Fleets of MD-11Fs and 747Fs are ageing, and the types have high cash operating costs. Andy Coupland, CEO of Aircraft Commerce Consulting examines the options for replacing these older types, and analyses the possible characteristics of a 777 P2F programme.

Assessing suitable replacements for the MD-11F & 747F

The medium- and long-term outlook for large widebody freighters is uncertain. The volatility of demand for air cargo in the aftermath of the economic crisis of 2008 has negatively impacted the risk profile of less fuel-efficient, large widebody freighters in the eyes of some operators and owners. This article looks at the possibility that passenger-to-freighter (P2F) conversions may emerge that offer sufficiently attractive operating characteristics to revitalise the industry appetite for such large widebody freighters.

Large widebody freighter fleet

The large widebody freighter category is generally defined as those aircraft that offer a gross structural payload in excess of 80 tonnes (176,374lbs). Excluding the handful of DC-10-30Fs, which barely reach the large widebody freighter payload threshold, and any remaining 747-200Fs, the current large widebody freighter fleet numbers 531 operational aircraft and 52 (9% of the fleet) in storage. Some 30 aircraft have been parted out since 2012.

In age terms, there is a clear polarisation between the two large widebody freighter types which remain in production, and the out-of-production legacy freighters. The 747-8F and the 777-200F fleets, which account for 41.2% of the in-service fleet, have an average age of only 4.8 years. The various 747-400 freighters, both factory-built and converted, together with the MD-11F, which comprise the remaining 58.8% of the fleet, have an average age of more than 20 years. The -400BCF, -400BDSF and MD-11F subset of this fleet, accounting for more than 30% of the combined total, have an average age of over 25 years. While jet freighter aircraft can enjoy protracted operational lives, and Boeing data suggests the average retirement age across the whole widebody freighter fleet is 31 years, the three oldest large widebody freighter fleets will reach this average retirement age within seven years.

GLOBAL LARGE WIDEBODY FREIGHTER FLEET - IN SERVICE & STORAGE

Aircraft type	In Service	Stored	Total	Average age	Age spread	% of fleet	On order	% of backlog
747-8F	79	0	79	4.2	8.0	14.9	25	45.5
777F	140	0	140	5.2	9.2	26.4	30	54.5
747-400ERF	35	5	40	11.8	7.1	6.6		
747-400F	110	10	120	16.2	15.5	20.7		
747-400BCF	20	12	32	26.5	9.3	3.8		
747-400BDSF	26	5	31	24.2	8.3	4.9		
MD-11F	121	20	141	23.8	10.2	22.8		
Total	531	52	583				55	

Conversely, some stored aircraft have been returned to service, and others may yet follow. Although over the past 20 years, 90% of stored aircraft returning to active service have done so within two years of being parked, stored freighters tend to have a higher re-activation rate at older ages. This reflects not only the preponderance of older aircraft in the freighter fleet, but also the greater volatility of the air cargo market, which drives a high level of short-term capacity reductions via the temporary parking of freighters.

The total number of large widebody freighters in service has varied little since 2008 (when the global fleet numbered 547 units). This is because air freight tonne kilometres (FTKs) grew by an average of only 2% per year from 2005 to 2015, leading to caution on the part of freighter operators, financiers and manufacturers. For the past nine years, large widebody freighters have generally only been added to the fleets as older examples have been retired. Carriers like Cargolux have, however, taken advantage of the availability of high-quality used 747-400Fs to increase the size of their fleets to exploit emerging opportunities.

Operator base

The largest 747-8F operators are Cargolux (14), Cathay Pacific (14) and Atlas Air (10), although UPS will operate a fleet of 28 once the entire order has been completed. The total fleet is spread across 10 operators in total.

Significant operators of the 777-200F are FedEx (34 in service, six on order), Qatar Airways (13 in service, three on order) and Emirates (13 in service). There are substantial fleets within the current operator base of 17 airlines.

The 312 active units of the legacy 747 and MD-11 freighter fleets are spread

If the payload of a converted 777-300ER freighter can be sufficiently enhanced, the type could become a cornerstone of the long-haul express package operators.

across 39 operators. Of the global integrators, FedEx operates 58 MD-11Fs (with eight in storage), while UPS operates a mix of 50 747-400Fs and MD-11Fs. However, even these totals understate the significance of the large widebody freighter fleet to the operation of the giant integrators. DHL, for example, makes extensive use of the 10-strong 777-200F fleet of Aerologic, a joint venture between DHL Express and Lufthansa Cargo. DHL and other integrators also extensively use the large freighter capacity of both legacy and ACMI freight providers. The proportion of the large widebody fleet that is dedicated to the carriage of express cargo is therefore hard to specify, although estimates of 35-40% appear realistic.

Outlook for large freighters

The International Air Transport Association (IATA) reported that, in 2017, air cargo had its strongest performance since the rebound from the global financial crisis in 2010. Year-on-year demand grew by 9.0%, a rate that outpaced the industry-wide growth in both cargo capacity and in passenger demand. Unusually, this increase was accompanied by improvements in load factors and yields, and therefore revenues. The outlook for air freight in 2018 is undeniably positive. A further 4.5% increase for 2018 is forecast, consumer confidence is buoyant, and the rise of international e-commerce and the transport of time- and temperature-sensitive goods, such as pharmaceuticals, appears to be inexorable.

Yet this renewed confidence may have come too late to avoid a fundamental challenge to large widebody freighter users and operators, for reasons that will be detailed below.

Impact of growth

An increase in demand for long-haul air cargo capacity does not, of course, automatically translate into an increase in demand for long-haul freighters.

The belly-hold volumes of the emerging generation of large widebody passenger aircraft, 8,131 cubic feet (cu ft) in the case of the 777-9, offer capacity equivalent to that of a narrowbody jet freighter, even after the requirements of passenger baggage have been met. In a 349-seat mixed-class configuration, the 777-9 would still have 6,750 cu ft of volume available for cargo, which equates to more than 54,000lbs (24.5 tonnes) of freight packed at 8.0lbs cu ft.

Yet while belly traffic is forecast to grow as a percentage of total air freight from the current level of 52% to 61% by 2036 (Airbus 'GMF'), Boeing's 'World Air Cargo Forecast' predicts a global fleet of about 1,950 freighter aircraft. Of these, about 730 new-build freighters will be needed by 2036: 55% mid-size and 45% large. The dedicated freighter fleet is therefore forecast to increase by 50% over the next 20 years, mainly driven by demand in the Asia Pacific region.

There are a number of key reasons for this confidence:

- Over the past five years, only 30% of the lower-hold capacity of new widebodies has served primary cargo airport routes.
- Range restrictions on fully-loaded passenger flights and the limited number of passenger frequencies serving high-demand cargo markets make freighters essential where both long-range and frequent service are required.
- Air freight demand is highly concentrated. About 85% of scheduled large freighter flights operate out of the top 50 cargo airports, including airports across North America, Asia, and Europe. This underscores the need for freighters to serve these markets and airports.
- Integrators, using freighters as an integral component of a door-to-door proprietary transportation network that is tailored to their customers' needs by using unique schedules and specialised aircraft, cannot replicate this business model using only lower-hold capacity.

In addition, freighter services offer unique attributes:

- Certain types of cargo, including outsize items, hazardous materials and some cool-chain goods, cannot be carried in the lower holds of passenger flights.
- Mistakes and disruptions occur in the supply chain, and although this risk has been mitigated by sophisticated software in recent years, the need for expedited shipments remains.
- Freighters are particularly well suited for transporting high-value goods because they provide highly controlled transport, direct routing, reliability, and unique capacity considerations.

An endangered species?

To satisfy the forecast requirement for freighter aircraft to meet the need for replacement and growth, Boeing's view (WACF 2016/2017) is that 'Although large freighters were historically sourced from both the conversion and factory-production channels, in the future we believe that demand in this segment will favour factory-produced aircraft'.

Although the order backlog for the only two active factory-built large widebody freighters (25 units for the 747-8F, equivalent to 31% of the operational fleet of that type; and 30 for the 777-200F, equivalent to 21.4% of the in-service fleet), appears at first sight to be relatively healthy, these orders only equate to 10.4% of the large widebody freighter fleet. They are barely sufficient to replace those units that will be retired during the period over which these new-build deliveries will be built.

Furthermore, it is considered unlikely that further orders will be received (or accepted) by Boeing for the 747-8F, given that no airline orders for the passenger version have been received since 2012.

LARGE WIDEBODY FREIGHTER WEIGHT SPECIFICATIONS

Aircraft type	DC-10-30F	MD-11F	777-200F	777-200ER P2F	777-300ER P2F	747-400BCF
MTOW - lbs	580,000	630,500	766,800	650,000	775,000	870,000
MLW - lbs	436,000	491,500	575,000	507,000	599,000	652,000
MLW/MFW margin - lbs	22,000	30,200	28,000	30,000	30,000	42,000
Margin as % of MZFW	5.3%	6.5%	5.1%	6.3%	5.3%	6.9%
MZFW - lbs	414,000	461,300	547,000	477,000	569,000	610,000
OEW - lbs	236,600	259,260	318,300	287,000	343,000	355,715
GROSS PAYLOAD - lbs	177,400	202,040	228,700	188,500	226,000	254,285
TARE (pallets) - lbs	9,704	10,988	11,165	11,165	13,398	15,295
NET PAYLOAD - lbs	167,696	191,052	217,535	177,335	212,602	238,990
TOTAL VOLUME - FT^3	17,659	20,378	22,371	22,371	28,139	27,012
DENSITY @ NET P/L - lbs/ft^3	9.50	9.38	9.72	7.93	7.56	8.85
DESIGN RANGE - NM	3,168	3,620	4,905	3,925	4,365	4,091

Aircraft type	747-400F	747-400F	747-400ERF	747-400ERF	747-8F	A380-800F
MTOW - lbs	811,000	875,000	811,000	910,000	987,000	1,300,755
MLW - lbs	666,000	652,000	666,000	653,000	763,000	941,394
MLW/MZFW margin - lbs	31,000	42,000	31,000	42,000	36,000	55,117
Margin as % of MZFW	4.9%	6.9%	4.9%	6.9%	5.0%	6.2%
MZFW - lbs	635,000	610,000	635,000	611,000	727,000	886,277
OEW - lbs	360,900	360,900	361,600	361,600	434,600	555,797
GROSS PAYLOAD - lbs	274,100	249,100	273,400	249,400	292,400	330,480
TARE (pallets) - lbs	15,295	15,295	15,295	15,295	17,560	20,118
NET PAYLOAD - lbs	258,805	233,805	258,105	234,105	274,840	310,362
TOTAL VOLUME - FT^3	27,467	27,467	27,467	27,467	30,312	37,870
DENSITY @ NET P/L - lbs/ft^3	9.42	8.51	9.40	8.52	9.07	8.20
DESIGN RANGE - NM	2,825	4,455	2,825	4,980	4,250	5,400

This freighter variant, now the flagship of large widebody freighters, is the sole remaining bearer of the 747 torch. Its demise would deny air cargo operators its outsize nose-loading capability, which is a function of the 747's double-deck configuration. This is unique among low-wing jet freighters, and has played a valuable role in the air cargo sector for almost 50 years. It is unlikely to be replicated by any future design.

How has a situation arisen where only the 777-200F factory-built large widebody freighter is available to meet rising demand? Even this is a member of a production programme which is soon to be superseded by a replacement in the form of the 777-8 and 777-9.

Robert van de Weg, vice president of sales and marketing at Volga-Dnepr Group, whose fleet includes seven 747-400Fs and 11 -8Fs, comments that: "The market is good right now, and has changed completely since 2008-2016. Apart from 2010, which was a correction year for 2009, these nine years of crisis blew a hole in the freighter order stream. I can easily foresee a future shortage of freighters because of ageing aircraft and lack of investment over the past decade."

Freighter attributes

In addition to class-leading fuel efficiency, desirable characteristics for a large widebody freighter can be summarised as follows:

- A payload in the 100-tonne class. A core network of trunk routes will support capacities of up to 135 tonnes (or even more), but such large aircraft suffer badly on routes with an acute directional imbalance of traffic, and during periods of reduced demand.
- A range equal to, or greater than, 4,500 nm with maximum payload. This allows non-stop flights to be made from China to Northern Europe for much of the year.
- A maximum payload density of 9.0lbs cu ft at provides a good compromise between general cargo at 8.0-12.0lbs cu ft, and express traffic at 6.5-8.0lbs cu ft. With express traffic densities declining while traffic volumes rise, a lower design density may be acceptable to some operators.
- Limited outsize loading capability, although full nose-loading will be impossible with any other candidate aircraft.

But does the nose-loading capability of the 747-8F have any relevance today anyway, when so much freight is e-commerce-related? "Very much so," says van de Weg. "Not so much for speed of loading and off-loading, that is not the main point. It is really about the amount of heavy out-sized freight that we are carrying, which is too big to be loaded easily through the side door. It is an area that we are focusing on commercially. That is the big plus of the 747-8F. That is what we are capitalising on. This is about 10% of our business in revenue, and one can say that the yield on out-sized cargo can easily be twice that of general cargo. We have to do much more to earn that, however, because we need to use loading equipment, engineering and extra loadmasters. We also use 16- or 20-foot unit load devices (ULDs), which can be loaded straight through the nose door, and we can connect pallets to cater for larger loads. This equipment is expensive, but we use it a lot."

Future freighters: 777 P2F

Might other freighter aircraft options exist, whether new-builds or conversions,

777 PASSENGER- & FREIGHTER CONFIGURED SPECIFICATION WEIGHTS

Aircraft variant	-200ER	-200P2F	+/-	-300ER	-300 P2F	+/-	-200LR	-200F	+/-
MTOW - lbs	656,000	650,000	-6,000	775,000	775,000	0	766,000	766,800	800
MLW - lbs	460,000	507,000	47,000	554,000	599,000	45,000	492,000	575,000	83,000
MZFW lbs	441,000	477,000	36,000	524,000	569,000	45,000	461,000	547,000	86,000
OEW - lbs	304,500	287,000	-17,500	370,000	343,000	-27,000	320,000	318,300	-1,700
GROSS PAYLOAD - lbs	125,550	188,500	62,950	154,000	226,000	72,000	141,000	228,700	87,700
GROSS PAYLOAD in tonnes	56.9	85.5		69.9	102.5		64.0	103.7	
GROSS PAYLOAD increase		50%			47%			62%	

which could match or exceed the requisite freighter attributes in respect to payload, range, volume and fuel efficiency?

The main candidate is a P2F conversion applicable to the 'ER' variants of the 777 family. First introduced into service in June 1995, 1,547 examples of all sub-types of this extraordinarily successful aircraft were delivered in the 23 years to the end of April 2018. Some 140 were factory-built freighters, but not one 777 built as a passenger aircraft has ever been converted to a freighter.

There are positive and negative reasons for this, in relation to the status of the aircraft as conversion feedstock.

Positive

- The 777 has been a hugely successful passenger aircraft, so potential feedstock values remained prohibitively high, even as used examples entered the theoretical 'zone of convertibility' at 15 years of age.

Negative

- The crash in freight volumes of 2009 and its aftermath caused a dramatic loss of confidence in the freighter market, and in P2F conversions in particular.
- The aircraft presents a very significant technical challenge as a P2F conversion.

The above factors have ensured that the 777 P2F has remained as a 'design study', although a number of organisations, including Boeing itself, have researched a conversion in depth.

Boeing began studying a Boeing Conversion Freighter (BCF) programme for the 777 in 2008, with a view to offering a 777-200 and 777-200ER BCF product after 2011. Despite the downturn in the air cargo business, expectations remained high that the conversions would be offered by 2013. The 777-200ER BCF was pitched as a natural progression upwards in size from the 57.2 tonne gross payload 767-300ERF and a lower-capacity complement, to the 747-400SF/BCF. A 777-300ER was not contemplated at that time, due to prohibitively-high market values, which have (arguably) persisted to this day.

Data released by Boeing at the time showed a 777-200ERBCF offering a payload of 81,646kg (180,000lbs), and a maximum-payload range of 4,000nm. This payload is more than 21.5% lower than that of the factory-built 777-200F freighter, which is based not on the -200ER platform, but on the upgraded 200LR, which features very significant structural and design enhancements. Industry perceptions were, and are, that a 777-200ER BCF would create its own new customer base among carriers.

The 777-200/-200ER BCF programme stalled after extensive discussions with integrators and general cargo operators, and remains so to this day.

Technical challenges

The 74 floor beams of all passenger-configured members of the 777-200 family (and 89 in the 777-300/ 777-300ER) are made from carbon fibre reinforced polymer (CFRP) composite material. This material has proved to be a durable, robust and light-weight substitute for aluminium in this application. It is said that Boeing has never received an operator request for a replacement CFRP floor beam.

The requirement to replace the CFRP of the 777 passenger aircraft with aluminium during any BCF conversion to raise the longitudinal running loads to the levels offered by other widebody freighters makes this P2F conversion one of the most complex and time-consuming ever contemplated. It may also be the most expensive, with estimates of $25-30 million widely cited.

A further P2F challenge facing the 777 arises because the type was one of the first aircraft to embody a completely new generation of systems technology on the flightdeck. These systems extensively monitor the condition of the aircraft and cabin, and cargo-specific modifications must interface seamlessly with these systems in normal operation.

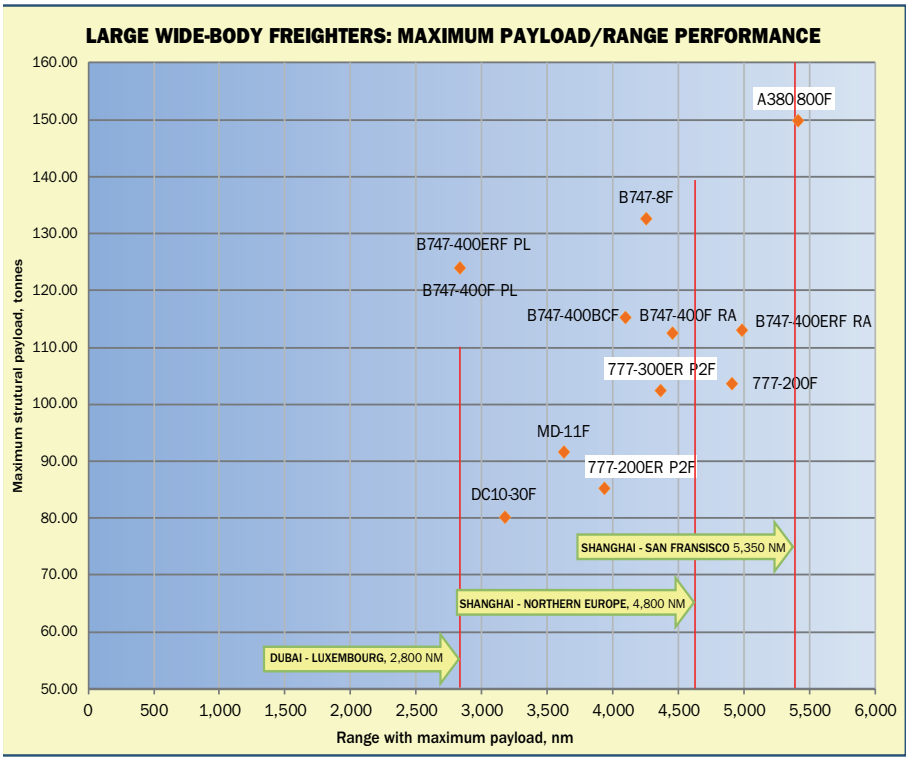
777 P2F outlook

Seven years on from Boeing's aborted foray into the 777 P2F arena there is plentiful availability of potential 777-200ER feedstock, and with the emerging possibility that a surfeit of early-build 777-300ERs could soon exist in the aftermarket, renewed interest is being shown in the 777 P2F opportunity.

IAI/Bedek has made it known for some five years that they have been evaluating the market and technical challenges and opportunities that such a programme would represent. Industry sources speak of supplemental type certificate (STC) approval for a 777-200ER STC being received in 2019, and a STC for a 777-300ER in 2020. The converted -300ER prototype would emerge a year or two later.

Rafi Matalon, general manager of marketing & business development at IAI/Bedek, has confirmed that this process is now finally moving to a conclusion. "We have not yet launched the 777 P2F programme, but I am hopeful that we will be in a position to do so within months," says Matalon. "Design weights for the -200ER P2F and -300ER P2F have been circulated, but I must stress that they are only for 'illustrative' purposes at the moment. We do, however, have a track record of achieving significant increases of 8-9% in the maximum zero fuel weight (MZFW) of converted passenger aircraft, without the support of the original equipment manufacturer (OEM). We are confident that when applied to the 777-300ER, this level of expertise will enable us to offer an aircraft with the payload of the factory-built -200F, but with up to 25% more volume."

The illustrative 777 P2F design weights are compared to the equivalent weights of the feedstock aircraft in passenger configuration *(see table, this page)*. The validation and certification of these design weights independently of the OEM would be a significant achievement, and with respect to the 777-300ER they have the potential to create a game-changing large widebody freighter. The



most remarkable figure is the predicted 569,000lbs MZFW of the -300P2F, which is 9% higher than the native MZFW of the passenger aircraft. It is also 22,000lbs higher than the MZFW of the payload-optimised 777-200F factory-built freighter. Equally, the all-important margin between MZFW and maximum landing weight (MLW) has been maintained at 30,000lbs, slightly higher even than the 28,000lbs margin between these two weights on the -200F. Reducing the -300ER P2F's operating empty weight (OEW) by 27,000lbs from the passenger aircraft's specification to 343,300 lbs compares favourably with the differential between the passenger-configured -200LR and the 777-200F differential, which is only 1,700 lbs.

No mention has been made of a P2F conversion of the 777-200LR, 55 of which remain in service with none on order. In principle, the -200LR could form the basis of a competitive P2F given that values for the aircraft in passenger configuration are relatively weak, although the business case for such an STC would need to be carefully weighed in view of the small feedstock pool.

We have applied the predicted -200ER and -300ER P2F weights to the standard nominal Boeing payload-range charts for both types, and adjusted the results to allow for typical long-haul reserves. Using this methodology a theoretical design range with maximum payload of 3,920nm for the 777-200ER P2F is derived, and 4,365nm for the -300ER P2F. While the latter is more than 500nm short of the range of the -200F, it compares favourably with the range offered by many of the legacy large widebody freighters.

777 P2F 'Lite'

A key technical challenge of a 777 P2F conversion is reinforcing the floor. The permissible running loads throughout the length of the cabin of the 777 passenger aircraft are 81lbs per longitudinal inch. These are sufficient to allow 89 tonnes of incident weight (cargo loading system plus gross payload, including tare), to be carried on the main deck of a 777-300ER P2F, if evenly distributed throughout the length of the cabin (in compliance with the aircraft's weight and balance manual). As proposed by LCF Conversions (a brand of Eolia Limited), a -P2F conversion of the 777-300ER is possible without a reinforced floor.

The ability to carry at least some heavy pallets, however, will confer operational and commercial flexibility on the freighter. This will be useful to both general cargo carriers and express integrators, given the significant amount of general cargo carried by integrators to supplement their own express traffic.

"A 'Lite' version of a 777 P2F could be attractive, but it would be a pure e-commerce aircraft. For certain integrators such a plane could be quite interesting," says van de Weg.

A380F

The freighter variant of the A380, the -800F, was launched in December 2000 simultaneously with the passenger variant, but the programme was suspended 11 years later. All 27 orders placed by FedEx, UPS and Emirates were subsequently cancelled, and the variant disappeared from the Airbus corporate website in 2015. The A380F has recently, however, reappeared as a 'design study' in Airbus presentations, and the extension of the foreseeable life of the A380 programme following Emirates' recent order prompts the inclusion of the A380F in this review of potential large widebody freighters.

The fact that early production passenger A380s are now being returned to lessors and may be parted out does not, however, mean they are candidate feedstock for a P2F freighter which would replicate the baseline -800F specification *(see table, page 64)*. The -800F was to be built on a strengthened and revised structure which was not only optimised for the carriage of freight, but was also intended to act as the basis for an -800ER and a stretched A380-900. The main deck floor-to-ceiling height was raised to 102 inches, four more than the passenger version to accommodate 96 inch tall ULDs, and Type 2524 light aluminium alloy floor beams were to be used in the freighter aircraft, rather than the composites and Type 2024 aluminium beams used on the passenger variant aircraft. There are numerous differences to cater for the freighter role and its attendant design weight increases of 65,000lbs in MTOW and 90,000lbs in MLW. These included a reinforced wing box, stronger frames, wing ribs, stringers and wing skins. Engine thrust was to have been increased to 76,000lbs from the passenger aircraft's nominal 70,000lbs, but this would have just been a plug-change on the engine.

Yet at the time the A380 was launched, Airbus predicted that a P2F programme would be developed for the passenger variant, and that conversions would begin in 2017-2020. So while detailed consideration of an A380 P2F is outside this scope of this article, it is possible that one might be developed to cater for the express package freighter market.

In ordering the factory-built freighter, FedEx spoke in 2009 of a single A380-800F taking the place of two MD-11Fs on transatlantic city-pairs. On the longer trans-Pacific distances such as Hong-Kong to Memphis, one A380-800F was envisaged to take the place of up to four smaller widebody freighters.

With a design range of 5,400 nm with a full payload of 150 tonnes, from a point such as Dubai, the A380-800F would reach all of Europe and Africa non-stop, as well as all of the Asia Pacific, and would fly as far as Washington and north-eastern North America.

The express operators were therefore planning to commercially exploit the fact that the A380's design was optimised to carry a large payload over an extreme range, which was also a design objective of the 777 programme. This is not

necessarily a desirable characteristic for a general freighter, since it burdens the airframe with a large wing and associated structure necessary to confer such range. The design weights of the A380-800F relative to those of the 747-8F provide dramatic confirmation of the cost in empty weight that must be paid for its unequalled non-stop range. At 555,797lbs the -800F OEW is 121,197lbs (28%) heavier than the OEW of the -8F, yet it carries a gross structural payload that is only 38,080lbs (13%) greater.

The previous generation, however, perfectly exemplified by the MD11, offered a high payload in relation to its OEW because the design range was significantly shorter.

An important attribute of the A380-800F of potential value to the integrators is the relative quietness of the A380 family, which has achieved compliance with 'QC2' noise limits at London Heathrow.

The A380-800F would not have a nose-loading capability, however, and nor could a P2F variant. Airbus's approach to the challenge of outsize cargo was to use a 168-inch wide by 103-inch tall cargo door on the main deck, such a door being 34 inches wider than that installed on the 747-400F.

It is likely that factory-built freighter versions of both the A350-800 and 777-8 will be produced, and the operating economics of such aircraft will be the subject of a future article.

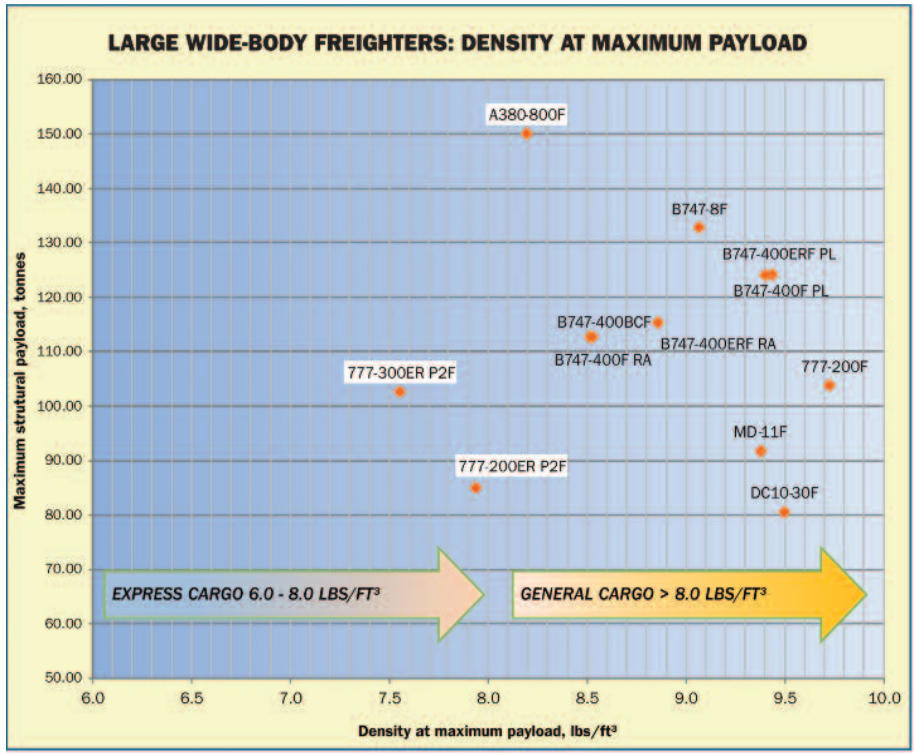
When compared to the current widebody freighter fleet, the 777-200ER P2F's net structural payload would position it between DC-10-30F and MD-11 freighters, while the 777-300ER P2F's 20% higher payload would make it almost equal to the -200F *(see table, page 64)*. The A380-800F's payload capability would be without equal.

The ratio of MZFW:OEW clearly illustrates how the later-generation A380s and 777s are optimised for range, not outright payload, and rely primarily on aerodynamic and propulsive efficiency to generate fuel burn savings over the previous generation of aircraft.

Volumetric payload

At a typical express package density of 7.0lbs per cu ft, the 777-200ER BCF would offer an identical volumetric payload to the 777F, while the 777-300ER P2F would offer 26% more volumetric payload at this density to the 777F, at least 2% greater volumetric payload than the 747-400F group of freighters, and only 7% less volumetric payload than the 747-8F.

The 777-200ER BCF would gross-out at packing densities in excess of 7.93 lbs per cu ft, and the -300ER P2F at 7.56 lbs per cu ft. The 777-200F, therefore, offers



greater volumetric payloads than the -200ER P2F aircraft at all packing densities above 7.93lbs per cu ft. Significantly, the 777-300ER P2F offers higher volumetric payloads than the -200F at all densities up to 9.5 lbs cu ft, by virtue of its 26% volume advantage.

The A380-800F would offer 25% more available volume than the 747-8F, and 34.5% more than a -300ER P2F.

The densities at which this volume can be used are as shown *(see table, page 68)*. For the carriage of cargo at its design density of 7.56 lbs per cu ft, the 777-300ER P2F demonstrates a remarkable 25.5% unit saving when compared to the 747-400BCF were carrying freight at the same density, and a 17.5% unit saving when compared to the 747-8F were the latter also to be carrying freight at 7.56lbs per cu ft. Only the A380-800F comes close to the efficiency of a 777-300ER P2F as measured by this metric, at 11% higher fuel burn per unit of flown volume.

Range performance

In addition to its competitive volumetric payload performance, the two proposed 777 P2F variants have a significant range advantage over the MD-11F. The 777-300ER P2F would offer about the same range as the 747-400F, while the performance of the A380-800F would exceed the range of the 777-200F by about 500nm.

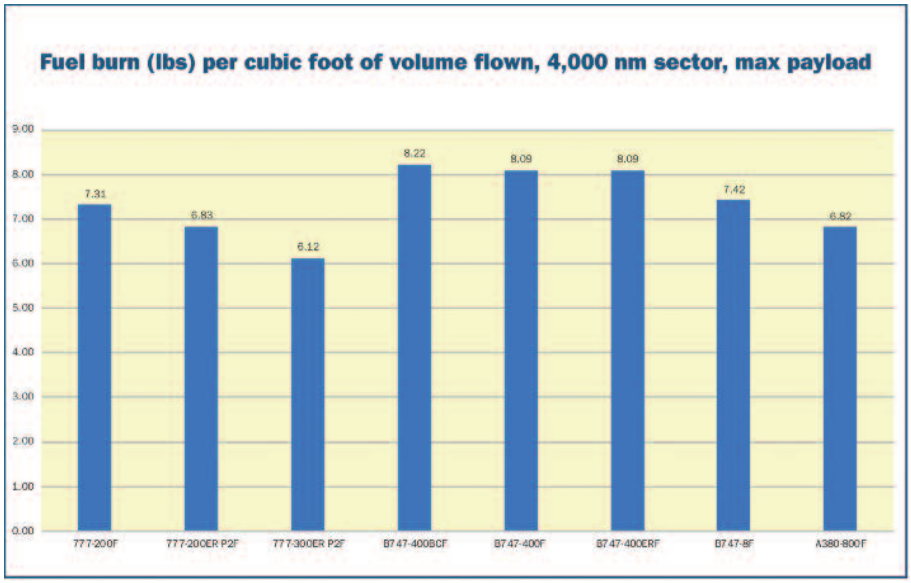
Potential operators

It is obvious that the major integrators will be candidates to operate any large widebody freighter offering competitive unit costs at the densities at which their traffic is being received from customers. The use of converted aircraft may not find favour with some operators, however, if they are able to obtain highly discounted prices on new-build aircraft and access finance at competitive rates. Equally, a converted aircraft such as the 777-300ER P2F, potentially offering a combination of acquisition price, operating economics, weight payload and volume that cannot be found in any new-build freighter, could change operator strategies favouring the use of only new-build aircraft.

But what of the mainstream general cargo operators of large widebody freighters? Would the traditional advocates of the 747 freighter consider adding, for example, the 777-300ER P2F to their fleets?

"It is not impossible to imagine that we would operate a big twin," says van de Weg. "We cannot ignore anything at the moment. What matters is what will be available as new-build freighters in the future. The 747-8F has been perfect for our niche, for the way we sell and operate. But we know the 777F is an excellent freighter aircraft. It performs well on certain routes, particularly on imbalanced flights and on flights with long ferry legs.

"A 777-300ER P2F conversion with the same payload as the -200F, but with 20-25% more volume, could be an interesting airplane for certain parts of the market," continues van de Weg. "If you look at traditional densities it would not be so interesting, but densities are changing because of the rise of e-commerce. A more voluminous aircraft could therefore be useful, even if it is not



The fuel burned per cubic foot of usable cargo flown assumes a 4,ooonm sector is flown at the maximum payload applicable to each type.

a great aircraft for heavy and outsize. It also depends on the alternatives. The 747-8F is such a versatile aircraft, and it serves all segments of demand very well. This includes pharmaceuticals, outsize and e-commerce. It is a great aircraft to mix-and-match various different types of freight, whereas the P2F would be optimised maybe for just one segment. So it is more risky from that perspective."

What of the A380-800F? Should the type again be offered to the market by Airbus? "Could an airline like AirBridge ever use such an aircraft? It is not an obvious choice, and there are so many obstacles with it," continues van de Weg. "It is a relatively heavy aircraft. The double-deck design would create a lot of problems for loading and offloading, but if you focus on the volume it would provide an e-commerce aircraft operating into heavily-congested airports which are slot-restricted. Therefore instead of two flights with smaller types, you operate one. In that kind of scenario the aircraft could have a chance, but the options are limited."

On-ramp costs

In respect to a new-build A380-800F, Airbus would only relaunch it once it had a viable base of customers prepared to pay the $1.5-2.0 million per month lease rates that such an investment would probably command. An A380 P2F is a totally different proposition, but lies outside the scope of the current analysis.

As for the 777 P2F, acquisition and conversion costs are always crucial in determining potential market demand for any freighter conversion. While this is undeniably true for the 777-200ER P2Fs, it is more true for the -300ER P2F, given current feedstock market values. Solutions to the payload, range, freight volume, and fuel burn equation that are made possible by the prospective 777-300ER P2F may be sufficiently attractive to justify a higher on-ramp cost for the P2F than has traditionally been assumed.

In respect to the conversion cost itself, there are indications that a conventional P2F conversion for either the 777-200ER or -300ER could cost $25-30 million.

In respect to feedstock prices, the current market value and base values for 777-200ERs remain above $20 million for all but the earliest-built aircraft, according to the value projections from IBA Group. The conversion of feedstock at such values would result in a $45-50 million P2F cost on-the-ramp, but recent industry rumours of a major P2F customer securing distressed A330 feedstock for $10 million to achieve an on-the-ramp cost of $20 million for the converted P2F may be instructive here.

While sub-$30 million feedstock prices for a 777-300ER in the early 2020s appear inconceivable as current market values for even the earliest aircraft remain at $60 million, significant impending lease returns of -300ERs may lead to a reduction in values. This could make a compelling case for the 777-300ER P2F to become a growing component of the large widebody freighter fleets by the mid-2020s.

"Realistically there will be some price reduction of the 777-300ER," says Stuart Hatcher, ISTAT appraiser and chief operating officer at IBA. "In the late 2000s there was still a premium on the -200ER, but this quickly changed. Once the fleet of A350s and 777X start building up, new solutions will be needed for the -300ER."

This view is strongly echoed by a number of industry observers, noting that while the 777-300ER in passenger configuration has not begun to test its secondary market because it is 10 years younger than the 777-200ER, it may well struggle to do so as those units not subject to lease extensions seek new homes. Some expect to see the 777-300ER facing the same aftermarket challenge that the -200ER is confronting, but magnified by virtue of the fact that it is an even larger aircraft. There are only 40 777-300ER operators in the world, and they are all first-tier network carriers. While many of these carriers that own them outright will keep them until they are 20 years old or more, those airlines that have them on 12-year leases may prefer to hand the aircraft back to the lessors in preference to examples of the next generation of widebody aircraft.

But even if feedstock was acquired at $50 million and the cost of conversion was capped at $20 million, would there be any appetite to take a 777-300ER P2F at a total cost of $70 million? "$70 million for a converted 777-300ER, already 16-18 years old and at a monthly lease rental of $750,000 could be possible, but it is towards the high end," says van de Weg. "It is not an obvious winner, because maintenance costs rise with an older aircraft. Ideally they would be converted when values have dropped dramatically."

Not all industry observers are sanguine about the prospects for a conventional 777 P2F programme. A veteran of several widebody P2F programmes, Cliff Duke, chief executive officer of LCF Conversions, and a proponent of a low-cost, main-deck door solution for the 777, observes that the cost of developing a 777 P2F solution to conventional specifications may be just too high on this third-generation aircraft. "A more pragmatic specification with significantly lower development costs may be the only way to justify the conversion investment and see the 777 variants used in P2F configuration," says Duke. "A P2F programme on a third-generation widebody will demand investment of $100 million. This will invariably mean high sales volumes and limited competition in their market niche to justify the programme investment case. Failure to meet these expectations creates a battlefield of the walking wounded, as a number of investors in second-generation widebody P2F programmes have found to their cost. The 777 falls into the category of high investment cost and reliance on limited market competition and high-volume sales to justify the programme." AC