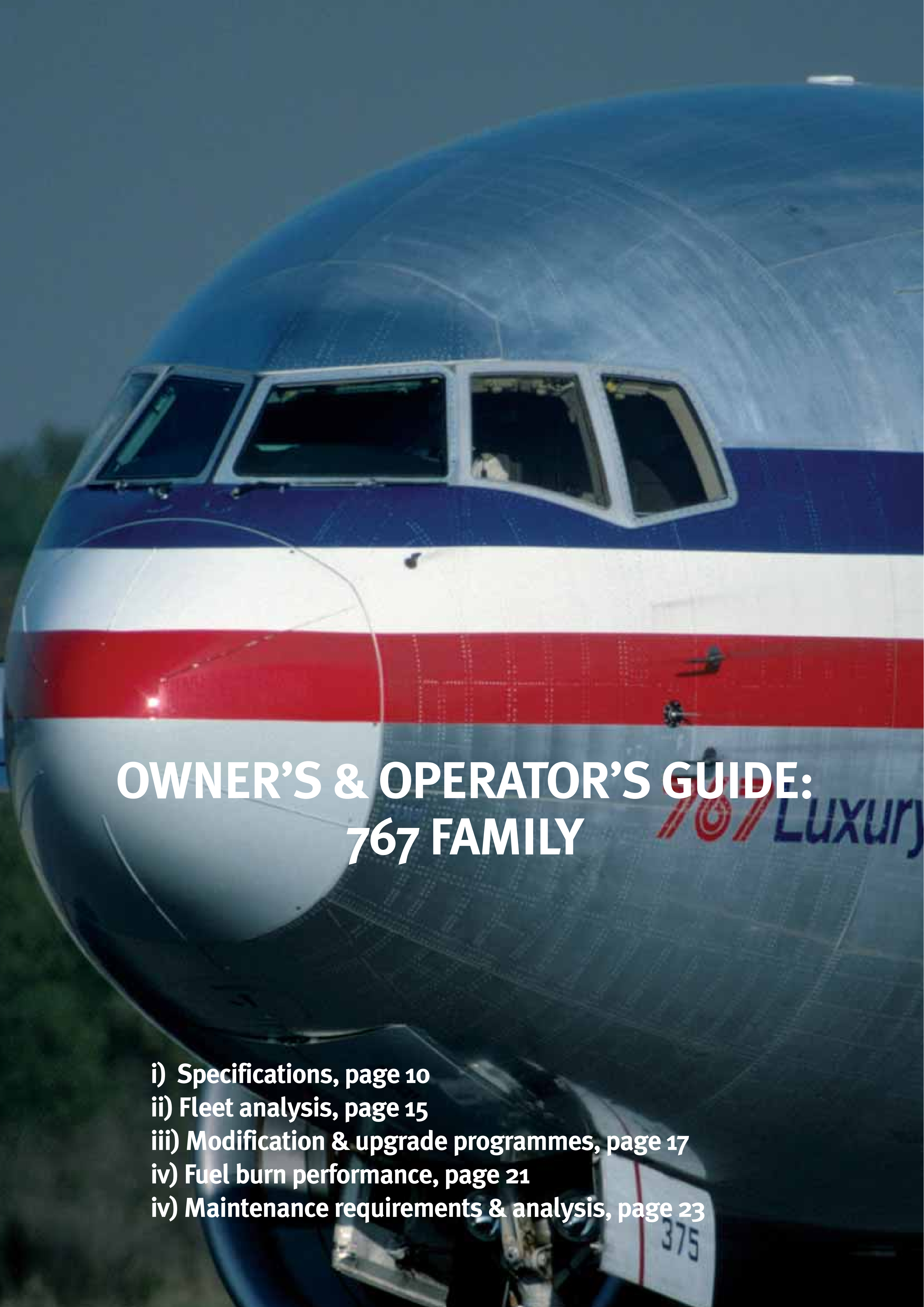

OWNER'S & OPERATOR'S GUIDE: 767 FAMILY

767 family specifications

The 767 family has five main variants, plus a factory freighter version. The 767 is further sub-divided by several engine types.

The 767 family is the most successful twin-engined widebody commercial aircraft, having sold more than 950 units. Its development ultimately led to three main variants: the -200 series, the -300 series and the -400 series. The -300 series accounts for the largest number of aircraft sold.

The 767 was developed in the late 1970s and early 1980s as a widebody sister to the 757 narrowbody *(see 757 family owner's & operator's guide, Aircraft Commerce, October/November 2005, page 5)*. One reason for the 767's introduction was to provide an alternative to the A300B2/B4 and the A310.

The 767 was developed at a time when the only long-range widebody aircraft available to airlines were the 747-200, DC-10-30/-40 and L-1011-500. The smallest of these had a tri-class seat capacity of about 220. All were heavy aircraft and equipped with three or four first-generation turbofans developed to power widebodies.

The 767 soon became an aircraft that could match or exceed the range provided by these older types, had fewer seats, which suited the capacity requirements of many carriers, had more fuel-efficient engines, and featured a lighter twin-engined design that would deliver several efficiencies and operating cost savings.

One feature introduced by the 767 and 757 was the two-man flightdeck using flatpanel, digital instruments with multifunction capability. Increased use of automation, such as the introduction of the engine indication and crew alerting system (EICAS) screens in the centre of the flightdeck panel, allowed operators to dispense with the flight engineer's station.

This new-style flightdeck was used in both the 757 and 767. This further led to the development of a common type rating for both aircraft. All 767 variants have the same pilot type rating, which means that a pilot is automatically certified to fly all 767 variants. The common type rating with the 757 means that a pilot certified on one aircraft is automatically certified to fly the other. An integral part of the common type rating is that the pilot has to attend a differences course. Pilots that do not remain current on either type have to carry out a take-off and landing in a simulator of the type they will be flying.

767-200 series

The initial 767 model was the 767-200 series. This came after a proposed smaller -100 model was dropped, and the 767-200 became Boeing's first widebody twin. The 767 was developed with a fuselage that allows a standard seven-abreast seat configuration in the economy-class cabin, with a 2-3-2 arrangement. The fuselage width was therefore narrower than Airbus's standard widebody fuselage, which was utilised for the A300/310, with eight-abreast seating, and also later by the A330/340.

Unlike most widebodies, the 767's narrower fuselage cross section only allows the side-by-side use of two smaller LD-2 containers.

The 767-200's fuselage is 176 feet long, which allows it to carry 174 seats in Boeing's standard tri-class layout, 216 passengers in a US-style dual class configuration, and up to 242 passengers in an all-economy layout with standard eight-abreast seating and a single type III overwing emergency exit.

The 767-200 soon gained popularity with Europe's all-inclusive charter carriers, and the aircraft was configured in a high-density eight-abreast economy class configuration, with two type III emergency exits which allowed a seat capacity of up to 290.

The 767-200 can carry 12 LD-2 containers in the forward belly space section, and another 10 LD-2s in the aft belly space section. Each LD-2 has an internal volume of 120 cubic feet, and so the 22 containers provide a total volume of 2,640 cubic feet.

The initial models of the -200 series were designed for US domestic and similar intra-continental operations, and were therefore developed with a standard fuel capacity of 16,700 US Gallons (USG). This fuel capacity was achieved through the use of fuel cells in the wings, and did not include the use of a fuel tank over the centre wing box.

The early aircraft had a maximum take-off weight (MTOW) of 282,000lbs, a maximum zero fuel weight (MZFW) of 242,000lbs and an operating empty weight (OEW) of about 174,000lbs *(see table, page 13)*. This gave the aircraft an approximate maximum structural payload of 68,000lbs. A typical load of 216 passengers would leave the aircraft with about 22,000lbs of freight capacity that could be carried in the belly space provided by the LD-2 containers.

The first aircraft were powered by the third-generation variant of the Pratt & Whitney (PW) JT9D: the JT9D-7R4 series. These were first rated at 48,000lbs thrust. The JT9D was the only PW engine to power all gross weight variants of the 767-200, and was selected for 51 of the aircraft built.

The alternative engine for the 767-200 was the General Electric (GE) CF6-80A. The -80A was a new engine and was the third-generation CF6 engine following the -6 and -50 series powering the DC-10 series and 747-200/-300. The CF6-80A is rated at 48,000-50,000lbs thrust for the 767-200. It has the same core engine configuration and fan diameter as the CF6-50 series.

The CF6-80A powers all gross weight variants of the 767-200, and was selected for 58 of the aircraft built.

The initial low weight 282,000lbs version had a range of about 2,250nm with a full load of 216 passengers. Higher gross weight models were developed with MTOWs of 300,000lbs, 310,000lbs and 315,000lbs *(see table, page 13)*. These aircraft have range capabilities of 3,200nm, 3,550nm and 3,900nm *(see table, page 13)* with a full load of 216 passengers.

This seat capacity and range positioned the 767-200 as a replacement candidate for 707s, DC-8s, L-1011s, DC-10s and A300B2/B4s operating short- and medium-haul services. The aircraft found favour with most US majors, being selected by United, American, Delta and TWA. It was also specified by Air Canada, Japan Airlines (JAL), All Nippon Airways (ANA) and Ansett.

Operators also have to consider noise compliance. Compliance with Stage 4 may become a concern for the 767 in the future. Stage 4 compliance is 10 equivalent perceived decibels (EPNdB) less than the maximum cumulative noise emissions permitted for Stage 3. Stage 3 margin is the difference between the cumulative emissions and the permitted cumulative emissions.

All 767-200s with the MTOWs and engines shown have a Stage 3 margin of 8.7-20.7 EPNdB *(see table, page 13)*. This means that their Stage 4 margins vary between -1.3 EPNdB and 10.7 EPNdB.

The first 767-200 was built in late

The 767-200ER has the longest range performance of all 767 variants. The type has been overshadowed, however, by the larger and more fuel-efficient -300ER.

1981, and the -200 model accounted for the majority of 767s built until late 1984. A total of 109 767-200s were built.

767-200ER

In parallel to the development of the -200 model, a longer or extended range (ER) variant of the -200 was being developed: the -200ER. This was mainly led by the initial development of extended-range twin-engined operations (Etops) in the early 1980s. Etops made it possible to operate a twin-engined aircraft over water for extended periods, and therefore use the long-range capability of a twin-engined aircraft in all global markets. Etops broadened the 767's market appeal.

The 767's range provided pressure on the safety authorities to allow Etops. All 767 airframe-engine combinations are now certified for 180 minutes Etops. That is, aircraft are permitted to take particular routeings over oceanic areas such that they have to be at most 180 minutes' flying time, on a single engine, away from a suitable diversion airport in the event of an engine failure.

The essential difference between the -200 and -200ER is that the -200ER has a higher fuel capacity of 24,140 USG and higher MTOW, which combined to give the aircraft a longer range capability. The higher fuel capacity of 7,440 USG over the -200 model was achieved through the use of a centre fuel tank over the wing box.

The first -200ER was built in early 1982, although production did not reach substantial levels until early 1985. The first -200ERs had an MTOW of 335,000lbs, and a range of 4,600nm with a full load of 174 passengers *(see table, page 13)*.

The first 767-200ERs were powered by the JT9D-7R4, rated at 48,000lbs thrust. These powered the lower gross weight variants of the aircraft, with MTOWs up to 360,000lbs. The JT9D was chosen by Qantas, Air Canada, El Al, Ethiopian Airlines and Air China. Some aircraft are now in operation with secondary users, including Maxjet Airways.

The first 767-200ERs to be powered by the GE CF6-80A entered service in 1985. Rated at 48,000lbs thrust, it powered the initial 767-200ERs with the lower gross weights.

Four higher gross weight models were developed with MTOWs of 345,000lbs, 351,000lbs, 380,000lbs and 395,000lbs. These gross weights gave the aircraft range capabilities of about 4,800nm, 5,250nm, 6,700nm and 6,850nm with a full passenger payload of 174 *(see table, page 13)*. The latter of these is the longest range capability of all 767 models.

The 767's weakness is its relatively low cruise speed. Its long-range cruise speed is Mach 0.80, which is slower than most other jetliner types, and can add 30-60 minutes' flight time to long-distance routes.

These higher gross weight -200ER aircraft started becoming available in the mid-1980s at the same time as PW's new PW4000 engine and the fourth generation of the CF6: the -80C2 series. The -80C2 can be divided into those with power management control (PMC) and full authority digital engine control (FADEC) systems. Engines with FADEC have more precise controls and longer removal intervals *(See 767 family maintenance analysis & budget, page 23)*. It is not possible, however, to upgrade engines to FADEC systems.

The PW4000 is a two-shaft turbofan, and the first variant had a 94-inch fan diameter. The first variant to power the 767-200ER, the PW4052, was rated at 52,000lbs thrust. The PW4056 and PW4060 rated at 56,000lbs thrust and 60,000lbs thrust also came available. The PW4000 powered the higher gross weight versions of the 767-200ER.

The new CF6-80C2B2/B4 and B6 were also used to power the higher gross weight versions of the 767-200ER. It became one of the more popular engines on the 767, and was selected to power -200ERs operated by American, Continental, USAirways, Malev and LOT Polish.

Its size allowed many carriers that were established on the North Atlantic either to downsize from aircraft that were 50 to 180 seats larger, or to open new routes with lower economic risk.

The 767-200ER was selected by United, American, Continental, Delta, USAirways, Air Canada, SAS, LOT Polish and Malev for this purpose. It suited the needs of many airlines from all around the world. Many North American carriers, for example, could enter the transatlantic market for the first time with a low-capacity aircraft.

The 767-200ER similarly allowed airlines in other parts of the world to downsize on established routes, or open new routes with low risk. The aircraft was an attractive alternative to the larger and heavier DC-10-30 for carriers in Africa, Latin America and other parts of the globe that experienced low traffic volumes. The 767-200ER was selected by El Al, Ethiopian Airlines, Air Zimbabwe, Air Mauritius, Qantas, Air New Zealand, Aeromexico, VARIG and Avianca.

All MTOW and engine combinations of the 767-200ER shown *(see table, page 13)* have a Stage 3 compliance margin of 11.5 to 21.8 EPNdB.

Production of the 767-200 continued only until 1987. The aircraft was overtaken by the -200ER, which continued to be built until 2001 when a last batch of civilian aircraft was manufactured for Continental Airlines.

767-300

Development of a stretched version of the 767 followed soon after the -200 series. Boeing started offering the -300 series in February 1983, and launch orders came from JAL. The first 767-300 entered service in 1986.

The -300 series retains the same wing and basic fuel capacity of 16,700 USG as the -200 series, but the -300's fuselage is 21 feet longer than the -200's. The 767-300 came with two options for door arrangements. The first had three main doors and two overwing type III emergency exits on each side of the fuselage. This option was selected by most US operators that ordered the 767-300. The second option was to have four main doors on each side of the fuselage.

Boeing's standard seat capacities for the 767-300 series were 204-220 passengers in a tri-class configuration, and 269 passengers in a US-style two-class configuration. All-economy seating accommodates 290 in a seven-abreast configuration. The 767-300, however, can seat up to 299 passengers with eight-abreast if equipped with a type III emergency exit, or up to 325 with four main exits.

The longer fuselage also allows the 767-300 to carry 30 LD-2 freight containers in its underfloor section, eight more than the -200 series. This gives the aircraft an underfloor containerised freight capacity of 3,600 cubic feet.

There were just two MTOW options of the 767-300: one of 345,000lbs and one of 350,000lbs. These have a range of 4,100nm and 4,450nm with a full load of 270 passengers *(see table, this page)*.

The initial 767-300s were powered by the JT9D-7R4, but JAL was the only airline to select the engine.

Lighter variants of the 767-300 were also powered by the CF6-80A, but these were mainly only aircraft operated by Delta Airlines.

The remaining 767-300s were powered by the new PW4056/4060 rated at 56,000lbs and 60,000lbs thrust, and the CF6-80C2B2/B4 rated at 52,500lbs and 57,900lbs thrust.

The MTOW and engine combinations of the 767-300 shown *(see table, this page)* have a Stage 3 margin of 8.6-14.8 EPNdB.

The 767-300 sold in small numbers, mainly to US majors for use on domestic services, and to Japanese carriers. Its main customers were JAL, Air China, Delta, ANA and Asiana Airlines.

767 FAMILY PASSENGER VARIANT WEIGHT & ENGINE SPECIFICATIONS

Variant		**-200**	**-200**	**-200**	**-200**
MTOW lbs		282,000	300,000	310,000	315,000
MZFW lbs		242,000	248,000	248,000	250,000
OEW lbs		174,110	177,000	176,550	176,650
Structural payload lbs		67,890	71,000	71,450	73,350
Fuel capacity USG		16,700	16,700	16,700	16,700
Seats		216	216	216	216
Range nm		2,250	3,200	3,550	3,900
Belly freight volume cu ft		2,640	2,640	2,640	2,640
Engine variant		JT9D-7R4/ CF6-80A	JT9D-7R4/ CF6-80A	JT9D-7R4/ CF6-80A	JT9D-7R4/ CF6-80A
Variant	**-200ER**	**-200ER**	**-200ER**	**-200ER**	**-200ER**
MTOW lbs	335,000	345,000	351,000	380,000	395,000
MZFW lbs	253,000	253,000	253,000	260,000	260,000
OEW lbs	181,130	181,250	181,350	181,500	181,610
Structural payload lbs	71,870	71,750	71,650	78,500	78,390
Fuel capacity USG	24,140	24,140	24,140	24,140	24,140
Seats	174	174	174	174	174
Range nm	4,600	4,800	5,250	6,700	6,850
Belly freight volume cu ft	2,640	2,640	26,40	2,640	2,640
Engine variant	JT9D-7R4/ CF6-80A	JT9D-7R4/ CF6-80A	JT9D-7R4 CF6-80A/ CF6-80C2B2	PW4056 CF6-80C2B4	PW4060 CF6-80C2B6
Variant		**-300**		**-300**	
MTOW lbs		345,000		350,000	
MZFW lbs		278,000		278,000	
OEW lbs		186,380		189,750	
Structural payload lbs		91,620		88,250	
Fuel capacity USG		16,700		16,700	
Seats		270		270	
Range nm		4,100		4,450	
Belly freight volume cu ft		3,600		3,600	
Engine variant		PW4056/ CF6-80A		PW4060/ CF6-80C2B2	
Variant		**-300ER**	**-300ER**	**-300ER**	**-400ER**
MTOW lbs		380,000	407,000	412,000	450,000
MZFW lbs		278,000	295,000	295,000	330,000
OEW lbs		193,940	198,440	198,440	227,400
Structural payload lbs		84,060	96,560	96,560	102,600
Fuel capacity USG		24,140	24,140	24,140	24,140
Seats		220	220	220	243
Range nm		6,350	6,750	6,750	5,600
Belly freight volume cu ft		3,600	3,600	3,600	4,560
Engine variant		PW4056/ CF6-80C2B4	PW4060/ CF6-80C2B6	PW4062/ CF6-80C2B7	CF6-80C2B7/8

767-300ER

It was clear following the development of extended-range capability for the -200 series that the same would be provided for the -300 series. The -300ER has the same fuel capacity of 24,140 USG as the -200ER, and an increased MTOW over the -300 variant.

The first orders for the -300ER were placed by American Airlines in March 1987 and the first aircraft entered service in February 1988. Five MTOW variants were developed, the first with a gross weight of 380,000lbs. Higher weight versions soon followed, however, and aircraft MTOWs of 407,000lbs and 412,000lbs were delivered in 1988 and 1989.

The aircraft with a gross weight of 380,000lbs has a range of about 6,350nm with a full load of 220 passengers. The other four gross weight variants have a range of about 6,750nm with a full load of 220 passengers *(see table, this page)*.

The 767-300ER did not use the JT9D and CF6-80A, but did use the PW4052/4056/4060/4062 and the CF6-

The 767-300ER equipped with CF6-80C2 engines was the single-most successful variant of the 767 family. The type is expected to continue to be popular, with large numbers being converted to freighter.

80C2B2/B4/B6/B7. These engines were rated between 52,500lbs and 60,800lbs to power aircraft with gross weights between 360,000lbs and 412,000lbs.

The Rolls-Royce RB211-524H became available on the 767-300ER in 1987, and soon afterwards was selected by British Airways. The airline ordered 29 aircraft, but some have since been acquired by Qantas. The only other carrier to select the RB211 was Yunnan Airlines in China.

The MTOW and engine combinations of the 767-300ER shown *(see table, page 13)* have Stage 3 margins of 7.8-16.0 EPNdB.

Despite its tri-class seat capacity being about 15 seats larger than the 767-300ER's, the A300-600R's range capability is 2,500nm shorter. Similarly, the A310-300 and 767-200ER have similar seat capacities, but the 767-200ER has a range advantage of up to 1,700nm. The 767-200ER/-300ER's range advantage over the A310-300 and A300-600R was the main factor in the 767 family winning the majority of orders in this market. The passenger variants of 767-200 and -300 series combined won more than 860 orders. This compares to less than 500 orders won by the A310 and A300-600 series.

The 767-200 and -300 also have the same pilot type rating, while the A310 and A300-600 have a common type rating. This gives the 767 a small advantage. The 767 family also has a common type rating with the 757, broadening the 767's commonality advantages. This was used by many of the 767's US customers which also selected the 757.

The 767-300ER was the 767 family's most successful variant, with the combination of its size and range proving popular with many airlines. For several years the 767-300ER was the most used aircraft on the transatlantic market, and was also widely used on many other long-haul markets. A total of 527 passenger variants of the 767-300ER have been ordered to date, out of 903 passenger aircraft of all 767 variants.

While the aircraft is officially still available from Boeing, the 787-8/-9 that have been developed to replace it are now selling in large numbers.

The 767-300ER's main customers are Delta, United, American, Continental, Hawaiian, Air Canada, Mexicana, LAN Airlines, British Airways, KLM, Martinair, Alitalia, JAL, ANA, Gulf Air, Qantas and Air New Zealand.

The 767-300ER continued to give airlines the ability to operate established long-haul services with smaller aircraft that had superior operating efficiencies over older generation widebodies, or allow airlines to begin new services with relatively low risk given the relatively small number of seats that had to be filled for them to break even.

The 767-300ER's payload-range performance also made it popular with European inclusive-tour carriers.

767-400ER

Following the success of the 767-300ER, it was logical to develop a stretched variant of the aircraft. This was on the basis that the -300 had offered a combination of higher capacity and lower seat-mile costs than the -200 series.

The 767-400ER included an increase in MTOW to 450,000lbs and a fuselage stretch of 21 feet over the -300 series. This resulted in a tri-class seat capacity of 243 and the ability to carry 38 LD-2 containers in the underfloor compartment. The -400ER's fuel capacity was the same as for the -200ER and -300ER, however.

The 767-400ER is powered exclusively by the GE CF6-80C2B7F/B8F rated at 60,800lbs thrust. The aircraft had a range of 5,600nm with a full load of 243 passengers *(see table, page 13)*.

The 767-400ER has four main doors on each side of the fuselage and so can accommodate up to 409 passengers in an eight-abreast, high-density configuration.

The 767-400ER was not developed until the late 1990s, when the similar sized A330-200 was also being developed. The first 767-400ER entered service in 1999. This arrival was probably too late to exploit higher market potential. The 767-400ER also has a slightly shorter range than the A330-200, and this disadvantage led to the 767-400ER achieving a poor sales volume. The aircraft only won 37 orders, from Delta and Continental.

767 freighter

The 767PF freighter variant was developed from the 767-300 in the early and mid-1990s, as a result of interest expressed by United Parcel Service (UPS).

The 767-300 freighter has MTOWs of 408,000lbs and 412,000lbs, the same as the 767-300ER. The aircraft also has the same fuel capacity, and MZFW of 309,000lbs and OEW of 188,100lbs when equipped with the GE CF6-80C2B6F/B7F engines. This gives it a gross structural payload of 121,000lbs.

As with the 767-300ER, the 767PF accommodates 30 LD-2 containers in the underfloor compartment. The aircraft can also carry 24 88-inch wide by 125-inch long by 96-inch tall containers on its main deck loaded in pairs, plus another two of these containers at either end of the deck. Each container has an internal capacity of 500 cubic feet, thereby giving the maindeck a containerised freight volume of 11,990 cubic feet. Added to the volume provided by the underfloor LD-2 containers, the aircraft has a total freight volume of 15,710 cubic feet. AC

767 family fleet analysis

The 767 fleet comprises five main passenger types and three freighter types. The number of each variant and model are analysed.

A total of 932 civilian variants of the 767 family have been built, and a further 27 aircraft are on order. The active fleet comprises 836 aircraft, including 746 passenger models and 90 freighters. A further 63 aircraft are in storage or temporarily inactive. To date, 33 aircraft have been destroyed or retired.

The fleet falls into four main groups: the -200 series, the -300 series, the -400 series, and freighter variants. The -300 series predominates, accounting for 654 of the 899 aircraft in the active and inactive fleet.

767-200 fleet

The 767-200 comprises one of the smallest sub-fleets of active 767s. There are now just 11 active aircraft, 10 of which are equipped with the JT9D-7R4, and one with CF6-80A engines *(see table, page 16)*. The JT9D-powered aircraft are operated by Air Canada, El Al, Maxjet and Japan Airlines (JAL). Most of these aircraft have accumulated more than 70,000 flight hours (FH) and 20,000 flight cycles (FC).

A large number of United and Air Canada aircraft with JT9D engines are in storage. Five aircraft with JT9D engines were also converted to freighter using Airborne Express's (ABX) unique passenger-to-freighter modification, which avoids the installation of a large cargo door. Special freight containers are loaded into the aircraft through the original passenger door.

Another 25 -CF6-80A-powered aircraft, previously operated by All Nippon Airways (ANA), were also converted to freighter using this modification, and are now operated by ABX.

Apart from the 46 aircraft that are parked or inactive, another 22 767-200s have been retired or destroyed.

767-200ER fleet

Of the 124 aircraft produced, there remain 104 active and 10 parked 767-200ERs.

The active fleet includes 85 passenger-configured aircraft, powered by four different engines: 21 aircraft with the JT9D-7R4; 15 with the PW4000; 24 with the CF6-80A; and 35 with the CF6-80C2 *(see table, page 16)*.

The JT9D-powered aircraft include those operated by Air Canada, El Al, Krasnoyarsk Airlines, Maxjet Airways and Air China. Qantas has sold its JT9D-powered aircraft. Many of these aircraft have accumulated more than 60,000FH.

The 15 active PW4000-powered aircraft are operated by Air China, Aeromexico, Air Zimbabwe, El Al and Avianca.

The majority of the 24 CF6-80A-powered aircraft are operated by American Airlines, while a few others are utilised by Transaero and Thomsonfly.

The 35 aircraft powered by the CF6-80C2 account for the largest number of the active 767-200ER passenger fleet. The majority of these aircraft are operated by Continental Airlines and USAirways, while other small fleets are operated by Bellview Airlines, Air Mauritius, LOT Polish, Thomsonfly and Malev.

A few additional CF6-80A- and CF6-80C2-powered aircraft are currently inactive, and are undergoing conversion to freighter.

767-300 fleet

The 767-300 has one of the smallest production runs of all 767 variants, and 102 of the 104 aircraft built remain in operation, including 13 JT9D-powered aircraft in operation with JAL. Having been used on domestic services, these aircraft have relatively low rates of utilisation, accumulating only 35,000-45,000FH over an operating life of 15-20 years.

The 767-300 fleet also includes a small group of 12 aircraft equipped with PW4056 and PW4060 engines. These are in operation with Shanghai Airlines, Air China and Delta Airlines.

The majority of the 767-300 fleet is powered by the CF6, with 22 aircraft using the CF6-80A and 55 aircraft the CF6-80C2.

All 22 aircraft with CF6-80A engines were delivered between 1986 and 1992, and are operated by Delta. These have now accumulated between 44,000 and

The -300ER is the most numerous of all 767 models, accounting for 501 out of 745 passenger-configured aircraft in service. The majority of these have CF6-80C2 engines.

SUMMARY OF 767 FAMILY ACTIVE & STORED AIRCRAFT

Aircraft variant	-200	-200ER	-300	-300ER	-400ER	TOTAL	-200F	-200ERF	-300ERF	TOTAL
ACTIVE FLEET										
JT9D-7R4	10	21	13			44	5			5
PW4000-94		15	12	176		203				
CF6-80A	1	24	22			47	28	5		33
CF6-80C2		34	55	293	37	419	4	5	44	53
RB211-524H				32		32				
TOTAL	**11**	**94**	**102**	**501**	**37**	**745**	**37**	**10**	**44**	**91**
STORED & TEMPORARILY INACTIVE FLEET										
JT9D-7R4	31	4				35				
PW4000-94				2		2				
CF6-80A	15	4	2	3		24				
CF6-80C2		2				2				
TOTAL	**46**	**10**	**2**	**5**		**63**				

60,000FH.

The fleet of 55 aircraft with CF6-80C2 engines comprises 34 aircraft operated by ANA, a further nine operated by JAL and a large fleet operated by Asiana Airlines. The nine aircraft operated by JAL supplement the 13 older aircraft equipped with JT9D engines.

767-300ER fleet

The 767-300ER accounts for the largest number of all 767 variants. To date, 508 aircraft have been built, and another 19 are on order.

Only five aircraft are in storage or inactive and two have been retired or destroyed. This leaves 501 aircraft still active *(see table, this page)*. Of these, 176 are equipped with PW4000 engines, 293 with CF6-80C2 engines, and 32 with RB211-524H engines. This makes the 767-300ERs powered by CF6-80C2 engines the most numerous type of all 767s, and also the most popular and sought-after model in the used aircraft market.

The 176 aircraft equipped with PW4000 engines are split between those with PW4052, PW4056, PW4060 and PW4062 engines. There are only 14 aircraft with PW4052 engines, rated at 52,000lbs thrust, and operated by United Airlines. These were delivered between 1998 and 2001, and so have only accumulated up to 25,000FH.

There are 17 aircraft with PW4056 engines, rated at 56,000lbs thrust. These are operated by Air Canada, Royal Brunei, and Hainan Airlines.

Aircraft equipped with PW4060 engines, rated at 60,000lbs thrust, constitute the largest group of PW4000-powered 767-300ERs, and total 133 units. These aircraft are operated by Delta, United, Hawaiian, Mexicana, Avianca, LAN Airlines, Martinair, El Al, Condor, Austrian, Ethiopian Airlines, Shanghai Airlines, Air China and Hainan Airlines.

A further 12 aircraft are equipped with the PW4062, which is rated at 62,000lbs thrust, the highest engine thrust rating available on the 767 family. These aircraft were built between 1992 and 2005, and are operated by LAN Airlines, Blue Panorama and Ethiopian Airlines.

The 293 aircraft equipped with CF6-80C2 engines can be split into four main groups, comprising aircraft with -80C2B2, B4, B6 and B7 engines.

There are just 12 active aircraft with -80C2B2/B2F engines, built between 1989 and 1997. The majority are operated by ANA.

There are 19 aircraft equipped with CF6-80C2B4s. These were built between 1986 and 1994, and are operated by LAB, Gulf Air and Delta Airlines.

The largest group of CF6-80C2-powered aircraft comprises 190, equipped with CF6-80C2B6/B6F engines, and built between 1988 and 2005. They are operated by a large number of airlines, including American Airlines, Delta Airlines, Air Canada, Qantas, Air New Zealand, LOT Polish, LAN Airlines, Aeroflot, Alitalia, EVA Airways, KLM, and ANA.

Another 72 aircraft are equipped with the CF6-80C2B7/B7F rated at 60,800lbs thrust. These aircraft were built between 1992 and 2005, and are operated by many of the same carriers that have -80C2B6-powered aircraft. In addition, JAL has a fleet of -80C2B7-powered aircraft.

LAN Airlines, ANA and JAL also have 19 -80C2B7-powered aircraft on order.

There are 32 aircraft equipped with RB211-524H engines. Three are operated by China Eastern, and the remainder are split between British Airways and Qantas.

767-400ER fleet

There are just 37 767-400ERs, all of which are powered by CF6-80C2B7F/B8F engines. Continental has eight aircraft with -80C2B7F engines. Another 29 aircraft have -80C2B8F engines, of which Delta has 21, and Continental eight aircraft.

767 freighter fleet

The 767 freighter fleet is split between factory-built freighters and aircraft converted to freighters. There are 91 active 767 freighters, split between 47 -200s and 44 -300s.

The -200Fs are five JT9D- and 28 CF6-80A-powered aircraft operated by ABX, as well as three CF6-80C2-powered aircraft operated by Star Air. These are all converted aircraft.

The -200ERFs comprise another six CF6-80A2-powered aircraft operated by Star Air, and four CF6-80C2-powered aircraft operated by Tampa Colombia.

No 767-300s have yet been converted to freighter, so all 44 aircraft in operation are factory-built freighters. These are all powered by the CF6-80C2B6F/B7F, and include the -300ERF model, with a fuel capacity of 24,140 US Gallons. These are operated by United Parcel Service, LAN Cargo and other members of the LAN Cargo group. Another seven aircraft are on order with JAL, ANA and LAN Cargo. AC

767 family modification programmes

The most prominent modification programmes available for the 767 are a flightdeck upgrade and several passenger-to-freighter modifications. A large number of aircraft are expected to be converted to freighters over the next 10 to 15 years.

Flightdeck upgrade

Innovation Solutions and Support (IS&S) has developed a flightdeck upgrade retrofit for the 767 and 757. This replaces the original enhanced attitude direction indicator (EADI) and enhanced horizontal situation indicator (EHSI) for each pilot with four new flatpanel displays. It also removes several analogue standby instruments.

The main purpose of this flightdeck upgrade is to remove instruments as well as the avionic line replaceable units (LRUs) that support them. It also reduces maintenance costs and takes out about 200lbs of weight from the aircraft.

The modification also standardises the latest formats available in the industry for the primary flight display and navigation displays. The upgrade also provides a solid foundation for developing the flightdeck to use an electronic flight bag (EFB), the main objective of which is to give the aircraft a paperless flightdeck. The documents in the EFB can be displayed on the new displays in the flightdeck.

The modification recently gained supplemental type certificate (STC) approval from the Federal Aviation Administration (FAA). Installation takes three or four days and costs a total of $250,000-275,000. IS&S is now working to get approval from Europe's Joint Airworthiness Authority (JAA). The first aircraft to be modified was a 767-200 for Airborne Express (ABX), and more of its aircraft are being modified.

Avionic upgrades

There are several avionic upgrades with which all aircraft types must comply when registered and operating in certain parts of the world. Some of these modifications are already mandatory, while others will become so. Airlines operating in some parts of the world will not be affected by these modifications, however.

The first of these modifications includes 8.33 KHz radio spacing, which has been mandatory since October 1999 throughout Europe, and is required to cope with the amount of airspace congestion there. This means that all affected aircraft will have been modified.

The second modification relates to the traffic collision avoidance system (TCAS) and Mode S air traffic control transponder. The Mode S transponder is mandatory for aircraft equipped with TCAS, and also where a regulatory authority requires a Mode S transponder to be fitted.

TCAS has been mandatory for all aircraft in the US since 1993, and in Europe since 2000. TCAS and Mode S equipment was not installed on the early production 767s. The 767 production incorporated this equipment in the 1989 to 1991 timeframe. All 767s delivered now have the equipment installed.

The third main modification, which is required worldwide, is the installation of enhanced ground proximity warning systems (EGPWS) or terrain awareness systems (TAWS). The FAA mandated that EGPWS/TAWS be installed on all new production aircraft from March 2002, and that aircraft already built should be modified by March 2005.

The JAA required installation of EGPWS/TAWS on new aircraft from October 2001, and that previously built aircraft be modified by January 2005.

The International Civil Aviation Organisation (ICAO) stipulated that the equipment should be installed on new production aircraft registered outside the US and Europe from January 2001, and on previously built aircraft by 2003.

Boeing started installing EGPWS/TAWS equipment on new production aircraft from May 1998.

Reduced vertical separation minima (RVSM) is a requirement for aircraft operating in Europe and the Atlantic Ocean area. RVSM only requires a calibration of pitot tubes to ensure accuracy of altimeter readings.

Basic area navigation (B-RNAV) is a European requirement for navigation accuracy to ensure that the aircraft does not deviate more than five miles from a planned track more than 5% of the time. The 767 meets this requirement because it is fitted with a flight management system (FMS) as standard. Precision area navigation (P-RNAV) is required in a few areas, for better accuracy of navigation. It requires a flat screen on the flightdeck, as well as the navigation database installed in the flight management computer to be P-RNAV compliant.

Freighter conversion

The 767-200 has now reached an age where its market values are sufficiently low to justify conversion to freighter. The total costs of aircraft purchase, conversion to freighter, additional maintenance and interest accrued are therefore low enough for a lessor to make a financial return from leasing the converted aircraft to a freight carrier at market lease rates. The bulk of the total cost incurred by a lessor is accounted for by the purchase cost of the used passenger aircraft. The drop in values of used 767-200s in recent years to a sufficiently low level has been a trigger for the first freighter conversions.

The values of 767-300s are still too high, but they are declining and are expected to reach a low enough level to trigger conversion of some of the oldest aircraft in the next few years.

There are two passenger-to-freighter modification programmes for the 767-200 that allow the conventional loading of maindeck freight containers on the aircraft. These are offered by Bedek Aviation and Aeronavali.

There is also the Airborne Express freighter modification which avoids the use of a conventional freight door, and instead utilises a system of passing specialised containers for carrying express packages through the original passenger door. A batch of 767-200s that have been converted for ABX are in operation with this system.

There is currently one freighter modification for the 767-300 offered by Bedek Aviation, but Boeing should start to offer its modification in a few years.

PAYLOAD CHARACTERISTICS 767-200/-200ER CONVERTED FREIGHTERS

Aircraft type	Aeronavali 767-200	Aeronavali 767-200ER	Bedek 767-200ER
MZFW-lbs	258,000	266,000	258,000/266,000
OEW-lbs	164,600	164,600	164,400
Gross structural payload-lbs	93,400	101,400	93,600/101,600
Type maindeck containers	88" X 125" X 96"	88" X 125" X 96"	88" X 125" X 96"
Number maindeck containers	20	20	19
Unit volume maindeck containers-cu ft	494	494	494
Unit tare weight maindeck containers-lbs	240	240	240
Total volume maindeck containers-cu ft	9,880	9,880	9,386
Total tare weight maindeck containers-lbs	4,800	4,800	4,560
Type lowerdeck containers	LD-2	LD-2	LD-2
Number lowerdeck containers	22	22	22
Unit volume lowerdeck containers-cu ft	124	124	124
Unit tare weight lowerdeck containers-lbs	203	203	203
Total volume lowerdeck containers-cu ft	2,728	2,728	2,728
Total tare weight lowerdeck containers-lb	4,466	4,466	4,466
Total volume all containers-cu ft	12,608	12,608	12,114
Total tare weight all containers-lbs	9,266	9,266	9,026
Net structural payload-lbs	84,134	92,134	84, 574
Maximum packing density-lbs/cu ft	6.67	7.31	7.64

767-200

The first issue to be considered for 767-200 passenger-to-freighter modifications is that there are 16 different maximum take-off weight (MTOW) variants of the 767-200/-200ER. These range from 282,000lbs to 315,000lbs for the -200 models and from 335,000lbs to 395,000lbs for the -200ERs.

Few freight carriers are likely to be interested in the 767-200, and most will require the -200ER's long-range capability. The majority of 767-200ERs still in active service have MTOWs of 351,000lbs to 395,000lbs.

Besides there being several different MTOW versions, there are also several wing numbers, each with its own limit on MTOW. While it is possible to get an MTOW upgrade kit from Boeing for an aircraft, the wing number will limit the possible higher MTOW. There are also several landing gear specifications and engine types.

The centre wingbox fuel tank can also be activated using a Boeing service bulletin, giving the aircraft the capability of the -200ER variant.

The -200 and -200ER share the same fuselage tube, and can carry the same number and type of freight containers and pallets. While the -200ER does have longer range performance, range is only extended when carrying less than a full payload on the converted freighters. The -200ER thus has a limited advantage.

Aeronavali

Alenia Aeronavali has the exclusive licence agreement with Boeing for the 767-200 passenger-to-freighter modification. Boeing will finalise the engineering package with Aeronavali, and Boeing will apply for the amended type design (ATD) certificate. Aeronavali will be responsible for the sales and marketing of the modification, as well as carrying it out. The modification will be available from June 2007.

The Aeronavali modification programme's main feature is the installation of a 134-inch wide by 103-inch tall maindeck freight door. Following conversion the -200 has a maximum zero fuel weight (MZFW) of 258,000lbs and an operating empty eight (OEW) of 164,600lbs without any containers or pallets loaded. This gives the aircraft a maximum structural payload of 93,400lbs *(see table, this page)*.

The 767-200ER has an MZFW of 266,000lbs and the same OEW as the -200. This gives the aircraft a maximum structural payload of 101,400lbs *(see table, this page)*.

Aeronavali will offer various operational weight increases, as well as avionic upgrades. Aeronavali can offer an upgrade of MZFW to 266,000lbs for both passenger and freighter-modified aircraft. Any aircraft that Aeronavali modifies to freighter will have a provision to upgrade MZFW to 266,000lbs. Aeronavali also offers a free maximum landing weight upgrade to 283,000lbs and an MZFW upgrade to 258,000lbs.

The 767-200 and -200ER have identical maindeck space for freight containers, and also have several options for container loading configurations. The one that provides the highest freight capacity is the use of 18 88-inch wide by 125-inch long by 96-inch tall containers loaded in nine pairs side by side, plus one of these containers at either end of the maindeck. These 20 containers each have an internal volume of 494 cubic feet, providing a total maindeck containerised volume of 9,880 cubic feet *(see table, this page)*.

Each of these containers has a tare weight of 240lbs and so the full complement has a tare weight of 4,800lbs *(see table, this page)*.

The 767-200's lower deck can accommodate 22 LD-2 containers by loading five pairs side by side in the forward section of the lowerdeck, and 12 in the aft section of the deck. This is unchanged from the original passenger aircraft's capacity. Each container has an internal volume of 124 cubic feet and tare weight of 203lbs. The full set of lower deck containers has a freight volume of 2,728 cubic feet and tare weight of 4,466lbs *(see table, this page)*.

The converted 767-200 and -200ER both have a containerised volume of 12,608 cubic feet and tare weight of

PAYLOAD CHARACTERISTICS 767-300 CONVERTED FREIGHTERS

Aircraft type	Boeing 767-300BCF	Boeing 767-300ERBCF	Bedek 767-300ER
MZFW-lbs	278,000	295,000	295,000
OEW-lbs	182,900	184,100	180,700
Gross structural payload-lbs	95,100	110,900	114,300
Type maindeck containers	88" X 125" X 96" Plus A2	88" X 125" X 96" Plus A2	88" X 125" X 96" Plus A2
Number maindeck containers	22/2	22/2	22/2
Unit volume maindeck containers-cu ft	494	494	494
Unit tare weight maindeck containers-lbs	240	240	240
Total volume maindeck containers-cu ft	11,708	11,708	11,708
Total tare weight maindeck containers-lbs	5,280	5,280	5,280
Type lowerdeck containers	LD-2	LD-2	LD-2
Number lowerdeck containers	30	30	30
Unit volume lowerdeck containers-cu ft	124	124	124
Unit tare weight lowerdeck containers-lbs	203	203	203
Total volume lowerdeck containers-cu ft	3,720	3,720	3,720
Total tare weight lowerdeck containers-lb	6,090	6,090	6,090
Total volume all containers-cu ft	15,428	15,428	15,428
Total tare weight all containers-lbs	11,370	11,370	11,370
Net structural payload-lbs	83,730	99,530	102,930
Maximum packing density-lbs/cu ft	5.43	6.45	6.67

9,266lbs *(see table, page 18)*. The 767-200 has a net structural payload of 84,134lbs and the -200ER a net payload of 92,134lbs.

The 767-200, with an MTOW of 320,000lbs, can carry a full payload up to about 2,000nm, while the 767-200ER with an MTOW of 351,000lbs can carry the payload up to about 3,200nm.

Alenia Aeronavali's modification has a list price of $11.0-11.5 million. This has to be considered in relation to probable used aircraft acquisition costs.

Bedek Aviation

Bedek Aviation has its own supplemental type certificate (STC) for a passenger-to-freighter modification on the 767-200/-200ER. During modification, the aircraft have the option of an MZFW of 258,000lbs or a higher specification of 266,000lbs. The aircraft also have an OEW of 164,400lbs without tare weight. This gives the aircraft a maximum structural payload of 93,600lbs or 101,600lbs, depending on MZFW.

The 767-200 and -200ER have various MTOWs and MZFWs, and Bedek can offer upgrades. These vary according to the size of the upgrade and the individual aircraft being modified, but costs vary from $200,000 to $500,000.

The 767-200's maindeck can accommodate 19 88-inch wide by 125-inch containers on its maindeck *(see table, page 18)*. This is one fewer of the same type of freight containers used by the aircraft converted with the Aeronavali modification. Bedek chose this loading configuration because the additional loading position was limited on weight.

These 19 containers provide a maindeck freight volume of 9,386 cubic feet and have a tare weight of 4,560lbs *(see table, page 18)*.

The lower deck carries the same number of LD-2 containers as described for the Alenia Aeronavali modification, and so have the same freight volume and tare weight.

In total, the aircraft has a total freight volume of 12,114 cubic feet and container tare weight of 9,026lbs. This gives the aircraft a net structural payload of 84,574lbs or 92,574lbs *(see table, page 18)*, depending on MZFW. This is similar to the aircraft converted by Aeronavali.

The 767-200 with an MTOW of 351,000lbs has a range of about 3,000nm when carrying a full structural payload. This aircraft can operate up to about 4,000nm with a gross payload of about 70,000lbs, equal to a net payload of 60,000lbs.

Aircraft with MTOWs lower than 351,000lbs have shorter range performance. These can be upgraded by Bedek during the modification process.

The 767-200ER, with an MTOW of 351,000lbs and fuel capacity of 20,450 US Gallons, can carry a full payload the same distance of 3,000nm as a -200SF, but extends the range to about 5,000nm for a gross payload of about 55,000lbs. Although the -200ER has a range benefit over the -200 for passenger models, the additional fuel capacity is of no real benefit for freighter-modified aircraft, since range is only extended when carrying payloads of about half the maximum .

The list price for Bedek's modification is less than $10 million, and includes the cargo loading system but not the weight upgrades.

To date, Bedek has received orders for 37 767-200 conversions, 21 of which have been delivered. Customers include Colombia's Tampa Cargo, Denmark's Star Air, and ABX of the US.

767-200F build costs

When 767-200s/-200ERs are being converted to freighters, the purchase price, conversion cost, probable maintenance and interest charges all have to be considered.

Market values for 767-200s are now down to about $3.5 million for the oldest -200s, and down to about $6.5 million for the oldest -200ERs. Possible maintenance costs relate to component repairs, a C check and an engine shop visit. A high maintenance requirement, however, will be reflected in a lower purchase price.

The cost of modification is $10-11 million, and if maintenance is in the region of $3 million then the total cost of

A small number of 767-200s have been modified to freighter, but the -300ER is expected to have the largest attraction to airlines as a modified freighter. This aircraft will have a gross structural payload of up to 114,000lbs.

build will be $16-17 million for a -200 and $19-20 million for a -200ER. Lessors have to consider this against the probable lease rates the market will bear.

767-300/-300ER

Two freighter modification programmes are being developed for the 767-300/-300ER. These aircraft are still relatively young and are in high demand with passenger carriers. Their market values are therefore still high.

One modification is being developed by Boeing and offered by Boeing Commercial Airplane Services (CAS). The other is being developed by Bedek Aviation.

Boeing CF

The Boeing converted 767-300/-300ER freighter (767-300BCF and 767-300ERBCF) have been designed to have a similar payload to the factory-freighter, the 767-300PF. Boeing will be the modification licence holder and market the modification, and Aeronavali will be the main modification provider for the aircraft. The first modified aircraft will be certified in late 2007.

The converted -300 will have an MZFW of 278,000lbs and a structural payload of 95,100lbs, excluding container tare weight. The converted -300ER will have an MZFW of 295,000lbs and OEW of 184,100lbs, giving a gross structural payload of 110,900lbs *(see table, page 19)*. This is about 10,000lbs less than the 767-300PF.

The aircraft can accommodate 11 pairs of 88-inch wide by 125-inch long containers on the maindeck, plus two smaller A2 containers at either end of the fuselage. The A2 containers each have an internal freight volume of 420 cubic feet, and the 24 containers provide a total freight volume of 11,708 cubic feet *(see table, page 19)*.

As with the pre-converted passenger variant, the -300 and -300ER can carry 30 LD-2 containers in their lower belly space, eight pairs in the forward section and seven pairs in the aft section. These provide a further 3,720 cubic feet of freight volume and have a tare weight of 6,090lbs *(see table, page 19)*.

Overall, the aircraft have total freight capacity of 15,428 cubic feet and container tare weight of 11,370lbs. This gives the -300 a net structural payload (revenue payload) of 83,730lbs, and the -300ER a revenue payload of 99,530lbs *(see table, page 19)*.

The 767-300BCF will be able to carry a full payload about 2,400nm, while the -300ERBCF will be able to carry a full payload about 3,600nm.

The cost of the modification is not known at this stage, but is expected to be in the region of $13 million.

Bedek Aviation

Bedek Aviation's modification for the 767-300ER is still under development, and the prototype will be available at the end of 2008.

Bedek hopes to offer a converted aircraft with an MTOW of 412,000lbs, which is the highest possible for the passenger and -300PF variants. The majority of the passenger-configured -300ERs in operation have MTOWs of 407,000lbs or more. Bedek will include the option of MTOW upgrades with its freighter modification programme.

Following modification to freighter, Bedek expects to have an MZFW of 295,000lbs, equal to the -300ERBCF, and an OEW excluding container tare weight of about 180,700lbs. This will give the aircraft a gross structural payload of about 114,300lbs *(see table, page 19)*. This is higher than the -300ERBCF on account of the lower OEW.

Bedek's main and lower deck configurations will be the same as the -300BCF, so the aircraft will have the same container volume and tare weights. This will give the aircraft a net structural payload (revenue payload) of 102,930lbs *(see table, page 19)*.

This aircraft is expected to have a range of about 3,500nm with a full payload, and is also expected to be able to operate up to about 4,500nm with a net payload of about 81,000lbs freight.

The modification is expected to cost close to the $10 million list price for the -200 modification.

767-300ERF build costs

The availability of 767-300ERs has reduced over the past two years, pushing up values. Any available aircraft are quickly acquired, and market values are in the $21-30 million range. The cost of modifying these to freighter will be $11-13 million, without considering discounts. An additional cost of maintenance of $2-3 million will take the total to a minimum of $30 million and more likely close to $35 million. This has to be considered together with probable market lease rates. These are likely to be in the $250,000-275,000 region. The current values are therefore too high for most to justify conversion. The values of the aircraft have to be $10-12 million in most cases.

The availability of 767-300ERs will increase again after two to four years as the first 787s are delivered. This will push values down to a level that will trigger freighter conversions. AC

767 family fuel burn performance

The fuel burn performance of the most prominent 767 family members are analysed.

The 767 family comprises five main types: the 767-200, 767-200ER, 767-300, 767-300ER and 767-400ER. These types are also broadly split between those powered by General Electric (GE) engines and those powered by Pratt & Whitney (PW) engines. There are also several maximum take-off weight (MTOW) variants of each airframe-engine combination. When basic variant, engine type and weight specifications are taken into consideration, there are more than 20 different variants of the 767.

The 767-200ER and 767-300ER account for the majority of 767s in the fleet *(see 767 family fleet analysis, page 15)*, although the 767-200 and 767-400ER play significant roles. The fuel burn performance of the 767-200, -200ER, -300ER, -400ER, -200F and -300ERF is analysed.

767 variants

The 767-200 fleet comprises aircraft with MTOWs of 300,000lbs, 310,000lbs, 320,000lbs and 335,000lbs, as well as aircraft equipped with JT9D-7R4D and CF6-80A engines.

The 767-200ER proved popular with many airlines around the world for long-haul operations. Operators in Africa, Latin America, North America, the Asia Pacific and Europe regularly used the 767-200ER for routes of 4,500nm or more.

The 767-200ER fleet includes aircraft with MTOWs of 313,000lbs, 335,000lbs, 345,000lbs, 351,000lbs, 387,000lbs and 395,000lbs. Most of these aircraft have a fuel capacity of 24,140 US Gallons (USG) and many also have extended-range twin-engine operations (Etops) capability. The most popular engine types are the JT9D-7R4D/E, PW4056, CF6-80A2 and CF6-80C2B2/4.

The 767-300ER is mainly utilised on routes of 3,000-5,000nm. There are more than 500 active 767-300ERs in operation, and most aircraft in the fleet have MTOWs of 360,000lbs, 407,000lbs and 412,000lbs. The majority of aircraft are powered by PW4060 and CF6-80C2B2/4/6/7 engines.

The 767-400ER was introduced as a natural follow-on to the -300ER, with Boeing intending the aircraft to offer airlines similar range capability with extra seating capacity. However, the 767-400ER has had limited success, and Delta and Continental are its only operators. All aircraft have an MTOW of 450,000lbs and a fuel capacity of 24,140 USG, and are powered by CF6-80C2B7/8 engines.

A few 767-200s have been converted to freighter, and although the -200ER has additional fuel capacity this only gives the aircraft added range when payload is less than maximum *(see 767 modification & upgrade programmes, page 17)*. This means that the additional range of the -200ER is unlikely to be of use to most freight operators. The 767-300ERF will have an attractive payload-range performance and a large number of these are expected to be converted to freighters over the coming years.

Fuel burn performance

A Jeppesen flight planning system has been used to analyse the fuel burn performance of the 767-200, 767-200ER, 767-300ER and 767-400ER on routes that are representative of the type of operations on which these aircraft are utilised.

The fuel burn performance of the 767-200F and 767-300ERF has also been analysed on a medium- and long-haul route.

The 767-200 has been examined in a tri-class configuration of 176 seats on a route between Los Angeles International (LAX) and La Guardia, New York (LGA). This route has a tracked distance of 2,188nm. When flown in an easterly direction to LGA, the aircraft experiences a tailwind of 20 knots. This reduces the tracked distance from 2,188nm to an equivalent still air distance (ESAD) of 2,101nm *(see table, page 22)*. The aircraft faces a headwind of 50 knots when flying the other direction to LAX, and increases the distance to an ESAD of 2,424nm.

An average weight of 220lbs per passenger has been assumed, giving the aircraft a payload of 38,720lbs. The specification weights of the aircraft used are shown, and two variants with JT9D-7R4D and CF6-80A engines have been analysed. Both aircraft have an MTOW of 320,000lbs, an operating empty weight (OEW) of 181,000lbs, and a fuel capacity of 16,866 USG *(see table, this page)*.

The fuel burn performances of the 767-200ER, -300ER and -400ER have been analysed on a route between LAX and Stockholm Arlanda airport (ARN).

This route has a tracked distance of 4,899nm. Aircraft operating in a easterly direction from LAX to ARN have a small tailwind averaging 4 knots, which takes the ESAD down to 4,856nm *(see table, page 22)*. Operations in the other direction face a headwind of 14 knots, increasing the ESAD to 5,007nm.

The 767-200ER has been analysed with JT9D-7R4E and CF6-80A engines, MTOWs of 345,000lbs and 360,000lbs, an OEW of 181,000lbs, and a fuel capacity of 20,446 USG *(see table, this page)*. The aircraft has also been analysed with a full payload of 176 passengers.

The 767-300ER has been analysed with an MTOW of 409,000lbs and a fuel capacity of 24,140 USG. The two engine types considered are the PW4060 and

WEIGHT SPECIFICATIONS OF ANALYSED 767 VARIANTS

Aircraft type	MTOW lbs	MZFW lbs	OEW lbs	Payload lbs	Seats	Fuel USG	Engine model
767-200	320,000	248,000	181,000	67,000	176	16,866	JT9D-7R4D
767-200	320,000	250,000	181,000	69,000	176	16,866	CF6-80A
767-200ER	345,000	253,000	181,000	72,000	176	20,448	JT9D-7R4E
767-200ER	345,000	253,000	181,000	72,000	176	20,179	CF6-80C2B4
767-300ER	409,000	288,000	199,000	89,000	215	24,149	PW4060
767-300ER	409,000	287,450	202,400	85,050	215	24,149	CF6-80C2B6
767-400ER	450,000	330,000	226,500	103,500	243	25,192	CF6-80C2B8
767-200F	351,000	258,000	164,600	93,400	N/A	16,866	JT9D-7R4D
767-300ERF	407,000	295,000	183,000	112,000	N/A	24,149	PW4060

FUEL BURN PERFORMANCE OF 767-200, -300, -200ER, -300ER & -400ER

City-pair	Aircraft variant	MTOW lbs	Engine model	Fuel USG	Flight time	Passenger payload	Fuel USG per passenger	ESAD nm	Wind speed factor
LAX-LGA	767-200	320,000	JT9D-7R4D	6,282	4:47	176	35.6	2,101	+20
LAX-LGA	767-200	320,000	CF6-80A	6,343	4:48	176	36.0	2,101	+20
LGA-LAX	767-200	320,000	JT9D-7R4D	7,294	5:29	176	41.4	2,424	-50
LGA-LAX	767-200	320,000	CF6-80A	7,375	5:31	176	41.9	2,424	-50
LAX-ARN	767-200ER	345,000	JT9D-7R4E	15,713	10:36	176	89.3	4,855	+4
LAX-ARN	767-200ER	360,000	CF6-80C2	15,486	10:36	176	88.0	4,855	+4
LAX-ARN	767-300ER	409,000	PW4060	16,894	10:35	215	78.6	4,855	+4
LAX-ARN	767-300ER	409,000	CF6-80C2B6	16,633	10:34	215	77.4	4,855	+4
LAX-ARN	767-400ER	450,000	CF6-80C2B8	17,858	10:36	243	73.5	4,855	+4
ARN-LAX	767-200ER	345,000	JT9D-7R4E	16,993	11:17	176	96.6	5,157	-14
ARN-LAX	767-200ER	360,000	CF6-80C2	16,124	11:17	176	91.6	5,157	-14
ARN-LAX	767-300ER	409,000	PW4060	18,054	11:18	215	84.0	5,157	-14
ARN-LAX	767-300ER	409,000	CF6-80C2B6	17,803	11:19	215	82.8	5,157	-14
ARN-LAX	767-400ER	450,000	CF6-80C2B8	18,784	11:18	243	77.3	5,157	-14

Source: Jeppesen

FUEL BURN PERFORMANCE OF 767-200F & -300ERF

City-pair	Aircraft variant	MTOW lbs	Engine model	Fuel USG	Flight time	Freight payload lbs	Fuel USG per ton-mile	ESAD nm	Wind speed factor
BOG-MIA	767-200F	351,000	JT9D-7R4D	5,033	3:12	93,400	0.09	1,406	-18
MIA-BOG	767-200F	351,000	JT9D-7R4D	4,969	3:07	93,400	0.09	1,361	-8
LHR-NBO	767-300ERF	407,000	PW4060	14,951	8:24	97,391	0.09	3,826	-4
NBO-LHR	767-300ERF	407,000	PW4060	15,864	8:46	100,989	0.09	4,013	-31

CF6-80C2B6. These aircraft have OEWs of 199,000lbs and 202,400lbs *(see table, this page)*. The aircraft has been analysed with 215 seats and a full payload.

The 767-400ER, equipped with CF6-80C2B8 engines, has an MTOW of 450,000lbs, an OEW of 226,500lbs and a fuel capacity of 25,192 USG *(see table, page 21)*. The aircraft has been analysed with 243 seats and a full payload.

The 767-200F has been analysed in both directions on Bogota-Miami as representative of a medium-haul route. The aircraft is powered by JT9D-7R4D engines, with an MTOW of 351,000lbs, an OEW of 164,600lbs, and a maximum zero fuel weight (MZFW) of 258,000lbs. It has a fuel capacity of 16,700 USG and a gross structural payload of 93,400lbs.

The 767-300ERF has been analysed on London-Nairobi, and has an MTOW of 407,000lbs, an OEW of 183,000lbs, an MZFW of 295,000lbs, and a fuel capacity of 24,140 USG. It is powered by PW4060 engines and has a gross structural payload of 112,000lbs.

The performance of all aircraft has been analysed with a long-range cruise speed of Mach 0.80, annual 85% winds and a taxi time of 20 minutes.

Fuel burn results

The two passenger variants of the 767-200 with JT9D-7R4D and CF6-80A engines have almost identical fuel burn, which implies that there is little economic difference between these two variants. This indicates that the 767-200 equipped with either engine type would make a suitable candidate for freighter conversion. The only probable difference between the two types would be engine-related maintenance costs.

The 767-200ER on the LAX-ARN route burns more fuel than the CF6-80C2-powered aircraft, which is more noticeable on the easterly routeing against a small headwind. The small fuel burn advantage of the CF6-80C2-powered aircraft is, however, unlikely to provide an advantage over aircraft equipped with JT9D-7R4 engines when conversion to freighter is taken into consideration.

There are small differences in the performance of the two 767-300ER variants. The difference in fuel burn per passenger is a maximum of 1 USG *(see table, this page)*, which indicates that both engine types will have almost identical fuel burns for the same operating conditions and payloads.

There is, however, a significant difference in fuel burn performance between the 767-300ER and smaller -200ER. The -200ER burns 10-11 USG more than its -300ER counterpart in both directions on the route analysed *(see table, this page)*. This is equal to an additional cost of $20 per seat at current fuel prices, which clearly illustrates the economic advantage of the -300ER. The -300ER is also likely to have similar, or possibly lower, maintenance costs compared to the -200ER. The -200ER is likely to have lower lease rentals than the -300ER, however.

The 767-400ER is marginally more fuel efficient than the -300ER, with the -400ER burning 4-5 USG less per passenger (equal to about 5%). This is equivalent to a cost saving of about $10 per seat on a one-way sector, which is a significant difference when passenger yields are considered. The small number of 767-400ERs in operation reduces the significance of its fuel burn advantage, however.

The 767-200F is able to carry a full payload in both directions on the Bogota-Miami route *(see table, this page)*. The northerly direction has an ESAD of 1,406nm. The 767-300ERF, however, has payload restrictions of about 3,500lbs on the southerly direction of London-Nairobi, and a payload restriction of about 11,000lbs operating in the other direction. In all cases, both the 767-200F and 767-300ERF have a fuel burn of 0.09 USG per available ton-mile *(see table, this page)*. AC

767 family maintenance analysis & budget

The 767 has acceptable mature maintenance costs. This will enable to remain popular for many years to come.

The 767 has become the most successful widebody, twin-engined aircraft, due mainly to its combination of medium size and long-range capability. It remains a dominant type in many medium- and long-haul markets, and will continue to occupy this position for several more years to come. Although its replacement, the 787-8/-9, is selling well, it will not exist in significant numbers for another six years, which means that the 767's future as a major passenger aircraft is secure for another 10 years. The 767 is also well placed to become a major freight aircraft over the next 10-15 years. The 767 therefore still has a good future.

There are five main groups of 767s, of which the -200ER, -300 and -300ER are the three most important types.

Aircraft in operation

Of the 745 active passenger aircraft, 632 are the extended range models, and are therefore mainly utilised on operations of 4.0 to 8.0 flight hours (FH). Annual utilisations vary between 3,500 and 4,500FH, and 450-1,100 flight cycles (FC). Few aircraft are now operated on medium-haul services, although the 767 is still prominent on US domestic services.

The average flight cycle (FC) time on which 767s are used affects maintenance planning, since base maintenance tasks have FH and FC intervals. Many heavy components also have removal and repair intervals that are FC-related.

Line maintenance programme

Like the 757 and other aircraft types of the same generation, the 767 has a system of line and ramp checks that include a pre-flight (PF) check, a transit (TR) check, and a daily check. Some operators also include a weekly check.

Terminology between airlines varies, but the PF check is performed prior to the first flight of each day's operations, and the TR check is performed prior to all other flights made during the day. PF and TR checks have a similar content and both comprise a walkround visual inspection. This was traditionally done by the flight engineer on three-man aircraft, but later became a task for ground technicians on two-man types like the 767. Flightcrew have been given this task more recently, in order to save costs relating to line mechanics. The PF and TR checks only have about 30 minutes of maintenance planning document (MPD) items, which include a check on the oil quantity indicators on the engines. The PF check also includes items relating to extended-range twin-engine operations (Etops), such as checking oils, fluids and redundant items that relate to avionics and fire extinguishers. "There are some maintenance tasks to be completed in addition to PF and TR checks, as was the case with most operators in the past," says Karel Bockstael, vice president of base maintenance at KLM Engineering & Maintenance. "For this reason, our PF checks are carried out by line mechanics."

Daily checks are completed once every 24 hours, with a maximum limit of 48 hours. If possible operators will do this check overnight.

Operators of aircraft that are used on long-haul operations will not necessarily be able to do this check overnight, so they will have to schedule this check with the operating programme. An aircraft will usually have a daily check performed when it returns to operating base. This may be each day, but the interval may be longer if the aircraft is operating on the longest distance routes.

A 767 that is therefore completing about 4,500FH per year, and has an average FC time of 7.0FH will complete about 640FC annually. Over the course of the year, the aircraft will have almost 365 daily checks and a total of 640 PF and TR checks.

The next largest line and ramp check in some airlines' maintenance programmes is the weekly check. This has a maximum interval of eight days, and is similar in content to the daily check, but has just a few more items. The weekly check can be regarded as the sixth or seventh daily check in succession.

A check programme

The next highest interval in the 767's maintenance schedule is the A check. The A check tasks are grouped into system and structural tasks. The MPD intervals for the basic A (1A) check system tasks

The routine content of the 767's base maintenance checks has several elements, and these increase with age. The rise in MH used for subsequent base check cycles and the resulting reserves are not excessive, however.

767 C CHECK COMPOSITION

C check	System tasks	Structural tasks	CPCP tasks	Interval FH/FC/Months
C1	1C	S1C		6,000/3,000/18
C2	1C +2C	S1C + S2C		12,000/6,000/36
C3	1C + 3C	S1C + S3C		18,000/9,000/54
C4	1C+ 2C + 4C	S1C + S2C +S4C	S4C	24,000/12,000/72
C5	1C	S1C	S1C	30,000/15,000/90
C6	1C + 2C + 3C	S1C + S2C + S3C	S1C + S2C	36,000/18,000/108
C7	1C	S1C	S1C	42,000/21,000/126
C8	1C + 2C + 4C	S1C + S2C +S4C +S8C	S1C +S2C +S4C +S8C	48,000/24,000/144
C9	1C + 3C	S1C + S3C	S1C	54,000/27,000/162
C10	1C + 2C	S1C + S2C	S1C + S2C	60,000/30,000/180
C11	1C	S1C	S1C	66,000/33,000/198
C12	1C + 2C + 3C + 4C	S1C + S2C +S3C +S4C	S1C +S2C +S4C +S12C	72,000/36,000/216

are 500FH, although these have been extended by many operators. VARIG, for example, has an interval of 600FH, while KLM Engineering & Maintenance has succeeded in getting its interval extended to 770FH with its experience.

The MPD has four groups of system tasks with multiple intervals of this basic interval. These are the 2A, 3A, 4A and 6A tasks, with corresponding multiple intervals of the 1A interval.

The 1A items are performed each A check, the 2A items every second A check, and the other tasks according to their interval. These five groups of tasks would therefore all be in phase when the A12 check is reached, which will be at an interval of 6,000FH for an operator with an MPD maintenance programme. The interval will be higher at 7,200FH for an airline with a basic interval of 600FH.

The 767 also has two groups of structural A check tasks. The S1A has an MPD interval of 300FC and the 5SA an interval of 1,500FC. These can be performed separately to the system tasks, but most operators group the S1A with the 1A tasks, and the 5SA in every fifth A check to simplify maintenance planning. The average FC time of most operators means that only a small portion of the FC interval of these tasks is used.

Base maintenance programme

The base check part of the MPD comprises a series of four C checks in a cycle, covering system, and structural and corrosion prevention and control programme (CPCP) tasks. There are also zonal tasks, which can be grouped with either system or structural tasks as necessary.

The system tasks have job cards with intervals based on FH and calendar time, while structural and CPCP tasks have intervals based on FC and calendar time.

The basic interval for the system tasks, the 1C items, in the MPD is 6,000FH and 18 months, whichever is reached first. An aircraft with an annual utilisation of 4,000FH will reach both limits at the same time. Aircraft with higher rates of FH utilisation will require checks more frequently than 18 months, while aircraft with lower rates of utilisation will accumulate fewer than 6,000FH in the 18-month limit.

The MPD also has base check system tasks with multiples of this basic interval. These are the 2C, 3C and 4C items with intervals of 12,000FH/36 months, 18,000FH/54 months and 24,000FH/72 months *(see table, this page)*. The fourth check in the cycle therefore has an interval of 24,000FH and six years. Actual utilisation of check intervals means that most operators will complete this cycle every five years, or every 20,000-22,000FH.

The 3C group of tasks is relatively small, while the 4C comprises a large group of inspections. All four groups of multiples will not actually be in phase until the C12 check, which is the fourth check at the end of the third base maintenance cycle. The base checks in the first three base maintenance cycles in which these four groups of system tasks are included, are summarised *(see table, this page)*. These three base maintenance cycles will be completed at an age of 15-16 years for most aircraft.

The basic interval for the structural tasks, the S1C tasks, is 3,000FC and 18 months, whichever is reached first *(see table, this page)*. Most aircraft operate at rates of less than 2,000FC per year, and so will reach the 18-month interval first. Structural tasks can be completed separately from system tasks, but this increases aircraft downtime.

The MPD also has structural tasks with multiples of these intervals. These are the S2C at 6,000FC and 36 months, S3C at 9,000FC and 54 months, and the S4C at 12,000FC and 72 months *(see table, this page)*.

In addition to annual rates of FH and FC utilisation, the 1C and S1C tasks both have an 18-month calendar interval. Similarly, the 2C and S2C have a 36-month interval, the 3C and S3C have a 54-month interval, and the 4C and S4C have a 72-month interval. It is therefore convenient for airlines to combine the 1C with the S1C, the 2C with the S2C, the 3C with the S3C and the 4C with the S4C, despite only a small portion of the FC intervals of structural tasks being utilised.

The structural tasks are repeated every base maintenance cycle in the same way that the system tasks are repeated. There is also a group of structural tasks referred to as the 8SC tasks. These have an interval of 24,000FC and 144 months. These are therefore first performed at the C8 check, then at the second C4 check *(see table, this page)*, and are repeated every eighth C check.

The CPCP tasks have a more complicated programme and sequence than the system and structural tasks. There are eight groups of tasks, which can be sub-divided into two groups.

The first group comprises those tasks that are performed once: the S4C, S8C and S12C CPCP tasks, which are carried out during the C4, C8 and C12 checks.

The second group of tasks are those with initial intervals and then repeat intervals. There are the S4C tasks which are repeated every S1C check, and a second group of S4C tasks that are repeated every second C check.

The S8C tasks are repeated every fourth C check, while another group of S8C tasks is also repeated every fifth C check. Finally the S12C tasks are repeated every eighth C check.

The arrangement of system, structural and initial and repeat CPCP tasks in each C check of the first three base maintenance cycles is summarised *(see table, this page)*. The table clearly shows how the workscope of the C checks varies throughout each of the four base check cycles, but also how the workscopes generally increase in size as the aircraft ages. The table shows the content in terms of MPD tasks up to an age of 18 years, and more likely 15-16 years. The earliest built 767s still in active service are 24 years old, but most aircraft range in age from six to 20 years old and so are in their second, third or fourth base maintenance cycle.

New maintenance programme

The organisation of base checks described has been superseded by a revised base maintenance programme, which was issued in 2005. Only a few 767 operators have begun to change their aircraft on to the new programme, and most are still utilising the original one.

The organisation of systems checks in the new programme has changed little from the original. The main change has been to incorporate the CPCP tasks into a new structural inspection and the zonal tasks.

The programme of structures tasks has now become more complex, with tasks having initial thresholds during the second and third base check cycles and repeat intervals. This has been done with the objective of simplifying the structural and CPCP tasks.

The revised maintenance programme is supposed to have reduced the number of tasks, since only structural tasks are left. Nevertheless, combining structural and CPCP tasks may not have reduced the man hours (MH) consumed to carry out the checks by the 40% projected by Boeing. Some maintenance providers predict that the MH used for routine inspections and non-routine rectifications relating to structural items will probably fall by only about 20%.

Line maintenance inputs

The number of different line and ramp checks performed on an aircraft depends on its pattern of utilisation and operation. This analysis examines an aircraft operating at an average FC time of 7.0, and completing 4,500FH and 640FC per year. Under this operation aircraft complete less than two flights per day. About 340 PF and TR checks and 350 daily checks will be completed each year.

The MH and material inputs vary with each operator. PF, TR and daily checks consume about 2MH. Operators have different maintenance programmes, and some include weekly checks. Different programmes have a different spread of MH for the individual line and ramp checks. In many cases, for example, PF and TR checks consume less than 1MH.

A conservative budget is for the PF and TR checks to each use 45 minutes and up to $20 in materials and consumables. Daily checks utilise 10MH and up to $100 in materials and consumables. A standard labour rate of $70 per MH for line and ramp maintenance takes the cost to about $75 for each PF and TR check, although the use of flightcrew to do these inspections will minimise this cost. These checks usually, in fact, require no material expenditure. Labour and materials are only required on those occasions that defects are found. The total cost for each daily check is $800.

The total cost for all these checks over the course of a year's operation is about $326,000, which is equal to $75 per FH *(see table, page 35)*.

A checks

The A check interval is assumed to be 500FH, and the actual interval is given as 400FH. This means that the full cycle of 12 checks will be completed about every 5,000FH. Some operators have longer intervals with the benefits of lower costs per FH.

A checks consume 300-400MH and $11,000 in materials and consumables. Some operators record MH consumption of up to 600MH, although the actual amount depends on non-routine rectifications and clearing technical defects.

A conservative average of 500MH and $11,000 can be used for budgeting purposes. A standard labour rate of $70 would take the total check cost to $46,000, which would equal a cost of $110-115 per FH when amortised over the 400-500FH interval *(see table, page 35)*.

Base check contents

The workscopes of base checks vary widely. This maintenance analysis mainly concerns aircraft in their second and third base check cycles. These are aircraft ranging in age from five to 16 years old.

The first main components of C checks are routine inspection tasks relating to system, structural, CPCP and zonal inspections. These inspections raise non-routine defect rectifications, and the non-routine ratio increases with age.

In addition to the routine inspections there are also sampling tasks, which are inspections in areas of the aircraft that are prone to cracks and corrosion, such as engine pylons and landing gear attachments. The fleet size determines how many aircraft actually require sampling tasks, which usually only affect 5-10% of the fleet.

The 767 also has out-of-phase (OOP) tasks for maintenance planners to take into consideration. These are inspections whose intervals do not match the other MPD tasks. To avoid increased aircraft downtime, OOP tasks will be scheduled with base checks. Many OOP tasks involve work on hard-timed components, such as the replacement of a battery or borescoping engines.

Another element of C checks is the removal of rotable components with hard time repair intervals. The 767 has about 2,200 rotable items accounted for by about 2,000 different part numbers. About 95% of these are maintained on an on-condition basis, but about 110 items are removed at fixed intervals to coincide with A and C checks.

These are life limited parts (LLPs), comprising mainly safety items such as gas bottles and evacuation slides. These are both open- and closed-loop items.

Besides these MPD inspections, there are several other elements of base checks that are more variable. Only some are not mandatory.

The first group of additional items comprises airworthiness directives (ADs), service bulletins (SBs), modifications and engineering orders (EOs).

Examples of SBs incorporated into 767 C checks in recent years include: wire bundle inspections; fire blocking insulations; fire extinguisher inspections in the cargo hold; lubrication of flight controls; and adjustments to flight control actuators. Cooper explains that the lighter of these SBs can consume 4-5MH, while larger ones can use up to 100MH.

A major AD affecting the 767 is the engine pylon improvement programme. This is covered by six ADs: two for each engine type. ADs 2001-02-07 and 2004-16-12 concern PW engines, ADs 2001-06-12 and 2004-16-12 for GE engines, and ADs 2000-19-09 and 2001-16-12 for Rolls-Royce engines.

These basically require structural strengthening on engine pylons, and are due prior to the aircraft reaching a total FC time of 37,500 or 20 years of age - whichever is reached first.

Cooper explains that this modification is heavy, and involves the removal of the engine, followed by the removal of the engine pylon from the wing. It therefore makes sense to combine this removal with a C12 check, which has a maximum interval of 18 years. The MPD also calls for a structural zonal inspection of engine pylons. Different groups of aircraft are affected differently, and Cooper estimates that up to 4,000MH will be required to comply with these ADs.

C checks will also be used to clear deferred defects that have accumulated, as well as to repair physical damage to the aircraft sustained during operation.

The other main items included in C checks will be interior refurbishment and cleaning.

Interior refurbishment concerns seats, carpets, sidewall and ceiling panels, overhead bins, passenger service units, in-flight entertainment equipment, toilets and galleys. As the refurbishment of these items is mainly a cosmetic consideration, it is therefore not mandatory.

Areas to be cleaned include seat covers, carpets and flooring material, toilets, galleys and the overall aircraft appearance.

Stripping and repainting the aircraft is a final item to consider, and may also have to be scheduled separately from C checks because of environmental considerations. Operators typically repaint aircraft every five to eight years, depending on aircraft utilisation and marketing requirements.

Base check inputs

The elements that make up base checks have been described. The routine content gradually increases as the aircraft progress through each base check cycle.

The MH required for routine inspections in the first and third base checks in the cycle, the C5 and C7 or C9 and C11, are relatively light. "The C5 and C7 only require about 1,650MH for routine inspections," says Peter Cooper, senior planning engineer at Shannon Aerospace. "This increases a little to 1,700-1,720 in the second cycle for the C9 and C11 checks. The C6 and C10 checks, the second check, require in the region of 3,300MH. There is little change in the routine MH between these checks because the system, structural and CPCP tasks are similar. The content of the C12 check is heavier than the C8, however, because of an increase in CPCP tasks. The C8 requires about 6,700MH for routine items, while the C12 needs about 8,000MH." This takes the total routine MH to about 13,350 for the C5 to C8 checks, and to about 14,600MH for the C9 to C12 checks.

These inputs will be added to by non-routine defects arising out of the inspections, and the amount of work generally increases with each base check cycle. "The non-routine ratio varies between aircraft and checks, but generally increases with age on a linear basis," explains Cooper. "The ratio in the second cycle is in the region of 75%. It increases to 80-100% in the third cycle, and will be at its highest at the C12 check."

This results in a total of 10,000 non-routine MH for the C5 to C8 checks, and 12,300MH for the C9 to C12 checks. The routine inspections and non-routine defects for the four checks in the second base cycle total 23,000-24,500MH, and increase to 27,000-28,500MH in the third base cycle.

This group of tasks and defect rectifications accounts for the majority of MH that have to be spent for base checks. "The other MPD items consume relatively little," explains Cooper. "An average for sampling tasks will be about 145 MH in the heavy check: the C8 and C12. MH used for ADs, SBs and modifications naturally vary, but excluding heavy modifications, averages have been 250-400MH for the first three checks and 500-1,000MH for the fourth heavy check. The OOP tasks require an average of 300MH per base check to complete, and about the same number of MH are required for routine hard-time component changes and clearing of defects. Finally, interior cleaning for items such as the carpets and the sidewall panels, and other cosmetic issues will utilise an average of about 200MH in each check.

"These four groups of tasks consume about 1,100MH for the first and third checks in the cycle, 1,200-1,300MH for the second check and 1,400-1,900MH for the fourth check," estimates Cooper. "The total for the four checks comes to 5,000-6,000MH, which brings MH used for the four checks to 28,000-30,500MH for the second base check, and to 32,000-33,500MH for the third base check."

The timing and scope for interior refurbishment depends on the operator, but this is usually performed once every base check cycle, and would be combined with the C4/8/12 check. Interior refurbishment will normally include painting or recovering wall and ceiling panels, refurbishing and covering overhead bins, and repairing bulkheads.

767 FAMILY HEAVY COMPONENT MAINTENANCE COSTS

4,500FH & 640FC per year	
Average FC time of 7.0FH	
Number of main wheels	8
Tyre retread interval-FC	200
Tyre retread cost-$	450
Number of retreads	3
New main & nose tyres-$	1,250/1,000
$/FC retread & replace tyres	**32**
Wheel inspection interval-FC	200
Main & nose wheel inspection cost-$	1,500/1,000
$/FC wheel inspection	**70**
Number of brakes	8
Brake repair interval-FC	1,700
Brake repair cost-$	50,000
$/FC brake repair cost	**235**
Landing gear interval-FC	5,000
Landing gear exchange & repair fee-$	500,000
$/FC landing gear overhaul	**100**
Thrust reverser repair interval-FC	6,000
Exchange & repair fee-$/unit	250,000
$/FC thrust reverser overhaul	**85**
APU hours shop visit interval	3,000
APU hours per aircraft FC	2.5
APU shop visit cost-$	260,000
$/FC APU shop visit	**87**
Total-$/FC	**609**
Total-$/FH	**87**

Galleys and toilets are also removed from their installations and refurbished, while seats will also refurbished and even re-covered. This process will consume 4,500-5,500MH, and about $200,000 in materials and parts.

The final item that must be taken into consideration is stripping the paint from the aircraft and repainting it. "This normally coincides with the heavy check, and so it is done every five years or so," says Haytham Nasir, assistant manager production planning at GAMCO. "Stripping and repainting are also often combined with refurbishing the aircraft interior and the heavy check, and such a workscope can have a downtime of up to five weeks. This can be shortened if the items that are replaced during the interior refurbishment are ready to be installed at the start of the check. Stripping and painting the aircraft utilise about 2,500MH and paint is about $30,000."

This additional 2,500MH for stripping and painting takes the total MH consumption for the four base checks to the region of 36,000MH for the second base check cycle, and up to about 40,000MH for the third base check cycle.

These totals comprise about 4,000 for the C5 and C7 checks, 7,000MH for the C6 and up to 21,000-22,000 for the C8 check. The total for the C8 will increase by up to another 4,000MH if the engine pylon improvement programme is included. This is more likely in the C12 check, however.

Checks will be a similar size in the third base check cycle, except the C12 will use 22,000-24,000MH, plus up to another 4,000MH to comply with the engine pylon improvement programme.

Materials and consumables

The use of materials and consumables falls into several categories. The first of these comprises routine inspections and defect rectifications. Cooper says that material expenditure commensurate with the MH used for both routine and non-routine items totals about $55,000 for the C5, C7, C9 and C11 checks. The expenditure is higher at an average of $75,000-80,000 for the second checks in the cycle, the C6 and C10 checks. The heavy checks, the C8 and C12, require $210,000-250,000.

The second category includes materials and consumables consumed for the sampling tasks, modifications and ADs, OOP items, routine component changes and clearing of defects, and cosmetic cleaning. These amount to $17,000-29,000, depending on the size of the check.

Materials for a full interior refurbishment will cost up to $200,000. Total materials, parts and consumables for the interior refurbishment and stripping and repainting for all items in the four checks of the full base check cycle is $700,000-750,000.

Summary base checks

Using an industry representative labour rate of $50 per MH, the total utilisation of 34,000MH in the four C checks of the second base check cycle has a cost in the region of $1.7 million for the first cycle. When combined with the cost of materials and consumables, these four checks have a total cost of $2.4-2.6 million.

An operation completing about 4,000FH per year will have a C check interval of about 5,000FH, and will complete a base check cycle about every 20,000FH. The total cost for the second cycle of base checks will be equal to a reserve of $120-130 per FH *(see table, page 35)*.

The labour used in the third cycle will have a cost equal to about $2.0 million, and when materials and consumables are added, the total cost of $2.75 million is equal to a reserve of $140 per FH *(see table, page 35)*. An additional reserve of $15 per FH should be budgeted for the engine pylon improvement programme.

Rotables

As described, there are about 2,200 rotable components installed on the 767, which are accounted for by about 2,000 part numbers.

Taking the heavy rotable items, such as landing gear, wheels and brakes, thrust reversers and the auxiliary power unit (APU) into consideration separately, the majority of these rotable components on the 767 are maintained on an on-condition or condition-monitored basis.

The random removals of these components require an inventory to be kept, and the logistics of transporting, testing, repairing, record keeping and storing them have to be organised or provided. This service can be provided by many suppliers. Excluding the heavy components, Christopher Whiteside, managing director at AJ Walter, estimates that a fleet of 10 767s accumulating about 4,500FH per year each would need to lease a homebase stock of hard-time, on-condition and condition-monitored rotables that have a value of about $10 million. A monthly lease rate factor of 1.5% means that the lease rental for this equipment would be about $150,000 per month, and equal to $1.8 million per year. This would result in an FH rate of $45 per aircraft. Whiteside explains that the remaining rotables could be supplied in an all-inclusive package by A.J.Walter, which would include all logistics services and the repair and management of all parts. The rate per FH for this element of the service would be $175, taking the total cost for the supply of rotables to $220 per FH *(see table, page 35)*.

Heavy rotables

This leaves the four heavy components of landing gear, wheels and brakes, thrust reversers and the auxiliary power unit (APU) to be considered. The cost of these components is related to FC maintenance intervals. Apart from the landing gear, these components are maintained on an on-condition basis. Their removal intervals, repair costs and related costs per FC are summarised *(see table, page 30)*.

Engine maintenance

Engine-related maintenance costs for the 767 family ultimately involve five major engine types, up to 10 thrust ratings and consideration for a wide range of operating conditions, average flight cycle times and levels of engine de-rate.

Since the majority of 767s operating are -200ER and -300ER variants, this analysis of engine maintenance costs focuses on the PW4000 and CF6-80C2.

The PW4000, with a 94-inch diameter fan, has four different thrust ratings for the 767 family: 52,000lbs, 56,000lbs and 60,000lbs thrust for the -200ER; and the same three ratings plus 62,000lbs thrust for the -300ER. The engine rated at 56,000lbs thrust is by far the most numerous on the 767-200ER, and the engine rated at 60,000lbs thrust is the most numerous on the -300ER.

The CF6-80C2 has five thrust ratings for the 767. The -80C2B2 rated at 52,500lbs and the -80C2B4 rated at 57,900lbs are the two main types powering the 767-200ER, while the -80C2B6 rated at 60,800lbs and the -80C2B7 rated at 61,500lbs are the two main types powering the -300ER.

Many operators fly these aircraft on routes averaging five to seven FH, but there are also extremes where aircraft are used on sectors of just one or two hours, or as long as eight or nine hours. The longer the average FC time, the higher the aircraft take-off weight and the lower the engine de-rate, which increases the exhaust gas temperature (EGT) of the engine, and can affect on-wing life. Engines used on long average cycle times tend to have removal intervals more related to engine flight hours (EFH). Conversely, engines used on intensive networks of short cycles tend to have removal intervals more related to engine flight cycles (EFC).

PW4000-94

There are two classes of PW4000 engines: those that have had the Phase III modification; and those that have not had the modification, which are known as Phase I engines. The Phase III modification kit was introduced in the mid-1990s and involved the installation of new engine hardware that had the effect of reducing fuel consumption and EGT, thereby increasing EGT margin. "Phase III engines tend to have EGT margins about 15 degrees centigrade higher than Phase I engines," explains Domenic Janutin, product management at SR Technics. "Phase III engines rated at 56,000lbs have test cell EGT margins of about 53 degrees C corrected for an outside air temperature (OAT) of 15 degrees C and standard day conditions. The on-wing readings when the engine is installed are higher by 5-10 degrees C. A Phase III PW4056 would therefore have an EGT margin of about 60 degrees following a shop visit, and a Phase I engine an installed margin of about 45 degrees. The test cell margin of a Phase III PW4060 or PW4062 is 38-40 degrees, and so about 50 degrees when installed."

All PW4000 engines have full authority digital engine control (FADEC) systems, which have been used to improve on-wing life.

German charter carrier Condor operates 767-300ERs with Phase III PW4062 engines. "These have test cell EGT margins of 30-40 degrees C after a shop visit," says Andreas Linke-Diesinger, propulsion systems engineer for the PW4000 at Lufthansa Technik.

These EGT margins can influence intervals between shop visits, but EGT margin erosion has to be considered. "The initial rate of EGT margin erosion is about 13 degrees C in the first 1,000EFC after a full refurbishment," says Janutin. "The blade tips and knife edge seals in the engines are worn down, but the EGT margin erosion rate then reduces to a rate of somewhere between 5-10 degrees C in the second 1,000EFC, and gradually declines to a low level after this."

This implies that the engines will lose 20-23 degrees C of their EGT margin in the first 2,000EFC. This will be equal to 8,000-14,000EFH for engines operated at an average EFC time of 4.0-7.0EFH. This will leave PW4056 engines with 35-39 degrees C, and a PW4060 with 35-30 degrees C at this stage. "The rate of EGT margin loss per 1,000EFC flattens to about only one or two degrees shortly after this, and PW4000-94 engines are rarely removed to EGT margin loss. The EGT margin still available and the rate of loss allows engines to stay on wing for several thousand more EFH, and engines tend to be removed because of deterioration of their hardware," explains Janutin.

The rate of EGT margin loss also depends on whether or not engines have had the ring case modification. "This modification concerns a design change in the inner case area of the latter part of the high pressure compressor (HPC), just in front of the combustion chamber. The old design had instability problems because of thermal expansion of the case with larger HPC blade tip clearances after acceleration to high power. This contributed to high power surges," explains Linke-Diesinger. "The HPC cases have been modified from the segmented case design to the ring case design. There is now one ring for each compressor stage from stage 8 to stage 15. This maintains a better blade tip clearance behaviour during thermal expansion of the case structure. Due to the better performance figures of the ring case, a reduced rate of EGT margin loss is expected. This modification was covered by AD 2003-19-15. The thresholds for the AD were that half of all engines on an operator's 767 fleet had to be modified by 31st May 2006. With half having been modified by now, the remainder will have to be modified by 30th June 2009. Unmodified engines lose EGT margin at a rate of about 2.0 degrees per 1,000EFH, while modified engines should have a lower rate of loss of about 1.5 degrees per 1,000EFH.

"Removal intervals until today are not much driven by EGT margin loss, however," continues Linke-Diesinger. "The removals are mainly driven by the ring case modification requirements and the stage II high pressure turbine (HPT) blades. The stage II HPT blades had a limit of around 2,500EFC because of a corrosion problem, which is equal to 17,500EFH at our EFC time of 7.0EFH. We now use better blades, and removal intervals can get up to 20,000-22,000EFH."

"PW4060 engines tend to remain on wing for 14,000-17,000EFH, while PW4056 engines typically have removal intervals of 17,000-20,000EFH," says Janutin. "Although there are various operating factors, PW4000-94 engines will stay on wing for up to 16,000EFH or 4,000EFC, whichever is reached first. They seldom stay on-wing for longer than 20,000EFH or 5,000EFC." Given that most engines operate on average EFC times of 4.0-7.0EFH, removal intervals will be more closely related to accumulated EFH.

Like all other PW engines, the PW4000 mainly conforms to a simple shop visit pattern of alternating performance restorations and overhauls. The intervals of 15,000-16,500EFH for PW4060 engines are equal to 2,000-3,750EFC, and the intervals for PW4056 engines are equal to 2,250-4,000EFC. These have to be considered in relation to shop visit patterns, workscopes and the need to replace LLPs.

The PW4000 has 24 to 26 disks and shafts. They have lives of 20,000EFC for PW4052/4056 engines, and 15,000EFC for PW4060/62 engines. A set of LLPs for the PW4000-94 has a list price of $3.4 million. Engine managers will aim to replace LLPs at an overhaul when full engine disassembly is already required.

The aim to achieve the lowest rate for LLP reserves would be for PW4052/4056 engines operating at a ratio of 4.0EFH:EFC and achieving about 4,000EFC between removals to have their LLPs replaced at the fourth shop visit, thereby leaving a stub life of about 4,000EFC, at a total time of 16,000EFC. Engines operating longer cycles of 6.0-8.0EFC and achieving 2,250-3,000EFC on-wing, would aim to have their LLPs replaced every sixth or eighth shop visit after 17,000-18,000EFC and to leave a stub life of 2,000-3,000EFC.

The slightly shorter EFC shop visit

The 767 has so far had few ageing aircraft issues or problems with major ADs. Operators should be aware of the engine pylon improvement programme AD, which has to be terminated by 20 years of age. This can add up to 4,000MH to a heavy C check.

intervals of PW4060 engines have to be considered in relation to their LLP lives of 15,000EFC. Engines operated on shorter average EFC times of 4.0EFH will have removal intervals close to 3,750EFC, and LLPs can then be removed at the fourth shop visit close to LLP expiry. Engines operated on longer cycles of 6.0-8.0EFC will have intervals of 2,000-2,750EFC, and so LLPs can be replaced at the fourth or sixth shop visit after a total time of about 15,000EFC, leaving little or no stub life.

This management and pattern of engine removals must be considered with shop visit workscopes. "Performance restorations on the PW4000-94 have used up to about 4,500MH, and $850,000 in parts and materials, and a maximum of $120,000 in sub-contract repairs," says Linke-Diesinger. "We have a high in-house repair capability, which keeps the cost of sub-contract repairs low."

A typical industry labour rate of $70 per MH would take the total shop visit cost to about $1.35 million. Costs could reach $1.5 million where the portion of sub-contract repairs was higher.

Overhauls usually include the low pressure turbine (LPT) and the fan and booster section. "For an overhaul we would use in the region of 5,500MH in labour, about $1.0 million in parts and materials, and a maximum of $120,000 for sub-contract repairs," says Linke-Diesinger. This would take the total to $1.5 million with a standard labour rate of $70 per MH. Many overhauls would have a higher material consumption, and may also use a higher rate of sub-contract repairs, in which case the total cost could reach $1.7-1.8 million.

When these two shop visits are amortised over two successive intervals, the resulting shop visit reserves are $90-100 per EFH for the PW4056 engines and $106-115 per EFH for the PW4060 engines.

LLP reserves have to be adjusted for EFC time, and are $24-53 per EFH for the PW4056 when operated on cycles between 4.0 and 8.0 EFH, and are $35-57 per EFH for the PW4060 when operated on cycles between 4.0 and 8.0 EFH. This takes total reserves for the PW4056 up to $115-155 per EFH for average EFC times of 4.0 to 8.0 EFH, and up to $142-170 per EFH for the PW4060 for average EFC times of 4.0 to 8.0 EFH *(see table, page 35)*. Unscheduled shop visits should also be considered. These occur on average at longer intervals than scheduled visits, and also have lower costs. An additional $25 per EFH should be budgeted.

CF6-80C2

In addition to the different thrust ratings of the CF6-80C2 family, the engine type is divided between those that have FADEC controls and those with power management controls (PMC). The main difference between FADEC and PMC engines lies in the compressor stators and the engine management controls. About equal numbers of CF6-80C2 engines powering the 767 have FADEC and PMC controls.

Most CF6-80C2 engines powering the 767-200ER and -300ER are the -80C2B4, -80C2B6 and -80C2B7 variants. Their EGT margin will depend on whether the engine is FADEC controlled or has PMC controls. Frank Herr, customer programme manager CF6 projects at MTU Maintenance, explains that FADEC engines have higher EGT margins. Herr says that mature engines with FADEC controls have test cell EGT margins of 35-45 degrees C corrected for a hot day temperature of 25 degrees C after a shop visit restoration, while a mature engine with PMC controls has a lower margin of 25-35 degrees on the same basis.

These test cell EGT margins can often decrease by about five degrees C when installed on the aircraft, although EGT margin does actually increase on a few occasions.

Engines operating on typical cycle times of 7.0EFH and a 10% take-off de-rate will lose 15-20 degrees C of EGT margin in the first 1,000EFC or 2-3 degrees C per 1,000EFH following a shop visit. Herr explains that PMC engines generally deteriorate fast and so have shorter on-wing intervals.

Vassil Vassilev, senior sales executive engine services at GAMCO, explains that EGT margin erosion is influenced by several factors, in addition to EFH:EFC ratio. Engines with an average EFC time of 7.0EFH lose about 2.7 degrees C of EGT margin per 1,000EFH. Vassilev explains that this increases to about 3.05 degrees per 1,000EFH for an engine operating at 3.0EFH per EFC, and rises further to 6.3 degrees C per 1,000EFH for an engine on a 2.0EFH average EFC time.

Despite these rates of EGT margin loss, Vassilev explains that on-wing removal intervals are more related to deterioration of first-stage HPT blades than loss of EGT margin. Vassilev further explains that hardware deterioration rather than loss of performance retention is the main driving factor in CF6-80C2s. GAMCO's experience is that CF6-80C2B4 engines, rated at 57,900lbs thrust, are capable of remaining on wing for up to about 3,500EFC in the sandy conditions in which Gulf Air operates, at an average EFC time of about 2.8EFH, if the engines have new HPT blades. This is equal to about 9,000EFH. This time is reduced if the engines' HPT blades have been repaired.

FADEC -80C2B6 engines operating at average EFC times of 7.0-8.0EFH can remain for about 2,400EFC or

DIRECT MAINTENANCE COSTS FOR 767-200ER/-300ER

Maintenance Item	Cycle cost $	Cycle interval	Cost per FC-$	Cost per FH-$
Line & ramp checks	326,000	1 year		75
A check	550,000	4,800FH		115
Base checks	2,400,000-2,750,00			120-155
Heavy components:			609	87
LRU component support				220
Total airframe & component maintenance				**620-655**
Engine maintenance:				
2 X PW4000				280-390
2X CF6-80C2				310-460
Total direct maintenance costs:				
2 X PW4000				900-1,045
2X CF6-80C2				930-1,115

Annual utilisation:
4,500FH
640FC
FH:FC ratio of 7.0:1.0

16,500EFH, while engines operated on shorter average EFC times of 4.0EFH can have intervals in the region of 14,500EFH or 3,600EFC.

Non-FADEC engines will have shorter intervals, and those operating on long-haul cycles of 7.0-8.0EFH will remain on wing for about 12,000EFH and 1,700EFC. Engines operating on shorter cycles of 4.0EFH achieve about 10,500EFH and 2,600EFC.

Most CF6-80C2s in operation conform to an alternating pattern of performance restorations and overhauls. A core restoration is required at every shop visit, while an overhaul on the fan/booster and LPT modules is usually required every second shop visit, but workscopes are determined by the condition of the modules.

All LLPs in the engine have a life of 20,000EFC, except those in the HPT module, which have lives of 15,000EFC. The aim of engine management would be to maximise the life of LLPs and to replace them when the engine requires a overhaul workscope.

FADEC engines operating at average cycle times of 6.0-7.0EFH, and at removal intervals of 2,500EFC, could have their 20,000EFC LLPs replaced at every eighth shop visit, with little or no stub life remaining. Engines operating at shorter average cycle times of 4.0EFH, with longer removal intervals in the region of 3,250EFC, could have the same LLPs replaced at the fifth shop visit, and will have removals forced by LLP expiry, thereby maximising the use of LLP lives.

A shipset of LLPs for the CF6-80C2 has a list price of $3.2-3.4 million, and reserve rates would be $125-135 per EFC, depending on EFC time and timing of replacement.

Non-FADEC engines with average EFC times of 7.0EFH and shorter removal intervals can replace their LLPs after 10 shop visits, and have a stub life of about 2,000EFC. LLPs would be replaced every sixth or seventh shop visit for those engines operating on shorter average EFC times of about 4.0EFH, and have LLPs replaced after a similar time and leaving a similar stub life. LLP reserves would be similar for FADEC engines.

Lighter shop visits, which usually take the form of a performance restoration, will use 4,000-4,500MH. Charged at a labour rate of $70 per MH, lighter shop visits would be equal to a cost of $280,000-315,000.

Not including LLPs, the cost of materials can be in the region of $850,000-950,000. The actual amount depends on the workscope, the engine shop's in-house repair capability and the percentage of parts manufacturing approval (PMA) components used.

The cost of sub-contract repairs will be $250,000-300,000, although the amount can fall to only about half this if the shop has a high in-house repair capability.

These three elements bring the total cost for the workscope to $1.4-1.55 million. The cost of LLPs is considered separately as a reserve for the full shipset.

Engines operating in a harsher environment will have more expensive shop visit workscopes because a higher number of parts will have to be replaced. Engines operating in a sandy environment will have their HPC blades replaced more frequently than engines in a cool environment. This will therefore increase the cost of the shop visit workscope by several hundred thousand dollars.

A heavier workscope can vary widely in content, since in some cases only one of the fan/booster and LPT modules need be worked on, and in others both will have to be worked on.

The labour content for this level of workscope will be 5,000-5,500MH, equal to a cost of $350,000-385,000. The cost of materials will be $1.0-1.1 million, not including LLPs. Again, the actual cost will depend on in-house repair capability, workscope content, and what percentage of PMA parts are included.

The final element of sub-contract repairs will be $350,000-400,000 for a shop with an average in-house repair capability.

This will take the total cost for the shop visit to $1.70-1.90 million.

While the costs for shop visits are the same for FADEC and PMC engines, engines with FADEC controls will benefit from lower shop visit reserves on account of their longer removal intervals. FADEC engines will have reserves of $105-120 per EFH, depending on EFC time. When LLP reserves are added, taking into consideration the average EFC times, reserves will be increased to $130-160 per EFH.

PMC engines will have higher shop visit reserves of $145-165 per EFH. Reserves for LLPs will take this up to $170-205 per EFH, depending on the average EFC time *(see table, this page)*. An additional $20 per EFH should be budgeted for unscheduled shop visits.

Summary

The 767 at a mature age has good maintenance costs for an aircraft of its size. The total airframe and component costs of $620-655 per FH would of course be higher for an aircraft operated on short- and medium-haul routes with shorter average FC times and lower rates of utilisation.

The 767 also benefits from not having any serious increase in airframe-related costs due to ageing aircraft issues. The engine pylon improvement programme only increases maintenance reserves by $15 per FH if amortised over the interval of a base check cycle.

The 767 will soon face competition from the 787, which will have more attractive maintenance costs. Many 767s are likely to be converted to freighter. The combination of the aircraft's size, fuel and maintenance costs and payload-range performance will make it attractive. AC