Demand for 50-70 ton freighters has increased rapidly over the past two years. A large number of A310 and A300B4 freighters need replacing, and Amazon's fulfilment services has fuelled demand for more aircraft. The costs of acquiring, converting and preparing 767-300ERs and A330-200s/-300s for service are examined.

767 & A330 converted freighter build costs

Demand for small widebody freighters, in the 55-70 ton category, has increased over the past two to three years. The number of conversions for 767-300ERs has increased.

Demand has been partly fuelled by FedEx's selection of the factory-built freighter in 2013, and also by the growth in shipments of internet shopping. Amazon's subsidiary Amazon Fulfilment Services operates an airline called Prime Air, and has also acquired shareholdings in Atlas Air and the Air Transport Services Group (ATSG), which operates ABX Air, Air Transport International (ATI) and Atlas Air. These airlines have acquired 767-200Fs and -300Fs in recent years, and operate in Prime Air's colours.

Demand for A330-200 and -300 conversions has lagged behind. They are still relatively young, so their acquisition costs are high. This article will examine the acquisition of suitable used passenger-configured A330s and 767-300ERs, their modification to freighter and associated costs, accompanying maintenance and preparation for service costs, and overall total build costs to provide a serviceable freighter and market lease rates.

Freighter demand

Demand for converted 767 and A330 freighters will be fuelled by the replacement of older aircraft and growth in overall demand. Freighters in the 50-70 ton category are operated by small package operators and general freight carriers operating medium-range routes with medium levels of demand.

There are almost 500 767-200, 767-300, A300, A310 and DC-10-10/MD-10-10 freighters in active service. About 445 are 767 and A300/310 variants.

These are operated in a mix of small package and general freighter roles. About two-thirds of the active fleet is operated in small and express package roles. The largest operators are FedEx, UPS and DHL/European Air Transport (EAT). They also include ASL Airlines Belgium (formerly TNT), Prime Air, Cargojet, and ABX Air.

Large numbers of factory-built A300-600 and 767-300 freighters are operated by FedEx and UPS, while ASL, DHL/EAT Atlas Air, and Cargojet all operate converted freighters. FedEx does, however, also operate 39 MD-10-10 and a small number of A310 converted freighters. The airline also has 59 factory-built 767-300PFs on order.

In total, airlines carrying general freight operate about 135 767-200, 767-300, A310, A300B4, and A300-600 freighters.

A large portion of the 50-70 ton freighter fleet is operated by FedEx (162 aircraft) and UPS (111). Of these aircraft, 228 are factory-built A300-600Rs and 767-300Fs. A few other airlines operate relatively young factory-built freighters.

Examination of the 50-70 ton freighter fleet reveals that about 190 aircraft are more than 25 years old. This includes all 42 DC-10s, which are 29-47 years old; but also another 148 767-200s, 767-300s, A300-600Rs, A300B2/4s, and A310-300s. This older part of the fleet represents an opportunity for 767 and A330 conversion programmes over the next 10-15 years. Some A310s and older A300-600Rs are operated by FedEx, which has taken delivery of 48 767-300ERFs in the last five years, and still has some outstanding deliveries.

This replacement of older aircraft is in addition to the demand for aircraft as a result of industry growth. The level of growth of demand for aircraft in this size category is partly illustrated by the larger number of conversions of 767-300ERs over the past two years.

The conversion of 767s to freighters started in 2002, and continued through to 2012, totalling 56 aircraft. Of these 56 aircraft, 24 former All Nippon Airways and TWA aircraft were converted to freighter, using an existing passenger door for loading specially designed containers used to carry express packages. This configuration avoids the high cost of installing a conventional cargo door, but also means some of the aircraft's internal fuselage volume is not used. This conversion was designed specifically for ABX Air of the US, and the 24 767-200s were modified between 1998 and 2003.

Of the 24 aircraft modified this way, one was subsequently broken for parts, and not modified to a conventional freighter, while the other 23 were later converted to conventional freighters from June 2009 to September 2012 using the Israel Aircraft Industries (IAI) passenger to freighter (P-to-F) modification. These 23 aircraft were the last 767-200s to be converted, and are now being operated by ABX Air and Atlas Air, mostly on a crew, maintenance and insurance (CMI) basis for DHL Airways in the US, or on an aircraft, crew, maintenance, and insurance (ACMI) basis for DHL Express in the US.

In addition, another 32 767-200s and -200ERs that were modified to conventional freighter are still being operated by a variety of airlines. Of these, 31 were modified by IAI, and one was converted by Aeronavali with the Boeing modification.

These 32 aircraft are operated in a variety of roles. ABX operates seven, some on a CMI basis for DHL in the US.

PAYLOAD SPECIFICATIONS FOR 767-300, A330-200 & A330-300 FREIGHTERS

Aircraft type	767-300BDSF	767-300BDSF	A330-200P2F	A330-200P2F	A330-300P2F	A330-300P2F
Description	No winglets	Winglets	High payload	Long range	High payload	Long range
MTOW - lbs	412,000	412,000	500,449	513,677	500,308	506,920
MTOW - tonnes	187	187	227	233	227	231
MZFW - lbs	309,000	309,000	392,423	374,786	392,423	385,700
MZFW - tonnes	140	140	178	170	178	175
OEW - lbs	180,800	183,800	240,236	240,236	251,327	251,327
Gross structural payload - lbs	128,200	125,200	154,324	134,550	141,096	134,373
Gross payload - tonnes	58	57	70	61	64	61
Freight accommodation						
Total ULD volume - cu ft	15,710	15,710	16,875	16,875	19,614	19,614
ULD tare weight - lbs	17,640	17,640	18,495	18,495	21,436	21,436
Net structural payload - lbs	110,560	107,560	135,829	116,055	119,660	112,937
Maximum packing density - lbs/cu ft	7.0	6.8	8.0	6.9	6.1	5.8
Total pallet volume - cu ft	13,217	13,217	16,260	16,260	17,972	17,972
Pallet tare weight - lbs	7,988	7,988	8,764	8,764	10,267	10,267
Net structural [payload - lbs	120,212	117,212	145,560	125,786	130,829	124,106
Maximum packing density - lbs/cu ft	9.1	8.9	9.0	7.7	7.3	6.9

Air Transport International (ATI) operates six for Amazon's Prime Air. These are also operated in the US.

Star Air of Denmark has the largest fleet of 10. Small fleets are operated by Cargojet, Amerijet, Aerounion and West Atlantic Sweden.

The conversion of 767-200s gave way to the larger -300ER variant. The first two 767-300ER conversions took place in 2008, and have continued. A total of 65 -300ERs have been modified, 22 with the Boeing modification and 43 with the IAI programme.

The number of conversions remained low for several years up to 2013, but rose to five in 2014, and seven in 2015. Demand has since climbed, with 15 being modified in 2016, and 19 so far in 2017. Eight aircraft were modified with the Boeing programme in 2016 and 2017, and 26 with the IAI modification.

The increase in 767-300ER conversion activity is due to demand from Amazon Fulfilment Services for Prime Air. Six of the aircraft converted in 2016, and 13 in 2017, were for Amazon Fulfilment Services, accounting for more than half of the 34 aircraft modified. These are operated by Atlas Air and ATI.

Another two aircraft are operated by ABX Air and Polar Air Cargo and operated on a CMI basis for DHL Express. Four aircraft have been modified for SF Airlines; three for Kalitta Air, some of which are operated for FedEx and DHL Express; one for Amerijet; one for Star Air; two for ATI for contracts; and one for Cargojet.

In addition to these recently converted aircraft, there are 17 767-300ERs known to be either in conversion or to have been bought for conversion over the next one to two years. At least 14 of these will be modified by IAI. At least three aircraft will be operated by Atlas Air on a CMI basis for Prime Air, and another four for Atlas Air will possibly be for the same operation. Five will be for Kalitta Air, one for ATI, and two for UPS.

A330 conversions have lagged behind 767s, but the first few have begun. Egyptair will convert three A330-200s for its own cargo operations. Eight -300s, six of which are ex-Thai International and one ex-Malaysian, will be converted and operated by DHL Air on behalf of DHL Express.

Conversions of A330-200s and -300s are expected to pick up as the feedstock of appropriate quality 767-300ERs is expected to shrink. The first A330-300F will enter service in 2018, and the first -300F will enter service in 2019.

Freighter characteristics

Following a P-to-F conversion the 767-300ER, A330-200 and A330-300 have gross structural payloads of 125,000-154,000lbs *(see table, this page)*. The difference between the maximum zero fuel weight (MZFW) and operating empty weight (OEW) of the converted aircraft determines gross structural payload.

The later-built A330-200P2F, converted by EFW, can be operated in two modes. One is a high MZFW for a high gross structural payload of 154,000lbs, while the other is a low MZFW, but high-gross-weight option for long range, which results in a gross structural payload of 134,550lbs *(see table, this page)*.

The later-built A330-300P2F can also be operated in these two modes, but the high MZFW mode has a gross structural payload of 141,096lbs *(see table, this page)*, which is about 13,000lbs less than the A330-200F in the same mode. This disadvantage is because the A330-300F has a lower MZFW and higher OEW than the -200F.

All aircraft can be operated with unit load devices (ULDs) or with pallets on the main and lower decks. ULDs provide higher useable volumes, but their lower tare weight results in the aircraft having a higher net structural payload.

ULDs are suitable for packages and high value cargoes, such as electrical items. These tend to have lower packing densities. Pallets are suitable for larger bulk items, such as fruit and flowers, and larger manufactured items. These have higher packing densities, and so require the aircraft's higher net structural payload that the use of pallets provide.

The net structural payloads and available volumes determine the aircraft's maximum packing densities, and the type of freight they are suited to transport.

767-300ERF

The various P-to-F programmes for the 767-300ERF provide different payloads, because although the Boeing and Bedek modifications both provide the same MZFW, the OEW varies between the two, and is also heavier for aircraft with winglets fitted. The Bedek-converted aircraft, the -300BDSF, has an OEW that averages 183,500lbs for an aircraft with winglets, and 180,800lbs for an aircraft without winglets. The gross structural payload for an aircraft with winglets is therefore 125,500lbs, and higher at 128,200lbs for an aircraft without winglets *(see table, page 82)*.

While there are various ULD configurations possible for the main deck, the highest total ULD capacity for both decks is 15,710 cubic feet. These ULDs have a tare weight of 17,640lbs.

For an aircraft without winglets, the net structural payload is 110,560lbs, while for one with winglets it is 107,860lbs. This allows a maximum packing density of 7.0lbs per cu ft and 6.8lbs per cu ft for these variants *(see table, page 82)*. This is typical for express packages and other light-density, high-value materials with lightweight packing.

The use of pallets on both decks provides a volume of 13,217 cu ft, and their associated tare weight is 7,988lbs. This allows a net structural payload of 120,212lbs for an aircraft without winglets, and 117,512lbs for an aircraft with winglets. The resulting packing density is 9.1lbs per cu ft and 8.9lbs per cu ft. This is typical of general freight.

The aircraft has a range of about 3,200nm with a full payload.

A330-200P2F

The converted A330-200P2F from EFW provides a gross structural payload of up to 154,000lbs (70 tonnes). The aircraft can be operated in two modes. That is, the A330-200P2F and -300P2F can operate where MZFW is traded for MTOW. A high MTOW option will extend range, but reduces MZFW and structural payload, which then lowers the maximum packing density that is possible with all volume occupied. Alternatively, a low MTOW can shorten range, but increase MZFW to increase structural payload.

There is a difference in MZFW of 17,637lbs, with an equal change in structural payload. The A330-200P2F's gross structural payload with a high MZFW option is 154,324lbs (70 tonnes), falling to 134,550lbs (61 tonnes) with a lower MZFW option *(see table, page 82)*. The difference in MTOW between the two modes is 13,228lbs.

Depending on engine type, the A330-200P2F has an OEW of 240,236lbs. This results in a gross structural payload of 154,324lbs in a high MZFW mode, and 134,550lbs in long-range, low MZFW mode *(see table, page 82)*.

With ULDs, the A330-200P2F has a total freight volume of 16,875 cu ft on its main and lower decks. The associated tare weight of the containers is 18,495lbs.

The resulting net structural payload of the high MZFW mode is 135,829lbs, which gives the aircraft a maximum packing density of 8.0lbs per cu ft.

In long-range, low MZFW mode the aircraft has a net structural payload of 116,055lbs, and a maximum packing density of 6.9lbs per cu ft *(see table, page 82)*.

With the use of pallets, the A330-200P2F has a total volume of 16,260 cu ft, and the associated tare weight is 8,764lbs. In high MZFW mode this gives it a net structural payload of 145,560lbs, and a maximum packing density of 9.0lbs per cu ft. This makes the aircraft suitable for the carriage of general freight.

This net structural payload is 28,048lbs and 24% higher than the 767-200BDSF.

In the long-range, low MZFW mode, the use of pallets gives the aircraft a net structural payload of 125,786lbs *(see table, page 82)*. The maximum packing density is 7.7lbs cut ft. The aircraft can carry a full payload, in long-range mode, up to 4,150nm.

It should be appreciated that the trade between MTOW and MZFW is only possible for aircraft built from 2004 onwards. There are four main groups of aircraft built prior to this. The first built from late 1997 to 1998 are only capable of an MZFW of 169 tonnes or 172 tonnes. This compares to a maximum of 178 tonnes for the high MZFW option of aircraft built from 2004.

Demand for 767-300ER and A330-200/-300F conversions is partially being fuelled by the retirement of older A300B2/4 freighters. DHL will have eight A330-300s converted.

Aircraft built from 1999 to 2000 (serial number (S/N) 370) can have a slightly higher MZFW of 173 tonnes, and aircraft built between 2000 and 2003 S/N 375 to 515) can have a MZFW of 173 tonnes or 175 tonnes. These three groups of aircraft built up to 2003 will therefore have lower gross structural payloads because of limited MZFW. The OEWs of these aircraft, however, are also about 1.5 tonnes lighter than aircraft from 2004 onwards. The gross structural payloads will therefore be up to 7.5 tonnes lower than the highest possible for the A330-200P2F.

A330-300P2F

The A330-300P2F can also be operated in these two modes. In the high payload version the MZFW is 392,312lbs *(see table, page 82).*

Depending on engine type, the A330-300P2F has an OEW of about 251,327lbs, which gives it a gross structural payload of 141,096lbs, equal to 64 tonnes *(see table, page 82.* This is actually 13,228lbs less than the A330-200P2F operated in the same mode. The -300P2F's payload disadvantage is because it has the same MZFW for its size, but its OEW is 11,091lbs higher.

In long-range, low MZFW mode, the A330-300P2F has a gross structural payload of 134,373lbs, 177lbs less than the -200F in the same mode.

When using ULDs, the A330-300P2F has a total container volume of 19,614 cu ft on both its decks, and an associated tare weight of 21,436lbs. This gives it a net structural payload of 119,660lbs in high MZFW mode *(see table, page 82),* and a maximum packing density of 6.1lbs per cu ft.

In long-range mode, the -300F has a net structural payload of 112,937lbs with ULDs. This results in a maximum packing density of 5.8lbs per cu ft.

The use of pallets on both decks provides a total volume of 17,972 cu ft, and a total tare weight of 10,267lbs.

The aircraft in high MZFW mode has a net structural payload of 130,829lbs, and a maximum packing density of 7.3lbs per cu ft. In long-range mode the net structural payload is 124,106lbs, and maximum packing density is 6.9lbs per cu ft. In this mode, it can carry a full payload up to 3,650nm.

Like the -200P2F, only later-built A330-300s can operate in the high MTOW or high MZFW mode after conversion. The first A330-300 built was serial number 012, and up to S/N 112 (built 1995) are limited to a MZFW of 167 tonnes, S/N 113 (1995) to S/N 244 (1998) are limited to a MZFW of 169 tonnes and 172 tonnes, S/N 256 (1999) to S/N 370 (2000) are limited to a MZFW of 173 tonnes, and S/N 375 (2000) to S/N 515 (2003) are limited to a MZFW of 173 tonnes and 175 tonnes. These lower MZFWs will have a commensurate affect on lower structural payload when compared to those of later-built aircraft *(see table, page 82).*

Conversion programmes

The two P-to-F modification programmes for the 767-300ER are offered by Boeing and IAI. Boeing sub-contracts most of the actual modifications to ST Aerospace in Singapore. Bedek Aviation converts most of the aircraft under the IAI programme in Tel Aviv.

The list price for the Boeing modification is about $15 million, and includes the cargo loading system (CLS) on the main deck floor.

The list price for the IAI conversion is about $13 million, including the CLS. Discounts of up to $1.5 million may be possible.

The P-to-F modification programme for the A3300 is provided by EFW, and aircraft are converted by ST Aerospace in Singapore. The list price for converting the A330-200 is $15 million, including CLS; and $16 million for the -300 series.

The cost of the conversion accounts for a large percentage of the total cost of preparing the aircraft for service. In addition, there will be the cost of acquiring the used passenger aircraft, upgrades and modifications to its avionics and systems, maintenance to prepare it for service, and the interest incurred between acquiring the aircraft and it earning its first lease rental when it enters service. This period can be up to a year, and will be even longer when a group of aircraft have been acquired and each one has to be converted in turn or in pairs.

Conversion candidates

There are 385 767-300ERs in active service and in passenger configuration. Of these 230 are equipped with CF6-80C2 engines, 11 with PW4052s, three with PW4056s, 101 with PW4060s, 28 with PW4062s, and 12 with RB211-525Hs.

The most suitable candidates for conversion can quickly be identified by eliminating older aircraft, those with less appealing engines and engine variants, and those with a high number of accumulated flight hours (FH) and flight cycles (FC). Finally, sisterships from large fleets will be sought after, so aircraft operated in small fleets are less likely to be considered as possible candidates.

Of the 230 CF6-powered aircraft, 179 are operated in large fleets, are in the appropriate age group, and have not accumulated an excessive number of FH and FC. All have been operated on long-haul operations, so they have accumulated under 1,000FC per year.

Three fleets of young aircraft are operated by Japan Airlines (JAL), All Nippon Airways (ANA) and the LATAM Group.

The ANA fleet of 25 aircraft varies in age from six to 21 years old, and has accumulated 54,000-103,000FH and 8,000-17,000FC.

JAL's fleet totals 30 units, is six to 16 years old, and has accumulated 4,000FH and 1,100FC per year; taking the highest-time aircraft to 65,000FH and 18,000FC.

The LATAM Group fleet of 36 aircraft is mainly operated in Brazil and Chile. These are six to 21 years old, and accumulate about 4,500FH per year.

Older fleets are operated by Air Canada, American Airlines, Condor, and Delta. Air Canada's fleet has 21 aircraft, which are some of the oldest, ranging in age from 16 to 29 years. These have accumulated 75,000-131,000FH and 10,000-23,000FC, having been used as long-haul workhorses. Many are due to be replaced with 787s.

American has a fleet of 25 units, which is 14-26 years old, and has accumulated 54,000-103,000FH and 8,000-17,000FC. Delta operates 35 aircraft, which are 16-27 years old, and have accumulated 70,000-115,000FH and 9,000-21,000FC.

Condor has a fleet of seven aircraft that are 16-24 years old, and have 77,000-96,0000FH and 10,000-16,000FC.

There are four different PW4000 variants powering the 767-300ER, and the lowest-rated PW4052-equipped fleet is just 11 aircraft operated by United. These are 18 and 19 years old, and have accumulated 60,000-70,000FH and 13,000-16,000FC. Despite the low-rated engine, they may continue to operate with United, given that the airline has tried to persuade Boeing to restart 767 production.

There are only three PW4056-powered aircraft. This leaves a maximum of 101 PW4060-powered and 28 PW4062-powered aircraft.

Of the PW4060-powered fleet, there are 77 more likely candidates. Delta operates the largest fleet of 30, which are 20-28 years old. These, however, have the highest accumulated time of 89,000-126,000FH and 12,000-18,000FC.

The United fleet is the second largest with 24 aircraft that are 16-27 years old. These have 60,000-109,000FH and 13,000-17,000FC total time.

Air Canada has 10 PW4060-equipped aircraft, with 54,000-102,000FH and 10,000-19,000FC. Two small fleets of six and seven aircraft are operated by Austrian and Condor. These aircraft are 17-26 years old, and their lowest total time is 80,000FH and 10,000FC.

There are a select group of PW4062-powered aircraft, which include: two operated by Air Canada that are 22 years old; two operated by Condor that are 24 and 25 years old; and six operated by Ethiopian Airlines that are 12-18 years old. There are therefore 87 PW4000-powered aircraft that are likely to be preferred conversion candidates.

Aircraft with RB2311-524H engines are unlikely freighter conversion candidates. Their high OEW, the scarcity of the engine type in the global fleet, and the difficulty in obtaining non-OEM support for engine maintenance makes these aircraft unattractive to freight operators.

Of the fleet of 385 active passenger aircraft, only 256 CF6- and PW4000-powered 767-300ERs are more likely to be sought for conversion to freighter.

The A330 fleet has more aircraft that make suitable conversion candidates: 507 active passenger-configured A330-200s; and 674 A330-300s.

The A330-200 fleet comprises 507 aircraft: 146 powered by the CF8-0E1; 71 by the PW4168/70; and 290 by the Trent 772.

The A330-300 fleet includes 123 CF6-powered, 107 PW4168/70-powered, and 444 Trent 768/772-powered aircraft.

Most A330-200s and -300s are relatively young, with the oldest being a -300 that entered service in 1994. There are 44 -300s that are either in storage or have been retired, and are the oldest and lowest gross weight aircraft. The oldest -300s in active service are a small number operated by Cathay Pacific. Most of the fleet, however, is less than 20 years old.

The CF6-80E1-equipped fleet includes

Prime Air is the airline operated by Amazon Fulfilment Services. These aircraft are operated in Prime Air colours, and are sub-leased to several freight carriers which operate them on a crew, maintenance and insurance (CMI) basis for Prime Air.

several large fleets. The youngest fleets include Delta Airlines (10 aircraft), EVA Air (9), Iberia (8) and Turkish Airlines (20). Fleets with aircraft 10-18 years old are China Airlines (24), Finnair (9), Qantas (10) and Qatar Airways (13).

The PW4168/70-equipped fleet has young fleets operated by China Southern (16) and Malaysian (15). Asiana (15) and Delta (21) have fleets with the oldest aircraft at 13-15 years. American has nine aircraft with the highest age of 18 years, and Korean Air has 21, with the oldest at 21 years.

The oldest Trent-powered A330-300s are operated by Cathay Dragon and Cathay Pacific. The two have a total of 60 aircraft, the oldest of which are 25 years old, with the youngest at less than three years.

Air Canada has eight aircraft, with the oldest at 19 years; and Garuda has six, with the oldest at 21.

There are many medium and large fleets with young aircraft that have an average age of less than 10 years. These include Saudia, Aeroflot, Air China, Air Asia, China Eastern, China Southern, Etihad, Garuda, Hainan Airlines, Hong Kong Airlines, Lufthansa, Philippine Airlines, Singapore Airlines, SWISS, Thai International, Turkish and Virgin Atlantic.

Like the A330-300 fleet, the -200 fleet is dominated by Trent-powered aircraft. The first aircraft was built in 1998, making it 19 years old. The first aircraft will therefore enter the zone of economic convertibility over the next few years.

The CF6-powered aircraft are found in several larger and many medium-sized fleets. Larger numbers are operated by Air France (15), Alitalia (14), Qantas (18) and Qatar Airways (13). A total of 105 aircraft are operated in smaller fleets by Aerolineas Argentinas, Air Europa, Iberia (10), KLM (8), TAP (7) and Turkish Airlines (8). No CF6-powered A330-200s are operated in North America. The oldest aircraft are 17 years old.

The PW4168/70-powered fleet is the smallest A330-200 sub-fleet. Delta is the only operator in the US, with 11 aircraft that were previously operated by Northwest. Other major fleets are operated by China Southern (10), Turkish Airlines (8), Korean Air (8) and TAP (6). Smaller numbers are operated by Aerolineas Argentinas, Brussels Airlines, and Hong Kong Airlines.

There are several large fleets of Trent-powered A330-200s . The three fleets operated in North America are American (15), Hawaiian Airlines (24) and Air Transat (10). Other large fleets are Air China (30), China Eastern (30) and Etihad (18). There are a large number of medium-sized fleets, operated by Garuda, Hainan Airlines, Kuwait Airways, South African Airways and Virgin Australia.

Aircraft acquisition

Acquiring used passenger-configured aircraft at the right age, with the appropriate range of accumulated FH and FC, and in the right maintenance condition is a challenging task for converters, lessors and freight airlines. Several issues have to be considered.

The first is acquiring aircraft with the right combination of age and accumulated FH and FC. Heavy and deep structural tasks increase in number and inspection frequency after certain total FC thresholds have been reached. This increases airframe maintenance costs. The same costs are escalated by an increase in non-routine ratio with time. The aircraft's maintenance planning document (MPD), and a knowledge and analysis of ageing maintenance issues are required.

At a fundamental level, aircraft have base check cycles with a sequence of checks that culminates in a heavy check. The freighter conversion progress involves stripping the aircraft down to the deepest level, and grounding it for several months. This offers the best opportunity to perform a heavy base check, perform any structural modifications and produce an aircraft that is at the start of its base check cycle when it enters service as a freighter. This check can be performed in parallel with the freighter conversion, and labour man-hours (MH) will be saved due to the access provided.

The ideal time, in terms of airframe maintenance, to acquire an aircraft is therefore when it is close to the last and heaviest check in its base check cycle.

767-300ER

The 767 has a base check cycle of four checks. The base interval in the MPD for a 'C' check is 18 months (MO). Most 'C' check tasks are either system or structural. System tasks have a combined base interval of 6,000FH and 18MO, and are performed on a whichever comes first (wcf) basis. There are six groups of tasks with multiples of these intervals, referred to as the 1C, 2C, 3C, 4C, 6C and 8C tasks. They are repeated as the respective multiple of the base interval.

Structural tasks have a combined base interval of 3,000FC and 18MO, again on a wcf basis. Six groups of tasks have multiples of this base interval: the S1C, S2C, S3C, S4C, S6C, S8C and S12C.

The fourth check in the cycle, nominally the C4 check, will therefore have the 1C, 2C, 4C, S1C, S2C and S4C tasks as the main components. There are also some calendar tasks. Tasks with higher multiples will come due for the first time at the sixth, eighth and twelfth C checks.

The full interval for the C4 check is therefore 72MO or six years. The ideal time to acquire a 767-300ER for conversion will be just before it reaches the end of its third or fourth base cycle, a short time before the C12 or C16 check is due. This will be at 16-17 years, and 21-23 years of age.

The total MH consumption for a

Atlas Air now operates several recently converted 767-300BDSFs for Amazon Fulfilment Services.

767-300ER at this stage can be 26,000MH for a passenger-configured aircraft. The absence of interior work saves 5,000-6,000MH, and more MH may be saved because of access. Allowing 20,000MH at a labour rate of $75 per MH, plus $400,000 for materials, brings the total cost to $1.9 million.

The 767 has ageing structural tasks, mainly in FC intervals. The lowest thresholds are 18,000FC, 20,000FC and 25,000FC. The 25,000FC group is large with 77 tasks. For aircraft operated on long-haul missions and at utilisation rates of 550-800FC per year, these will come due at 31-40 years of age. Aircraft converted at 17-23 years of age can operate for at least 10-12 years before these tasks come due, and so avoid their high cost. A 17-year-old aircraft that has averaged 650FC per year will have accumulated 11,000FC, and so have 14,000FC left until the first major group of ageing tasks comes due.

Other groups of ageing tasks come due at 30,000FC and higher up to 90,000FC, but are unlikely to ever be performed.

An additional consideration are the aircraft's interior furnishings and equipment. The ideal condition for a converter is an aircraft with an old interior that would otherwise require significant expenditure on up-to-date premium cabin seats and in-flight entertainment (IFE) and cabin connectivity systems, which can cost $8-10 million for 767s and A330s. An old interior will be disposed of, and the aircraft is more likely to be a freighter conversion candidate than one that could be remarketed to a passenger airline.

A330-200 & -300

The A330's maintenance programme was based on a base check programme of a cycle of eight checks with a maximum interval of 144MO or 12YE, escalated from a total interval of 120MO/10YE when the aircraft entered service in 1994.

The basic C check interval was 18MO. The cycle included two heavy checks with groups of deep, structural tasks: the C4 and C8 at 72MO and 144MO. The base check cycle system was changed in 2011 to a system of six C checks, with the C3 and C6 being the two heavy checks that coincide with the 72MO and 144MO structural tasks.

The C3/72MO check will consume a total of 25,000MH, and the C6/144MO check a total of 40,000MH. The latter will, however, include about 9,000MH for interior refurbishment.

Including a budget of 30,000MH plus $500,000 for materials, the cost of a heavy check is $2.75 million. An intermediate check, with 23,000MH plus $300,000 for materials, costs $2.0 million.

The A330 has several groups of heavy structural tasks at 17,000FC, 20,000FC and 24YE. The 24YE is a large group of 138 tasks. They also have repeat intervals of 6YE and 12YE, so the aircraft becomes more maintenance-intensive after 24 years.

An ideal time to convert an A330 will be just before its second C3/72MO check at about 15 or 16 years, or just before its second C6/144MO check at 21 years. This considers the initial base check interval of 10YE. Freight operators have to consider the cost impact of the 138 24YE tasks as they come due, and be prepared for the cost.

Again, it will be preferable to acquire an aircraft with an old interior that is due for replacement. A large number of MH can be saved on a heavy check combined with freighter conversion because of access and the absence of interior refurbishment.

A second main consideration in aircraft acquisition will be weights and production batch number, and therefore the ability to upgrade weights, especially the MTOW and MZFW. Later-build aircraft have this capability. The implications are that the earlier-built aircraft cannot have the MZFW weights as described *(see table, page 82)*, so they have lower gross structural payloads than listed. The further implications of that are that older aircraft are only suitable for express package operations. Later-built and higher weight aircraft will be more suited to general freight operations.

The cost of weight upgrades, such as MZFW or MTOW, for A330 P2F modifications are included in the cost of conversion. The Bedek IAI conversion for the 767-300ER will incur additional costs for weight upgrades, since it is a non-OEM modification. Technical access fees will also have to be paid.

The avionics specification of aircraft is becoming increasingly important. Several hundred thousand dollars may need to be invested in some cases.

An important means of mitigating the risk of escalating maintenance costs is the condition and maintenance status of engines. Engines that have accumulated a lot of time on-wing, especially since hot-section refurbishment and high-pressure turbine blade replacement, will risk incurring high shop visit costs shortly after entry into service as a freighter. Splitting engines into modules and swapping modules is also risky, since findings at inspection can escalate maintenance workscopes.

A policy for minimal risk will be to acquire engines with a high maintenance status. A preference should be for engines with life-limited parts (LLPs) that have the equivalent of at least 10 years of operation remaining, equivalent to 7,000-10,000 engine flight cycles (EFC). It is possible to swap engines, and gain 'green time' or time-continued engines with a better maintenance status.

Landing gears and other heavy components can be swapped relatively

The oldest and lowest weight A330-300s have market values that are estimated to be less than $15 million. This puts them in the economic zone of convertibility. Total build costs are likely to be less than $30 million. The early-build aircraft, however, have low MZFWs following conversion, and so relatively low structural payloads.

easily.

There will be a relatively short supply of time-continued landing gears for the A330 on the aftermarket. If a landing gear needs an overhaul, then an exchange fee of $200,000 and an overhaul fee of $400,000-500,000 can be expected. The cost for a 767 will be marginally less.

All aircraft should be fitted with a new set of tyres and brake disks, and have overhauled wheel rims fitted before service entry. In the case of the 767, this will cost about $490,000, and $540,000 for the A330.

Aircraft values

The actual purchase price of a used aircraft will be a reflection of its maintenance status, avionics specification and its weight standards.

There will be a trade-off between the asking price and an aircraft's maintenance status. A typical issue is that larger fleets often cannibalise the oldest aircraft, or the fleet member in the poorest maintenance condition. Airlines then swap engines and some higher value components onto aircraft they intend to keep operational, and aircraft that are being phased out have the poorest engines and components.

The 767-300ER, A330-200 and A330-300 fleets are large and include several airlines with relatively large numbers of sisterships. This should make it relatively easy to acquire good quality 767-300ERs and A330-300s within the next to three years, and less challenging to acquire suitable A330-200s within five years.

The estimated current market value, provided by IBA, of 767-300ERs, is $11.0-13.5 million for 1994-1996-built aircraft, at 21-23 years old; and $18.5-20.0 million for 2000- and 2001-built aircraft, at 16-17 years old. The older aircraft can probably be operated for at least seven years until ageing maintenance tasks are required, and up to 10 years; and 16-17 year old aircraft operated for another 14 years.

A330-300s are more likely to be sought for conversion to freighter than younger -200s. Clearly the oldest -300s will have the lowest values, but will also be low-specification weight aircraft. Values for 1993- to 1995-built A330-300s are put at $9.6-12.5 million by IBA, and are forecast to decline by $1.2-1.3 million per year. Younger aircraft, of 1999-2002 vintage are estimated to have values of $24-32 million.

A330-200s are younger, so their values are still relatively high. The earliest built 1998-2001 aircraft have estimated values of $19.1-25.8 million, which will decline at a rate of $0.40-1.8 million per year.

Total build costs

The largest elements of total build costs are aircraft acquisition, and freighter conversion.

A total of $3.5 million or more for all elements of maintenance except engine-related items can be required. There will be a trade in aircraft acquisition cost, however, and all elements the aircraft's maintenance status. The aircraft values used assume engines to be on a half-life condition, in which case no major maintenance, swap of an engine or major component maintenance will be required. If it is required, the cost should be reflected in a commensurate reduction in aircraft purchase price.

A 1994-1996 vintage 767-300ER will have an average value of $12 million. A heavy check will incur a cost of $1.9 million, but there will be a reduction is purchase price of at least some of this amount.

With conversion to freighter, total build cost for the aircraft will be about $24 million.

A younger, 2001-vintage aircraft with a value of $19.5 million, and which is assumed to need a similar level of airframe, component and avionic maintenance and upgrades, will have a total build cost of $31-32 million *(see table, page 82).*

A 1995-1998 A330-300 will have a low value of $11.5 million, or less if market demand is weak. Total build costs with conversion included will be about $27-28 million *(see table, page 82).* This aircraft will be in the group with limited MZFW, and so have a payload characteristics that make it suitable for express package operations.

A 1998-2001 A330-200 with a value of about $21.0 million will have a total build cost of $40 million *(see table, page 82).* This aircraft will have a small limitation on MZFW and therefore structural payload of a up to four or five tonnes.

What can be appreciated is that engines can be leased out for up to $4,000 per day for three to four months, and thus provide funds to offset some of the cost.

A330-200s built in 2004, which can have the highest possible MZFW, have market values of $33-34 million. This would have a total build cost of about $50 million.

These build costs have to be considered against likely market lease rates for converted freighters of the same vintage. It is possible for a 767-300BDSF to command lease rentals of $250,000-300,000 in the current market, in particular when demand has improved over the past two years.

Lease rentals for older-generation A330-200P2Fs are $425,000-475,000 per month, and up to $575,000 per month for A330-300P2Fs. - *CHW* AC