine inspections are marginally lower, a non-routine ratio of about 40% is experienced and less MH are required for modifications, and cleaning and interior refurbishment. This would lower the reserve for by about $20 per FH.

The main cause of maintenance cost escalation during the second and third base check cycles is the increase in routine inspections and non-routine ratio. An increase in non-routine ratio by about 10 percentage points across all four checks in the cycle, and an increase in routine inspections raises the total MH consumed by about 5,000. The C4/D check in this case will consume about 18,000MH. The cost of materials and consumables also rises, and total cost for the four checks of the cycle rises to about $2.1 million, an increase of $300,000-400,000 that takes the amortised rate up to $155 per FH *(see table, page 26)*.

A similar rate of increase is experienced for the third base check cycle. Experience of the fleet shows that the increase in non-routine ratio has been about another 10 percentage points, while MH used for routine inspections also increase slightly. Total MH for the four checks of the cycle are in the region of 33,000, of which the C4/D check uses

about 19,000. Total material and consumable cost also increases to about $700,000, and total cost for the four checks is in the region of $2.35 million. This equals a rate of $175 per FH when amortised over the 13,500FH interval *(see table, page 26)*.

This demonstrates that the rise in base check maintenance costs is in the region of about $20 per FH for each base check.

These base check costs also have to be considered for aircraft that are modified to freighter configuration. These are likely to have a lower rate of annual utilisation than passenger aircraft, which is likely to be in the region of 1,500-2,000FH per year, even when carrying general freight on medium-haul. Utilisations will be lower than this for aircraft that are used for carrying express packages and in many cases may not exceed 1,000FH per year. These lower rates of utilisation will have the effect of reducing the number of FH achieved between C checks and for the whole base check cycle compared to passenger aircraft, because of the 18-month interval for C checks. The interval between subsequent C4/D checks is thus likely to be 7,500-10,000FH.

The MH and materials consumed for all checks will be less than the equivalent checks for passenger aircraft, however. First, there will be fewer routine inspections because of the removal of some cabin items relating to passenger configuration. Non-routine MH will also decrease, although deterioration of freight handling systems will counter some of this reduction to a degree.

The aircraft will also require fewer MH for interior cleaning, and most freight operators perform fewer modifications on their aircraft than passenger airlines. One of the largest reductions will be MH used for interior refurbishment, since most items will be absent in freighter aircraft. Some MH will be required for maintenance of a crew toilet and sidewall panels on the main deck, however. MH used for stripping and painting can also be minimised, and repainting is likely to be done less frequently than for passenger aircraft.

It is therefore possible that a converted aircraft in its third base check cycle could consume about 26,000MH compared to about 33,000MH used by a passenger aircraft. This would result in a reserve of about $190-220 per FH over the expected interval.

Heavy components

Heavy components of wheels and tyres, brakes, landing gear, thrust reversers and auxiliary power unit (APU) collectively account for 10-15% of total maintenance costs. These components all have cycle-driven maintenance costs, so aircraft operating on long average cycle times will benefit with lower rates per FH.

Main and nose wheel tyres have average removal intervals in the region of 300-400FC. Retreads are made at an average cost of $300-400 per tyre, and three or four retreads are possible before tyres have to be replaced. New main wheel tyres cost about $1,100, and nose wheel tyres about $900. These factors equate to an overall cost for tyre remould and replacement of about $16 per FC.

Wheel inspections are made at the same time as tyre remoulds, and repairs can cost $900-1,250 for each wheel. This combines to a total cost of $27 per FC.

Brake repair intervals depend on the severity of landing and braking action by pilots, but an interval of 2,500FC is representative. An average repair costs about $35,000 per unit, and the overall cost per FC for all eight brake units is $112.

These three elements total $155-165 per FC, which will be $57-61 per FH for an aircraft with an average cycle time of 2.7FH.

Landing gear overhauls have a hard time interval, and an eight-year removal is normal. At a utilisation rate of about 2,700FH and 1,000FC per year, the landing gear will be overhauled about every 22,000FH and 8,500FC. Market

rates for landing gear exchange and repairs are in the region of $400,000, equalling a rate of $18 per FH and $49 per FC.

Thrust reversers are also repaired on an on-condition basis, but an interval of 5,000-6,000FC is representative of the 757 fleet. An average shop visit cost and exchange fee is $250,000-275,000 for an engine shipset, and so the total cost for both shipsets amortised over the interval equals a reserve of $90-105 per FC. This equals $35-40 per FH for a FC time of 2.7FH.

The GTCP 331-200 used on the 757 has an average interval between shop visits of about 3,500 APU hours. How this relates to an aircraft FH interval depends on how long the APU is used between between flights. If it is used for one hour between flights it will have a removal interval of about 3,500FC and about 9,000FH. An average shop visit cost of $300,000 will equal a reserve of about $86 per FC and about $35 per FH.

Combined, these four component groups have a total cost of about $390 per FC and $155 per FH *(see table, page 26)*.

Rotables

There are many ways an airline can access rotable components. Large operators have their own repair shops and own their inventories. These have many direct and indirect cost elements and make it impossible to identify costs relating to a particular fleet.

Third party support contracts provide visibility in the cost of rotable inventory, repair and management. Airlines will lease a home-base stock, and pay a power-by-the-hour (PBH) fee for access to the remaining inventory, and a pay another PBH fee for the repair and management of all components.

The capital cost for a fleet of 10 757s will be $8-10 million, depending on which part numbers are included or excluded. A lease rate for this might be $100,000 per year for each aircraft, and so about $35 per FH. The fee for access to remaining parts kept in a pool by the component provider will be $65-80 per FH. The third element of a repair and management fee will be $160-180 per FH.

These three elements total in the region of $260-300 per FH *(see table, page 26)*, depending on inclusions and contract terms.

Engine maintenance

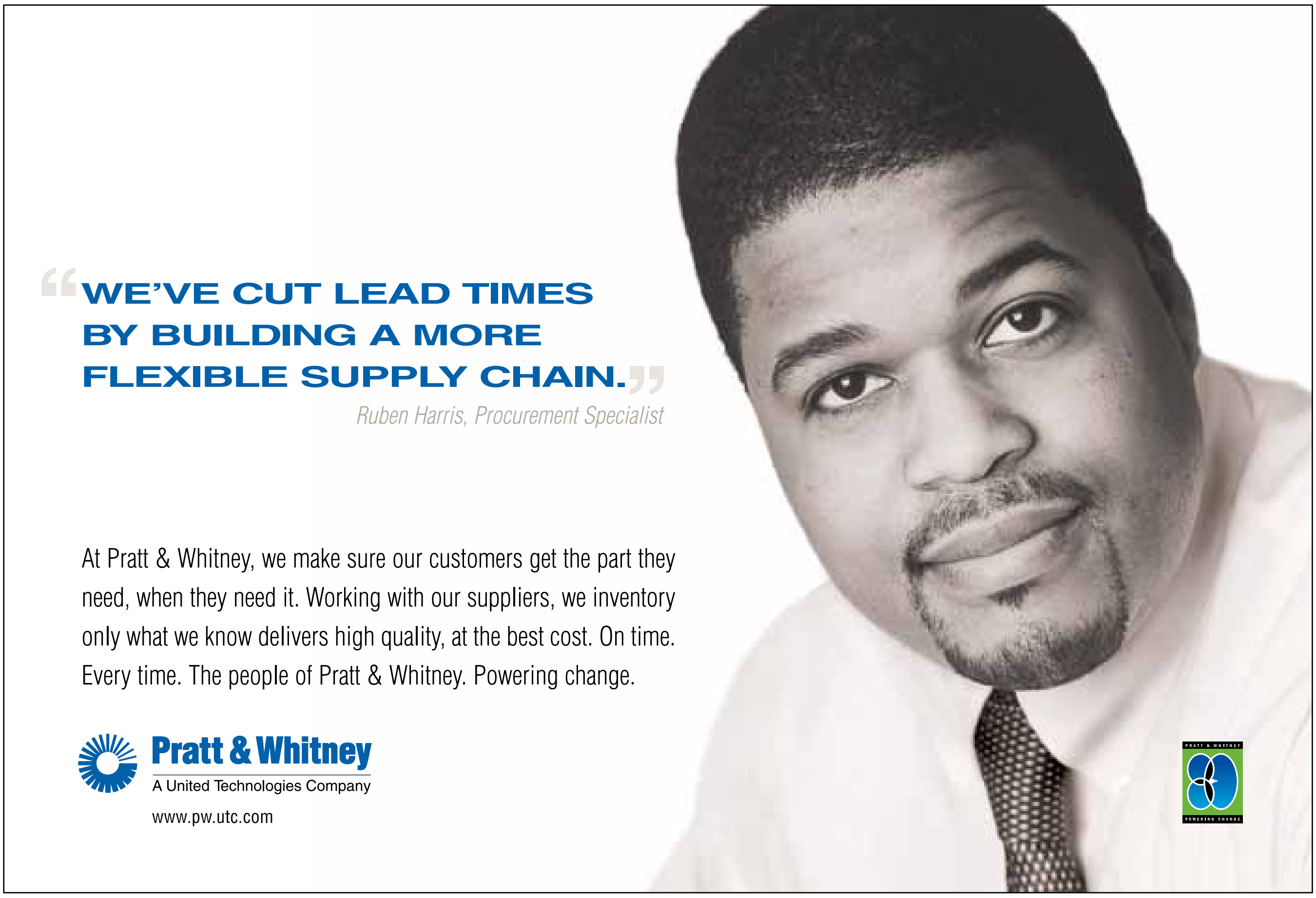
The distinction between the two engine types on the 757 is clear. The PW2000 powers a smaller number of aircraft for a few carriers. The engine suffered negative publicity during its initial operation because of poor on-wing reliability, which it has since overcome to achieve competitive reliability.

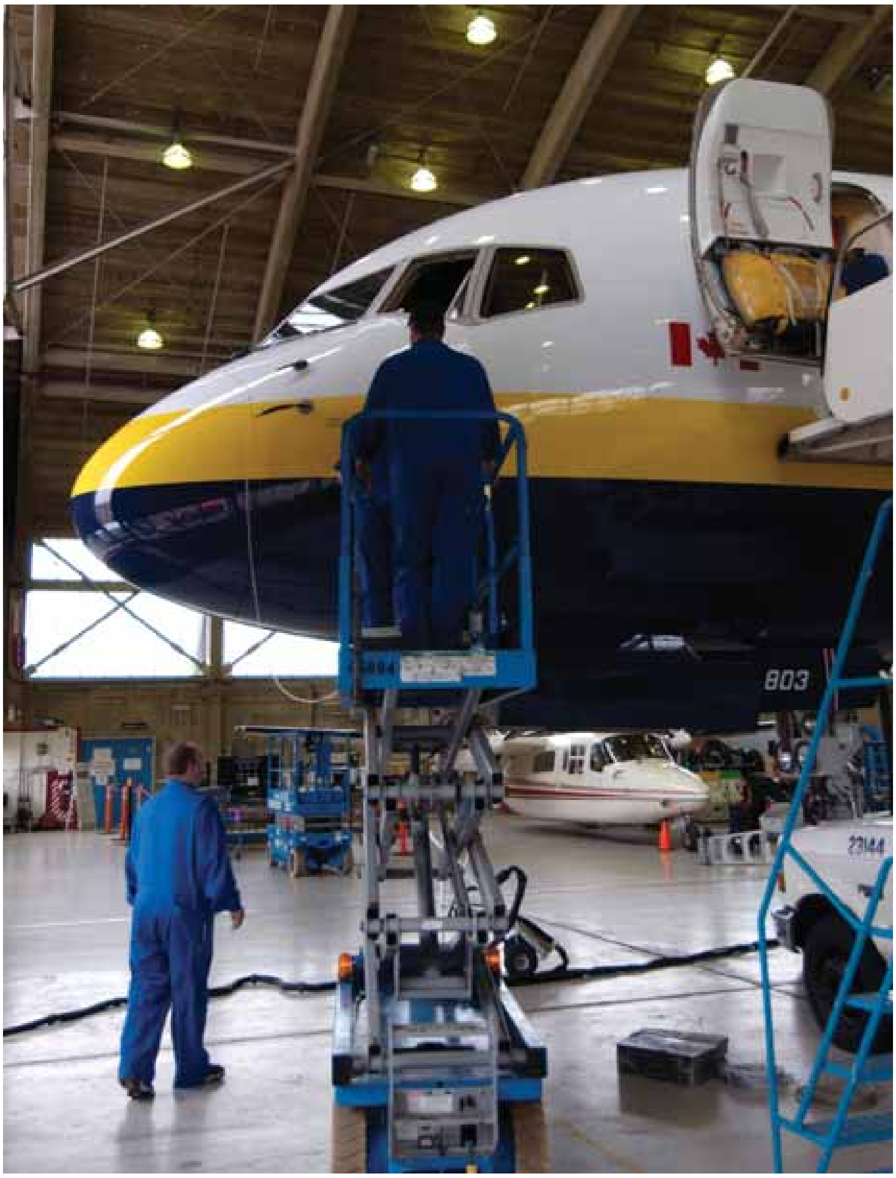
The RB211-535E4 gained a large number of customers at the expense of the PW2000's reputation for poor reliability. Rolls-Royce-owned and joint venture shops dominate the repair and overhaul market. Iberia and Ameco Beijing are independent shops that also overhaul the engine. The RB211-535E4, is reliable, but has gained a reputation for being expensive to overhaul.

The RB211-535E4 on average achieves intervals between planned removals that are 15,000-20,000 engine flight hours (EFH) in many cases. LTU, which operates at an average FC time of 3.0 hours, has an average interval of about 14,000EFH. The main causes of engine removal are hot section distress, rather than erosion of exhaust gas temperature (EGT) margin.

Andrew Gainsbury, programme manager at Total Engine Support (TES) says that the RB211-535's EGT margin is generally not an issue with on-wing reliability. "Most removals are not driven due to performance deterioration," he explains. Intervals for mature engines are usually 5,000-8,000EFC. An average interval of 15,000-20,000EFH might thus be expected by an operator with a 2.5:1 ratio.

Common removal causes include thermal deterioration of the high pressure (HP) turbine blades or combustion chamber and expired life limited parts (LLPs).





The 757 achieves total maintenance costs in the region of $1,200-1,450 per FH. The engine type on the aircraft has the largest effect of total costs. Despite negative publicity about poor reliability in the early years of operation, PW2000 engines have lower costs per FH as a result of their shop visit costs being lower than the RB211-535's.

Gainsbury explains that RR has four levels of engine shop visit workscope which can be applied at engine or modular level. "Engines will typically go through a level 3 workscope after 15,000-20,000EFH. Every second major shop visit is usually a level 4 workscope," explains Gainsbury. "Shop visits thus alternate between level 3 and level 4 workscopes. The engine comprises seven modules and a level 3 workscope requires work on each module, so a level 4 workscope involves more in-depth work and often a higher replacement rate of parts.

"The cost of a level 3 workscope will be in the region of $3.0 million," continues Gainsbury. "Materials are expensive, for example, and a new set of HP turbine blades costs around $600,000." Experience has shown that investing in more thorough shop visits gives a good on-wing life and in the longer term tends to work out cheaper per flying hour than more frequent, cheaper 'Check-and-Repair' shop visits.

Level 4 shop visits can cost in the region of $3.5 million, and so reserves for shop visits will typically be in the region of $200-215 per EFH. The rate would be higher for engines operating at a shorter FC time of 1.0-1.5EFH.

The RB211-535 LLPs vary in life limit between 14,000EFC and 27,000EFC throughout the engine. A shipset of LLPs (including uniquely in this engine, fan blades and annulus fillers) has a list price of about $2.65 million, and so a reserve of about $150 per EFC will cover their replacement. This is equal to a reserve of $55 per EFH at an average EFC time of 2.7EFH.

This takes total reserves for the RB211-535E4 to the region of $220-270 per EFH *(see table, page 26)*.

The PW2000 fleet can be divided into two sub-fleets. Pratt & Whitney (PW) introduced a reduced temperature configuration (RTC) modification on engines built from 1994. This production modification supercharged the lower pressure compressor (LPC) to increase airflow through the engine core. The CET-kit (modification of engines in service) could also be used to modify the low-speed rotor system of earlier-built engines by installing it during a shop visit. "About 50% of the fleet of engines built prior to 1994 have been modified," says Kurt Gschwind, PW2000 programme manager at PW. "It is most cost-efficient to install the RTC kit when the LLPs in the LPC are due to expire, and the kit costs about $1.1 million per engine.

"In addition to the RTC, we also introduced another modification known as the combustion exit temperature (CET) modification," continues Gschwind. "This increases core flow and turbine cooling air to reduce the EGT and so prolong the life of the hot section. The overall effect of these two modifications is that it improves EGT margin by about 25 degrees centigrade over an unmodified engine."

A RTC-modified PW2037 has an EGT margin of about 46 degrees centigrade, while the higher thrust-rated modified PW2040 has a margin of about 40 degrees centigrade. "EGT margin for unmodified engines is 28-35 degrees," says Leo Koppers, senior vice president of marketing and sales at MTU Maintenance. "RTC-modified engines have EGT margins that are 15-20 degrees higher. The RTC modification certainly has a large impact, but it is an expensive modification."

Koppers puts average rate of EGT margin deterioration at 7-8 degrees per 1,000EFC for an engine with an average EFC time of 2.0EFH. This implies unmodified engines might be expected to have a removal due to performance deterioration after about 4,000-5,000EFC, while modified engines would have intervals of 5,500-7,000EFC. These would equate to 11,000-13,500EFH for unmodified engines and 15,000-19,000EFH for modified engines when operating at an EFC time of 2.7EFH. The main cause of removals is loss of engine performance. Some airlines that operate in a hot environment stick to a soft time of about 8,000EFH, but most engines operate in large fleets with US carriers.

"EGT margin loss is not an issue for modified engines," says Gschwind. "The main causes of removal have been HPC blade failures, HPC stator failures and LLP expiry. Most engines, like other PW types, conform to a pattern of alternating hot section inspection and overhaul shop visits."

DIRECT MAINTENANCE COSTS FOR 757-200

Maintenance Item	Cycle cost $	Cycle interval	Cost per FC-$	Cost per FH-$
Ramp checks	$1,050,000	4,800FH		$220
A checks	$300,000	4,800FH		$65
Base checks (2nd cycle)	2,100,000	13,500FH		$155
Base checks (3rd cycle)	2,350,000	13,500FH		$175
Heavy components:				
Landing gear	$400,000	22,000FH	49	18
Wheel, tyre & brake inspections & repairs			155-165	57-61
Thrust reverser overhauls	$530,000-550,000		90-105	35-40
APU	$300,000	9,000FH	86	30
Total heavy components			390	$155
LRU/rotable component support				$260-300
Total airframe & component maintenance				**$855-915**
Engine maintenance:				
2 X RB211-535E4				$440-520
2 X PW2037/2040 (RTC)				$320-390
2 X PW2037/2040 (non-RTC)				$400-490
Total direct maintenance costs:				**1,175-1,435**

Annual utilisation:
2,700FH
1,050FC
FH:FC ratio of 2.7:1.0

The complete core is always worked on during the first shop visit, while all modules are overhauled during the second shop visit. Excluding replacement of LLPs, the lighter shop visits have a cost of $1.5-2.0 million. Overhauls have a higher cost of $2.0-2.5 million. Labour is a small portion of these costs, being just $300,000-400,000. The majority of costs are materials, parts and sub-contract repairs.

The amortised costs for unmodified engines over two removal intervals averaging 12,000EFH equals a reserve of $145-170 per EFH. The reserve for modified engines that achieve an average interval of 17,000EFH will be $105-120 per EFH. This saving of $35-60 per EFH that older engines will realise a payback on the investment for the RTC modification after about 20,000EFH. This is equal to about eight years of operation, although the modification will also enhance the aircraft's and engine's residual value.

Like most other PW engines, LLPs in the PW2000 have almost uniform lives. All parts, except two in the LPT, have lives of 20,000EFC. The on-wing intervals of 5,000-7,000EFC imply that LLPs will be replaced every third or fourth shop visit after a total accumulated time of 15,000-20,000EFC. A shipset of LLPs has a list price of $3.0 million, and so reserve for LLPs will be $150-200 per EFC. This equates to $55-75 per EFH for an average EFC time of 2.7EFH.

Total reserve for unmodified engines will therefore be $200-245 per EFH for unmodified engines and $160-195 per EFH for RTC-modified engines *(see table, this page)*.

Summary

In this analysis the 757 benefits from a long average FC time, which has the effect of diluting almost every element of the maintenance cost by: reducing the number of ramp checks in a given FH interval; diluting the FC-related costs for heavy components; reducing the PBH rate paid for rotable support; increasing FH on-wing intervals for engines; and diluting reserves for engine LLP replacement.

Total costs per FH shown *(see table, this page)* are for an aircraft in its second or third base check cycle, and so likely to be 5-15 years old. Engine reserves account for about one third of total costs. While the original PW2000 engine received negative publicity about its on-wing reliability, poor performance is offset by low shop visit costs, and the engine still has lower overall reserves than the RB211. RTC-modified PW2000s have even better overall economics, reducing total aircraft maintenance costs by $240-260 per FH compared to an RB211-powered aircraft. This difference in engine reserves is the major cause of variation in total maintenance costs shown.

The effects of MH and materials used in ramp and line checks should also be considered. Efficiency leading to fewer MH will have an impact on total maintenance costs.

Operators should also consider the effect of utilising the aircraft on shorter average cycle times. This will have the effect of raising the cost of per FH of most elements of maintenance. For a given number of FH more line and ramp checks will be performed, heavy components will have a higher cost per FH, and engines will have a higher reserve rate because of the impact on LLPs.

Future freighters

As already described, freighter aircraft are likely to operate at lower rates of utilisation. Average FC times of freighters in operation will be similar to those used here for general freight, but may be lower for many aircraft used in small package operations.

To offset the effect of lower rates of utilisation and shorter average FC times, freighter aircraft will have smaller workscopes for airframe checks, and so save some costs. Maintenance costs for heavy components and engine reserves will only be affected by average FC time. LRU components will have lower costs per FH because of the absence of passenger-related items. The constraint of an 18-month C check interval will reduce the base check cycle interval for aircraft operating at low rates of utilisation.

Freighter aircraft are thus likely to experience higher base check-related costs per FH, but slightly lower rotable-related costs for aircraft operating at a lower rates of utilisation but at similar average FC time to passenger aircraft. Costs per FH for other elements will be little affected.

Freighters operating at lower utilisations and on shorter cycles will experience higher costs for many elements of maintenance. The reserve for engine LLPs per FH, for example, would alone increase total maintenance costs by about $130 per FH if average FC time was halved to 1.35FH. AC