The majority of the 543 large widebody freighter aircraft are forecast to be retired over the next 20 years. Freight traffic growth has also continued at a steady pace, and so up to 700 aircraft are forecast to be required. The options currently available to airlines are explored.

The market for large widebody freighters

The fleet of large freighters has grown by about 100 aircraft or 22% to 543 over the past 10 years, an average increase of 10 units per year. Another 14 aircraft are being reactivated from storage and going back into service, taking the fleet to 557. The fleet has grown consistently despite the global economic downturn that started in 2008. Moreover, the industry had one of its highest ever rates of traffic growth in 2017, at more than 9%. This brings into focus the market for large freighters serving intercontinental routes, which depends on two main factors: fleet profile and traffic growth prospects.

The largest freighter available is the 747-8F, with a gross structural payload of 292,400lbs, while the MD-11F has a gross structural payload of 209,800lbs. The two main types in between are the 747-400 and the 777-200LRF. The basic weight specifications of the four main types are summarised *(see table, this page)*.

Not all these four main types are now available to freight carriers to replace older aircraft or provide additional capacity for growth or fleet replacement. The MD-11F and 747-400F are no longer in production. Also, with the exception of two aircraft in 2017, the two 747-400 passenger-to-freighter (P-to-F) programmes have not been active since 2012. Bedek Aviation has said, however, that it will still convert 747-400s with its -400BDSF programme if there is demand.

This leaves just the factory-built 747-8F and 777-200F available to airlines, and the possibility of 777-200ER and 777-300ER P-to-F programmes coming available at some point in the future.

Main issues

The main issues that determine the market for large freighters are the profile of the current fleet, and the prospects for global freight traffic growth.

A detailed view of the fleet profile gives information relating to the size, age and quantity over the past 10 years for each type. Further analysis suggests how many aircraft are likely to be stored, reactivated from storage, retired or delivered over the next few years in the case of each of the four main types.

Traffic growth

Freight traffic growth can be estimated, but there are a large number of variables that determine how much traffic will actually be carried by large dedicated freighters, including: the portion carried as belly freight in passenger aircraft; improvements in logistics; and other alternatives to dedicated freighters.

It is expected that dedicated freighters will carry more than half of air cargo traffic. E-commerce has been growing at a high rate of 20% per year for the past five years, and will generate a fourth category of freight operator in the future.

The overall rate of global freight traffic growth was lower than historical levels pre-2008. Air freight traffic grew at an unprecedented rate in 2017, partly making up for an extended period of slow growth. The historic levels of 4.5% growth per year are expected to return.

The global forecast is growth of 4.2% per year for the next 20 years. Clearly this assumes no limitations being placed on industry development. This is equal to total freight volumes more than doubling over the period to 2037. The transpacific market is forecast to have the highest annual rate of 4.7%, while the mature transatlantic will be at 2.5%. Europe-Asia Pacific is expected to be close to the global average. In line with this growth, the large freighter fleet is forecast to grow from its current size of 540-550 aircraft to 830 in 2037. This will be a net increase of 280 aircraft for growth, equal to an average annual net increase in the fleet of 12-13 units. A large portion of the current fleet will also have to be replaced.

The current large freighter fleet mainly comprises three- and four-engined aircraft. Most MD-11Fs and 747 Classics and -400s are expected to retire over the next 20 years, and to be replaced with twin-engined aircraft.

Current fleet

There are 543 aircraft in this size category in active service, and another 14 being reactivated. This is split between 81 of the largest 747-8Fs, 211 747 Classics and -400s, 141 777-200LRFs, and 124 MD-11Fs.

The total number of large freighters in 2000 comprised 291 units: 217 747s and 74 MD-11s. The fleet peaked at 482 aircraft in 2007, and then dipped to 443 in 2009 following the global financial crash of 2007/08. The fleet has steadily climbed since 2013 from 498 aircraft to 543, an average increase of nine aircraft per year.

To estimate the probable number of retirements from the current fleet requires an analysis of the categories of freight airlines, and their fleets. The three main categories are: consolidator airlines; cargo divisions of major passenger carriers; and general freight carriers. The definition of the last category is not that clear, since some airlines in this group perform sub-contracted services for a portion of their operation with these large aircraft for the main consolidator carriers: FedEx, UPS and DHL. Moreover, some general freight airlines are also performing a greater portion of their services for e-commerce operations. E-commerce now has the highest annual growth rate, and may soon become a fourth category of freight operation with airlines or separate fleets dedicated for this role.

Of the 543 aircraft, 164 are operated

LARGE FREIGHTER WEIGHT SPECIFICATION & PAYLOAD CHARACTERISTICS

Aircraft type	747-8F	747-400BCF /-400BDSF	777-200LRF	MD-11F
Factory-built or converted	Factory	Converted	Factory	Factory & converted
MTOW - lbs	987,000	870,000	766,800	630,500
MZFW - lbs	727,000	610,000	547,000	461,300
OEW - lbs	434,600	360,640	318,300	251,500
Gross structural payload - lbs	292,400	249,360	228,700	209,800
Tare weight of pallets - lbs	17,560	15,295	11,165	10,988
Net structural payload - lbs	274,840	234,065	217,535	198,812
Freight volume - cu ft	30,312	27,012	22,371	20,378
Maximum packing density - lbs per cu ft	9.07	8.66	9.72	9.75
Volumetric payload @ 8.0lbs/cu ft	242,496	219,736	178,968	163,024

by consolidator carriers, mainly FedEx and UPS; 198 by cargo and freight divisions of major passenger airlines, and 181 by what may generally be regarded as general freight carriers *(see table, this page)*.

The 164 aircraft operated by consolidator and express package carriers comprise seven 747-8Fs operated by UPS, 18 747-400s operated by ASL Airlines Belgium and UPS, 45 777Fs operated by Aerologic and FedEx, and 94 MD-11Fs operated by FedEx and UPS.

747-8F fleet

The production of 747-8Fs began in 2010, and to date there are 81 in active service, with an average of 10 new aircraft delivered per year. There are also 21 aircraft on firm order, and a quantity of letter of intent (LoI) orders.

The 747-8F is split between seven aircraft operated by UPS, 33 operated by freight divisions of passenger carriers, and 41 by general cargo carriers.

The oldest 747-8F is therefore eight years old. Given the eight-year interval for the aircraft's first two heavy or D checks, and subsequent six-year interval, it is possible that operators could retire the 747-8F between the fourth and fifth D checks, after it reaches 25 years of age. Its continued economic viability for this length of time is not certain, however. An average retirement age of 25 years means that about 50 of the current fleet may be retired over the next 20 years.

The seven aircraft operated by UPS were delivered from 2017, and the airline accounts for all 21 aircraft on firm order. All of these are likely to remain in service over the next 20 years.

A large portion of the aircraft operated by the other two groups of airlines is likely to be retired in the latter part of the next 20 years, and would leave 31 of the current fleet in operation.

747 Classic & -400 fleet

There are now only nine 747 Classic freighters and 191 747-400Fs in service.

The nine 747 Classics are 27-34 years old, indicating a that small portion of 747s are operated for more than 25 years. All of these aircraft are expected to retire within five to eight years.

The 747-400Fs in service comprise 146 factory-built -400Fs/-400ERFs, 23 Bedek-converted -400BDSFs, and 22 Boeing-converted -400BCFs. These 191 aircraft in the active -400 fleet were built from 1989 to 2009.

In addition, 27 aircraft have been permanently retired and another 23 are in storage. Retired aircraft include a single -400F, and 26 converted aircraft. Most of the retired converted aircraft, 22 units, are -400BCFs converted by Boeing; and four are -400BDSFs, converted by Bedek Aviation. The average age of retirement for these converted aircraft was 23 years old. A large portion of these was retired at 20-22 years old in 2013-2015. This followed a period of a few years when cargo traffic had stopped growing. However, another group of 12 aircraft were retired at a later age of 26-28 years.

There are also 23 aircraft in storage, 11 of which are known to be going through the reactivation process and back into operation. Many of these have been in storage for a relatively short period.

Of the 202 aircraft in active service or that are in storage but being reactivated, most are likely to be retired over the next 20 years. The profile of the 747 Classic fleet indicates, however, that a small portion of the fleet will still be in service in 2037. The youngest aircraft are now nine years old, so they will be 28-29 years old in 2037.

Some estimates expect 20-25 of the 202 aircraft currently in operation to still be active by 2037. This indicates that 175-180 aircraft will have been retired, and will need to be replaced by 2037.

777-200LRF fleet

The fleet of 141 777-200LRFs has been in operation since 2008, and deliveries have averaged 14 per year. There are another 56 aircraft on firm order, with more held under LoIs.

The 141 in-service aircraft are operated mainly by consolidator airlines AeroLogic and FedEx (45 units), and cargo divisions of major passenger airlines (90), including: Air China, China Southern, China Airlines, Emirates, Etihad, Korean Air, Lufthansa Cargo and Qatar Airways. A small number are also operated by general freight carrier Southern Air.

Given that the oldest aircraft in the 777-200F fleet are 10 years old, about half of these may retire over the next 20 years. The aircraft's twin-engine configuration may, however, prove to be a factor that extends its life beyond the traditional 25-year average for three- and four-engined freighters.

Assuming an average retirement age of 25 years old, about 70 aircraft in the current fleet will retire over the next 20 years.

MD-11F fleet

Of an original total of 180 MD-11Fs built from 1990 to 2001, 121 are in service, 44 have been retired and seven are in storage. The average age at retirement is 21, although some have been retired as young as 16 years old. Most were retired in 2013-2016.

Active MD-11s are 17-28 years old. Even though three aircraft are being reactivated for service, all 124 are forecast to be retired by 2037.

Total aircraft market

Aircraft retirements from the current fleet of 557 over the next 20 years are forecast to be about 434 units *(see table, page xx)*: 124 MD-11Fs, nine 747 Classic freighters, 180 747-400 freighters, and 50 747-8Fs. These will retire at an average rate of 22 aircraft per year.

In addition to these retirements, increased traffic will require 280 more aircraft for fleet growth. The total number of aircraft required will thus be

There are 81 747-8Fs in active service, and another 21 aircraft on order. Without further orders being placed, production of the largest freighter will cease within eight years.

about 714 units over the next 20 years. This is an average of 36 aircraft per year.

This raises the issue of what types will satisfy this demand in the 210,000-293,000lbs gross payload category.

As described, 56 777-200LRFs and 21 747-8Fs are on firm order with a small number of airlines.

Of the 56 777-200LRFs, 25 are for consolidator carriers: 10 for DHL; one final delivery for AeroLogic; and 14 for FedEx. The 14 aircraft for FedEx are in addition to the 35 it has had in service since 2008. The DHL aircraft are for its international operations serving the US. These are operated by Polar Air Cargo, Aerologic, and DHL Air and EAT. The 777-200LRFs will be operated by these three carriers painted with DHL's colours.

A further 28 firm orders for 777-200LRFs are for the cargo divisions of nine major passenger airlines, including: All Nippon Airways, Ethiopian Airlines, LATAM Cargo Brazil, Lufthansa Cargo, Qatar Airways and Hong Kong Airlines. There are also three orders for an unannounced customer.

33 LoIs are held: 29 for Air Bridge Cargo/Volga Dnepr and four for DHL. Of the 21 firm orders for 747-8Fs, 20 are held by UPS, and one by an unannounced customer. The 20 aircraft for UPS are in addition to those it has been operating since 2017.

Air Bridge Cargo/Volga Dnepr also has 15 firm orders for 747-8Fs, with UPS holding 20 LoIs for the type.

The demand for each of the four main types currently operated does not equally apply according to the three airline categories. There are large differences in use of each of these four or five types according to the market they serve. The major consolidator airlines are more likely to acquire all-new aircraft in this size category, given the high rates of utilisation and relatively high yields that can be generated.

In the meantime, the general freight carriers are more likely to convert used passenger-configured aircraft. The cargo divisions of major passenger carriers have also operated some converted aircraft, such as 747s and MD-11s that they previously operated as passenger aircraft. These airlines have then added to their fleets with factory-built freighters.

Based on the current distribution of the large freighter aircraft fleet between the three major categories of cargo airline, the consolidators will require 214 new aircraft over the next 20 years, the freight divisions of passenger carriers will require 264, and general freight carriers will account for the other 236.

The consolidator carriers already have 45 aircraft on firm order, suggesting that they will need to acquire another 170 aircraft over the next 20 years.

Passenger airline cargo divisions have 31 orders for 777-200LRFs, and so will need to acquire another 233 aircraft over the next 20 years.

General freight carriers have no outstanding orders for freighters with a payload in excess of 210,000lbs, and so will have to acquire about 236 units over the next 20 years. The definition of general freight airline is less clear. This group includes airlines such as Cargolux, Mattinair, Polar Air Cargo, Atlas Air, Kalitta Air and Western Global, and a number of airlines that operate as sub-contractors for several airlines.

Options for acquisition

Freight carriers have four main options for acquiring aircraft. Each of these will be considered.

The first of these is to reactivate freighter aircraft in storage and return them to active service. This is a short-term solution that will only supply a small number of aircraft, however.

The second option is the conversion to freighter of passenger-configured 747-400s. This is now only possible with the Bedek Aviation P-to-F modification, with the last aircraft being converted with the Boeing modification in mid-2012. This is also only likely to provide a small number of aircraft.

The third option is to order new factory-built 747-8Fs and 777-200LRFs; which are the only large freighter aircraft types currently being manufactured.

The fourth option is to wait for a P-to-F modification programme to be developed for the 777-200ER and -300ER. The main candidates for developing such programmes are Boeing and Bedek Aviation.

Not all freight airlines would consider all four options, and the options contemplated would partly depend on the category of airline.

Each of these four options is considered in detail.

There is also the possibility of a fifth option coming available in the future: freighter variants of the A350-1000 and 777-8X/-9X. It is assumed here that freighter versions of the A350-1000 and 777-9X would have gross structural payloads close to the 747-400F, while the 777-200LRF's payload would be about 42,000lbs less.

Reactivate 747-400F & MD-11F

The potential of reactivating parked 747-400Fs and MD-11Fs and returning them to service first requires an analysis of parked aircraft. There are 23 parked 747-400Fs and 11 parked MD-11Fs.

The 23 parked 747-400s comprise: four 747-400ERFs that are 11-16 years old, 11 747-400Fs that are 10-22 years old, four 747-400BDSFs that are 21-27 years old, and four -400BCFs that are 24-28 years old.

The four -400ERFs are all relatively young aircraft.

Three aircraft are 10 and 11 years old; two of these were operated by SF Airlines of China and one by Cargo Air Lines of Israel. These three have been parked for almost seven years, but are being reactivated and returned to active service over the next few months. Two will go back into operation with SF Airlines, and one will go into operation with Air Cargo Europe, based in Liege, Belgium.

One 747-400ERF (serial number 33096) has only been in storage since April 2017, and was previously operated by Sky Lease Cargo. This aircraft has CF6-80C2B5F engines, and has accumulated 47,900FH and 6,190 flight cycles (FC). It is therefore potentially available for reactivation.

Of the 11 parked 747-400Fs, six are being reactivated and returned to active service: one aircraft previously operated by EVA Air going into service with Atlas Air; two returning to service with Nippon Cargo Airlines after briefly being parked; one going back into service with Kalitta Air since being parked in February 2017; one going back into service for Uni-top Airlines of China; and an ex-Malaysia Airlines aircraft going into service with Silk Way Airlines of Azerbaijan.

The other five parked -400Fs are potentially available for reactivation. These include three CF6-80C2B1F-powered aircraft that were operated by China Airlines and have been parked since the first half of 2012. These were built in 2000 and 2001. They have accumulated 48,000-53,000FH and 7,540-9,130FC.

A fourth aircraft is equipped with PW4056 engines and was built in 1994. It is the oldest of stored -400Fs, and has accumulated 75,800FH and 13,200FC. The aircraft is the highest-time -400F available, but has been in storage only since June 2018. It was originally operated by Singapore Airlines Cargo up to 2010, and then by El Al Cargo.

The fifth PW4056-powered aircraft is 20 years old, and has accumulated 40,400FH and 6,530FC. It was operated by Korean Air, until being parked in January 2017. This is the lowest-time 747-400F available.

Of the four -400BDSFs parked, two are potentially available for reactivation. One aircraft is equipped with CF6-80C2B1F engines, and is the highest-time parked aircraft, with 119,000FH. It was previously operated by Asiana Airlines, and been parked since May 2017.

The other -400BDSF that could be reactivated is a PW4056-equipped aircraft that has been parked since May 2017. It was previously operated by Southern Air Transport and Air Atlanta Icelandic. It has accumulated 80,700FH and 10,800FC.

Two -400BDSFs are being reactivated and returned to service with Suparna Airlines and Saudia.

The four parked -400BCFs are 21-28 years old, so they are less likely reactivation candidates.

There are 11 parked MD-11Fs. These can be divided into two or groups.

The first group of three aircraft is due to be reactivated and returned to service with Western Global Airlines. These are managed by NEFF Air LLC, and were operated by Western Global, and then parked in 2015 and 2016. They are all fitted with CF6-80C2D1F engines, and were built in 1994, 1999 and 2000. They will be returning to service with Western Global, based in Sarasota, Florida. It operates two 747-400BCFs and 10 MD-11Fs. The three parked aircraft will thus increase its operating fleet to 13.

The second group is eight aircraft that are being retired. Seven have PW4460/62 engines and were operated by FedEx, while the other was operated by Saudia, and has CF6-80C2D1F engines.

There are therefore no additional aircraft available for reactivation.

The issue of freighter aircraft coming off lease extends to those that may have heavy airframe checks and maintenance visits coming due, or have larger engine maintenance requirements looming such as replacing life limited parts (LLPs) or heavier shop visit workscopes. Moreover, aircraft may have ageing maintenance

To date, 81 747-400s have been converted to freighter. Most conversions were completed by 2012, but two more were modified in 2017. Bedek Aviation has said its concversion programme is still available if required. About 175-180 747 freighters are expected to have retired by 2037.

requirements due to an accumulated large number of FH and FC or just old calendar age. All these issues may make reactivating parked aircraft uneconomic.

Convert 747-400

The option of converting a passenger-configured 747-400 may still be considered by some airlines. This is only likely where there are no 747-400Fs coming off lease or due to come off lease, or there are no suitable parked aircraft to be reactivated. Moreover, converting a 747-400 only provides a solution for the next few years, since it has the disadvantage of a relatively high fuel burn in relation to its gross payload, in comparison to the smaller twin-engined 777-200LRF.

Acquiring a 747-400 and converting it to freighter has, however, an overall lower capital cost and a lower lease rental compared to a 747-8F. The lease rental for a 747-8F is estimated at the region of $750,000 per month for the oldest aircraft, and up to about $1.4 million per month for new deliveries. The lease rental for a converted 747-400 will clearly need to be less than the lowest market rate for a 747-8F, but high enough to justify the total investment of aircraft acquisition and conversion to freighter.

This has to be considered in relation to the two gross structural payloads of the aircraft, which are 292,000lbs and 249,000lbs *(see table, page 62)*. The 747-8F's payload is thus 17% higher than the -400BCF/-400BDSF.

To date, 81 aircraft have been converted under the Boeing and Bedek Aviation programmes. Bedek Aviation converted 29 aircraft from April 2006 to August 2012, and two more aircraft in 2017. Of the 31 conversions, 12 were combis and 19 were passenger aircraft.

Boeing converted 50 aircraft from June 2005 to July 2012. Of these, 11 were combis and 39 were passenger-configured aircraft.

The continuing demand for large freighters may increase the likelihood of more aircraft being converted. Conversion will cost in the region of $25 million for a passenger-configured aircraft and about $10 million less for a Combi. Acquisition cost of used 747-400s will be directly related to the value and maintenance condition of their engines. This might be an average value of $7-9 million for an aircraft will half-life engines. Taking total cost into consideration, lease rental would have to be up to $450,000 per month for the converted aircraft. This may be hard to achieve in the current market.

Considering an aircraft for conversion to full freighter requires an analysis of the remaining active and parked passenger- and combi-configured fleet, on the basis that most retired aircraft will no longer be acceptable conversion candidates.

The most likely aircraft to be considered for conversion are those fitted with CF6-80C2 and PW4056/60 engines. Only four out of 81 aircraft converted are RB211-524G/H-powered.

There are 144 CF6- and PW4056-powered passenger and combi aircraft in active service and parked or in storage. These are divided between 80 aircraft with CF6-80C2 engines and 64 with PW4056 engines.

The CF6-powered aircraft can be sub-divided into four groups.

First, there are eight combi-configured aircraft operated by KLM. These are the most desirable candidates for freight conversion because their rear cargo door will save on the cost of conversion. Combi aircraft will only need to remove the passenger interior and strengthen the floor in the passenger cabin.

These eight aircraft are 16-28 years old, and have accumulated 83,000-114,000FH and 9,600-16,700FC. They have never been parked, but are all scheduled to be parked in 2020 and 2021 as they come off lease.

The second group is 62 active passenger-configured aircraft. The largest fleets are 13 aircraft operated by Lufthansa, nine operated by Thai International, eight operated by Rossiya, and eight operated by Virgin Atlantic.

Many of the 62 aircraft are due to be retired over the next few years as these airlines phase out the last of their 747s.

Flynas has two aircraft that are due to come off lease at the end of 2018 and 2019. Qantas's last CF6-80C2-powered -400 is due to be parked in 2020. Four of five aircraft operated by Rossiya Airlines, which were previously operated by Japan Airlines and then Transaero, are due to come off lease in 2023 and 2024. Royal Air Maroc's single aircraft is due to come off lease in September 2018. Saudia has four aircraft, at least one of which is due to come off lease in October 2018.

The third group is six CF6-80C2B5F-powered 747-400ERs operated by Qantas. Qantas is known to be phasing out all of its 747s, and these six aircraft are the last in its fleet. These are all scheduled to be parked in June 2020.

The fourth group is four aircraft that are parked. This includes one Combi that was operated by wet lease operator Eaglexpress Air Charter of Malaysia, which has suspended operations. The aircraft was parked in December 2016, and may be an attractive freight conversion candidate.

The 64 PW4056-powered aircraft comprise 32 active and 32 stored passenger-configured units.

The fleet of 32 active aircraft includes fleets operated by Air India (4), El Al (4), Korean Air (4), Air China (3), Corsair (3), Saudia (3) and Garuda Indonesia (2).

El Al's four aircraft are due to be parked in 2019. The two Garuda aircraft were previously operated by Malaysian Airlines, and their leases expire in September 2018.

The current MD-11F fleet is 121 aircraft, out of 180 built. While a small number are being reactivated for service, all aircraft are forecast to be retired by 2037.

Lion Air of Indonesia operated two aircraft, one of which was retired in December 2017. The remaining aircraft is due to be retired in late 2018.

Royal Air Maroc has one PW4056-equipped aircraft, which has come off lease before the CF6-80C2-equipped aircraft is phased out.

The 32 PW4056-equipped aircraft in storage include many that are due to be permanently retired, including 22 aircraft managed or previously operated by United Airlines (9), Delta Airlines (5), AAR (2), Jet Midwest (2), Mahan Air (2), Air China (1) and VEB Leasing (1).

Two aircraft are known to be due for reactivation and entry back into service. These include one operated by Kabo Air and one by Mahan Air.

The on-going maintenance costs of these aircraft can be minimised. First, aircraft can be operated up to when their heavy airframe checks are due, and then retired. This saves the need for heavy check reserves for the last few years of operation. Large savings can be made in engine maintenance through the use of used serviceable material in shop visits, and time-continued life limited parts and modules *(see The economics of using repaired and serviceable parts in engine maintenance, page 43)*.

New 747-8F & 777F

Acquiring new 747-8Fs and 777-200LRFs is only economically viable for an airline that can expect to achieve high rates of utilisation. These are required to minimise the finance cost per ton-mile, and amortise the high monthly lease rentals arising from the aircraft's high list prices.

The 747-8F and 777-200LRF have list prices in 2018 of $404 million and $320 million. With typical purchase discounts, these translate into monthly lease rates of $1.4 million per month for newly delivered 747-8Fs, and $1.2 million per month for newly delivered 777-200LRFs.

In the case of the 747-8F, about half the aircraft in service are operated by consolidators and cargo divisions of major passenger airlines. The other half, 41 aircraft, are operated by general freight carriers, which indicates a potentially wider market appeal than the 777F. Most of the 41 747-8Fs are operated by just five carriers, however: AirBridgeCargo, Atlas Air, Cargolux, Polar Air Cargo, and Silk Way Airlines. These airlines all have regular contracts and are also able to achieve high rates of utilisation.

Both types have been introduced and had deliveries over a sustained period of unprecedented record low interest rates. This has favoured new aircraft, since lease rate factors and monthly lease rentals have been kept low for an extended period. Nevertheless, the finance charges are much higher than those for older and converted freighter aircraft, and can only be justified either by a high-yield freighter operation, which is usually small package and consolidator operations, or operations that result in high rates of aircraft utilisation, or a combination of these two factors.

AeroLogic operates mainly for DHL, and achieves annual rates of utilisation of 4,800-5,000 flight hours (FH) with its 777-200LRFs. Other examples of high rates of annual utilisation for the 777F are Qatar Airways (5,700FH), Ethiopian Airlines (5,500FH), Lufthansa Cargo (5,200FH) and Emirates (4,800FH).

The 747-8F is the largest freighter type available in the market, with a gross structural payload of about 292,000lbs *(see table, page xx)*. While there are 22 outstanding orders for the 747-8F, and 15 LoIs held by Volga Dnepr, production of the 747-8F will stop unless more orders are placed. Besides existing operators, there are few prospective candidates to place further orders that would keep production going. It is possible that a small number of orders could be placed by existing operators of 747-400Fs, such as SIA, Cathay Pacific and Korean Air.

The 777-200LRF is based on the 777-200 series airframe, and has the same fuel capacity as the passenger-configured -200LR variant. It has a gross structural payload of 225,000-229,000lbs, making it the second smallest to the MD-11F *(see table, page xx)*. There are 148 aircraft in service, with deliveries starting from 2009, and having averaged about nine per year for the past three years.

The 777F faces a similar issue to the 747-8F, that is the possibility of few further orders being placed by airlines, and so production potentially ceasing.

777 P-to-F conversion

While a P-to-F conversion programme does not yet formally exist for the 777, several have been looked at. As with the 747, Boeing and Bedek Aviation division of IAI have made studies on a freighter modification for the 777. Any progress has been delayed by the downturn in freight traffic and the consequences for the large widebody freighter fleet.

There is a fundamental technical issue facing any P-to-F programme for the 777 family. This is the use of 74 and 89 carbon fibre reinforced plastic (CFRP) floor beams on the -200 and -300 passenger variants. In contrast, stronger Aluminium was used for floor beams in the 777-200LRF. CFRP was used in the passenger aircraft to provide strength while lowering the aircraft's operating empty weight (OEW). CFRP is also resistant to corrosion.

These floor beams limit the floor load, and therefore the gross weight of pallets and ULDs and the resulting freighter aircraft's overall gross payload, if they are not replaced during the conversion process. These CFRP floor beams can be replaced with aluminium beams, but this would increase the downtime and cost of

There are 141 777-200LRFs in service, and another 56 aircraft on firm order. More orders are expected since up to 700 new freighters in the large aircraft category are likely to be required over the next 20 years.

the freighter modification. If a P-to-F conversion were to include this change in the floor beams to add strength and payload capability, its list price is estimated to be $25-30 million.

The other main issues of a P-to-F modification include the need to substantially increase the aircraft's maximum zero fuel weight (MZFW) and reduce its OEW to achieve a sufficiently high gross structural payload. The factory-built 777-200LRF is based on the fuselage of the 777-200LR passenger variant.

There are large differences in weights between the 777-200LR and the -200LRF, however. The -200LRF has an MZFW of 547,000lbs, an OEW of 318,300lbs and a gross structural payload of 228,700lbs *(see table, page 62)*. The -200LR's MZFW is 86,000lbs lower than the -200LRF's MZFW, and is the main reason the passenger variant has a 87,700lbs lower gross structural freighter variant with the same fuselage barrel. The 777-200ER has an even bigger difference in MZFW compared to the -200LRF at 106,000lbs.

Boeing studied a conversion programme for the 777-200 and -200ER is 2008, resulting in the 777-200BCF.

Clearly the -200ER and -200LR would both need large increases in MZFW during the conversion process to acquire a gross structural payload that is not significantly lower than the factory-built -200LRF's payload of 228,700lbs.

The 777-200 and -200ER passenger variants have lower OEWs than the -200LRF, however. The -200 and -200ER would see a reduction in OEW of about 17,500lbs during conversion, which partly offsets the need for large increases in MZFW.

The projected MZFW of the 777-200BCF was 477,000lbs and the OEW 287,000lbs, and so provides a gross structural payload of 188,500lbs. The aircraft would therefore have a payload 40,200lbs lower than the factory-built 777-200LRF, and 21,300lbs lower than the MD-11F.

Bedek Aviation was considering developing possible STCs for a P-to-F modification for the 777-200ER and the -300ER. The programme may be launched in 2019; there are illustrative design weights for both variants. A P-to-F modification is more likely for the 777-300ER because of its ability to provide a reasonable gross structural payload.

Preliminary figures are for the converted -300ER (-300ERBDSF) to have an MZFW of 569,000lbs (having been increased from 524,000lbs in the passenger variant); and an OEW of 343,000lbs, having been reduced from about 370,000lbs on the passenger aircraft. This will generate a gross structural payload of 226,000lbs. This is just 2,800lbs less than the 777-200LRF.

The 777-300ERBDSF will also have a gross payload that is 23,000lbs less than the 747-400BDSF, 49,000lbs less than the highest payload variant of the 747-400F, and 66,000lbs less than the 747-8F.

The 777-300ERBDSF, or converted -300ER freighter, will have about a 25% higher volume than the -200LRF because of the -300ER's longer fuselage. The projected 777-300ERBDSF would have a containerised freight volume of 28,139 cubic feet, and the containers would have a tare weight of about 13,500lbs. The aircraft would thus have a net structural payload of 212,500lbs, and a maximum packing density of 7.55lbs per cubic foot.

One possible factor that may delay or even halt Bedek developing a P-to-F programme for the 777-300ER is that Boeing is now examining the possibility of developing a P-to-F programme for the same aircraft. The most interesting issue with such a modification will be what Boeing does in respect of the issue relating to the floor beams.

777-300ERF economics

There is a large pool of potential feedstock for conversion. To date, 790 aircraft passenger-configured 777-300ERs have been delivered, all equipped with GE90-115 engines. The aircraft went into service in 2004, and is still being manufactured. The larger fleets of the oldest aircraft are being operated by: Air France and Japan Airlines (up to 15 years); All Nippon Airways (up to 14 years); Emirates and Etihad (up to 13 years); Air Canada, EVA Air, and Singapore Airlines (up to 12 years); and Air India (up to 11 years).

A main issue to consider will clearly be on-ramp costs of providing a serviceable freighter, the likely monthly lease rate the aircraft can command while remaining competitive, and the on-going operating costs.

As described, the conversion has a projected cost of $25-30 million. A manual cargo loading system (CLS) would have a price of about $1.1 million, and a powered system a price of $1.9 million. The total conversion cost could get close to $35 million.

Monthly lease rentals of converted aircraft clearly have to be less than the lower rentals of $700,000-750,000 per month for the oldest 777-200LRFs and 747-8Fs. Given typical lease rate factors, it limits the acquisition cost of used 777-300ERs to $25-30 million. This may not be inconceivable, given that there are almost 800 in service and that by the early or mid 2020s are large number of aircraft will be returned from leases. Values will drop until there is a market.

While all current types have been considered, there is also the possibility of future freighter types. One particular possibility is a freighter version of the 777-9X. This is likely about 10 years after the passenger variant has entered service. The A350-900 is another possibility. AC