There are about 180 DC-10, A300B4, A310 & 767-200 freighters in operation. These have an average age of 35 years, and many will need to be replaced over the next five years. The freight capacity characteristics, availability and operating costs of the best replacement options are analysed.

Replacement options DC-10, A300B4, A310 & 767-200 freighters

Although the freight market has not experienced any notable traffic growth since 2008, there are more than 180 767-200F, A300B4, A310 and DC-10-10/-30 freighters in operation. These are 25-42 years old, with an average age of 35 years. Even with a possible need for long-term adjustments to overall global freighter capacity due to a depressed air freight market, most of these aircraft will need replacing over the next five years. There are another 67 of these types that have been parked since 2008, most since 2011. This suggests that consolidation in this size category has already been made.

Replacement considerations

The 767-200F, A300B4-200F, A310-200F, A310-300F, DC-10-10F and DC-10-30F have gross structural payloads of 88,000-178,000lbs *(see table, page 54)*, or 45-80 tons.

Once the tare weight of containers, unit load devices (ULDs) or pallets is deducted, these types have net structural payloads of 77,000-159,000lbs (36-76 tons). These five types have ranges with maximum payload of 2,000-3,500nm *(see table, page 54)*.

These five aircraft models have maximum containerised or ULD volumes of 10,644-17,590 cubic feet (cu ft) *(see table, page 54)*. These reflect the volume available with ULDs that use the maximum amount of space on the aircraft's main and lower decks.

The net structural payloads and the maximum containerised volumes result in maximum densities of 5.6 to 9.1lbs per cubic foot (cu ft) *(see table, page 54)*.

There are several container or ULD loading configurations for each type, so volumes, net payloads, packing densities and volumetric payloads will vary. Using ULDs that provide the highest containerised volume can allow them to be interlined with other aircraft types.

Pallets are more commonly used for general freight. These provide similar volumes to the maximum ULD volume, but the pallets have lower tare weights, so the aircraft have higher net structural payloads than when loaded with ULDs, and also higher packing densities.

Replacement candidates

The first aircraft to consider as replacement options for these older types will therefore have gross payloads, containerised volumes and range performance that are similar to those of these five models.

At the smaller end is the 757-200F, which has a gross structural payload of up to 78,350lbs for various passenger-to-freighter modification programmes *(see table, page 54)*.

There are several types at the higher end that could be considered as DC-10-30F/MD-10-30F replacements. These include the A330-300P2F and -200P2F. These both have smaller net structural payloads than the DC-10-30F, however, so larger types may be required. The two next largest aircraft are the MD-11F and the 777-200F. The MD-11F has a gross structural payload of up to 197,000lbs, while the 777-200F's is 224,800lbs. The MD-11F is no longer manufactured and is also popular with its operators, so it will be hard to acquire. The 777-200F is only available as a factory production freighter, but a passenger-to-freighter modification programme could be developed.

Between the DC-10-10F and 757-200F are the 767-300ERF and the A300-600RF. These have gross structural payloads of 125,500lbs and 107,370lbs *(see table, page 54)*. They have maximum containerised volumes of 15,754 cu ft and 14,316 cu ft, and a range of 3,600nm and 2,600nm with maximum payload. They therefore have net structural payloads of 107,860lbs and 91,554lbs, and corresponding maximum packing densities of 6.8lbs per cu ft and 6.4lbs per cu ft respectively.

Payload accommodation

While the highest gross and net structural payloads of each type give an impression of their size as a freighter, there are several different ULD and pallet configurations, and consequently tare weights, net payloads and packing densities for each aircraft type.

Different ULDs to the ones that provide the maximum possible volume have to be used on each aircraft type for different situations. These include allowing the ULDs to be interlined between aircraft types that have different fuselage cross-sections and dimensions. That is, ULDs that are relatively small for a widebody, and do not use the full width or height of the main deck, can be interlined with narrowbody aircraft. This is especially important for freight airlines carrying express packages via hubs.

European Air Transport (EAT) is one example. The airline operates a trans-European hub-and-spoke style operation at a main hub at Leipzig, Germany, and several other smaller hubs. "We operate a mixed fleet of A300-600Fs, 757-200Fs and 737-300Fs," says Geoff Kehr, senior vice president Aviation Europe, at DHL.

BASIC PAYLOAD CHARACTERISTICS 35-80 TON FREIGHTERS

Aircraft type	DC-10-10F/ MD-10-10F	DC-10-30F/ MD-10-30F	A300B4-200F	A310-300F	767-200ERF
MTOW-lbs	440,000	572,000	373,760	361,620	351,000
MZFW-lbs	335,000	414,000	277,780	251,320	266,000
OEW-lbs	217,300	236,000	177,780	162,920	164,000
Gross structural payload-lbs	117,700	178,000	100,000	88,400	102,000
Range with maximum payload-nm	2,400	3,500	2,000	3,300	3,000
Maximum ULD volume-cu ft	17,590	17,590	13,398	12,672	12,184
ULD tare weight-lbs	18,915	18,915	14,810	11,792	13,636
Net structural payload-lbs	98,785	159,085	85,190	76,608	88,364
Maximum packing density-lbs/cu ft	5.62	9.04	6.36	6.05	7.25

Aircraft type	A330-300P2F	A330-200P2F	767-300ERBDSF	A300-600RF	757-200PCF no winglets
MTOW-lbs	500,308/506,920	500,308/513,532	412,000	375,890	255,000
MZFW-lbs	392,312/385,700	392,312/381,292	309,000	286,600	194,000
OEW-lbs	245,746/246,848	240,2360	183,500	179,230	115,650
Gross structural payload-lbs	146,566/138,852	152,076/141,056	125,500	107,370	78,350
Range with maximum payload-nm	3,600	3,900	3,600	2,600	2,500
Maximum ULD volume-cu ft	19,020	15,984	15,754	14,316	8,390
ULD tare weight-lbs	21,188	17,740	17,640	15,816	6,600
Net structural payload-lbs	125,378/117,664	134,336	107,860	91,554	71,750
Maximum packing density-lbs/cu ft	6.59/6.19	8.40	6.85	6.40	8.55

"Our network of routes averages about 500nm via several hubs. Having ULDs that interline between the A300-600 and the narrower 757/737, which have the same cross-section, is essential because we need to achieve fast ULD transit at hubs. Unpacking and re-packing them takes too long and adds a lot of cost.

"We therefore have to use a 125-inch X 88-inch base dimension ULD, which also a height of 79 inches and a curved profile that matches the 757's and 737's full main deck contour," continues Kehr. "The ULD is also used in a double-row, side-by-side (SBS) configuration on the A300-600. This is therefore two ULDs with a width of 88 inches across the fuselage main deck. The A300-600's cross-section actually allows the use of two ULDs, each with a base width of up to 96 inches, so our system does not use all the available space on the A300-600's main deck and results in less than optimum containerised volume. Even so, it is overall more economic to be able to interline ULDs between aircraft, and save the time and cost of unpacking and re-packing them at the hub between flights."

EAT uses larger ULDs on the A300-600s in some cases, so a mix of ULDs will be carried on its main deck.

Volumetric payload

In addition to the choice between the various ULDs that can be used on each type, pallets have lower tare weights and they provide the aircraft with a higher net structural payload. This allows a higher maximum packing density, which is the net structural payload divided by the total available volume for a given configuration of ULDs or pallets on the main and lower decks.

The volumetric payload is the total available volume multiplied by the packing density, up to the maximum packing density. For example, 15,000 cu ft packed at 6.5lbs per cu ft is a volumetric payload of 97,500lbs. Volumetric payload is therefore the important factor in determining aircraft revenue-generating capacity.

Maximum possible packing density will vary with ULD and pallet configurations, and their corresponding tare weights. Maximum possible packing density will be higher with pallets, because of their lower tare weights and higher net structural payload.

Packing density of freight varies with the type of cargo. General freight with lower yields tends to have higher packing densities, and can be 7lbs per cu ft and higher in many cases. Most types of general freight can be safely carried on pallets.

Higher-value general freight of more luxurious or electrical items tends to have lower packing densities, and shippers may prefer to use ULDs. The aircraft's lower available net structural payload and possible packing density will be offset by the higher yields generated.

Express packages and parcels, and mail have low packing densities of 6.5-7.0lbs per cu ft. This type of freight will also be packed in ULDs.

Each ULD or pallet configuration will have different corresponding volumetric payloads. The different ULD and pallet loading configurations; and the resulting volumes, maximum packing density and various volumetric payloads for a range of packing densities are considered for each type.

Replacement issues

Apart from age, the DC-10, A300B4, A310 and 767-200 have several other issues that will force the retirement, and need for a replacement, within the next five years for the majority. These include: securing technical and engineering support for engines and components; rising maintenance costs; impending ageing aircraft issues and airworthiness directives; the cost of a three-main flightcrew on the DC-10 and A300B4; looming requirements for avionics upgrades; and generally high fuel burn.

DC-10F/MD-10F

Most DC-10s/MD-10s are operated by FedEx. A small number are operated by Kelowna Flightcraft, UK operator AV Cargo Airlines, Solar Cargo and TAB Airlines. More than 60 of 70 active DC-10Fs are more than 30 years of age.

FedEx has announced the retirement and accelerated retirement of up to 38 of its MD-10s, as well as 36 A310s. It has

The A300B4-200F is operated in small numbers, and consequently it is becoming harder to find technical support, and the necessary maintenance & engineering capability to operate the aircraft.

46 767-300PFs on order and more 757-200SFs due for delivery, although it is not clear how many of these will be used to replace MD-10F capacity. FedEx has 65 active MD-10s and another 12 parked aircraft. The retirements will therefore leave about 27 aircraft in service.

The DC-10-10F has a gross structural payload of 117,7700lbs, and the -30F has a gross structural payload of 178,000lbs.

The various main and lower deck ULD and pallet configurations are summarised *(see table, page 58)*.

The DC-10-10F is limited to express package operations by a low maximum packing density of 5.6lbs per cu ft with ULDs, and 6.6lbs per cu ft with pallets.

The -30F's higher structural payloads of 158,500lbs and 169,800lbs with ULDs and pallets provide it with higher packing densities of 9.1lbs and 10.3lbs per cu ft *(see table, page 58)*. This means the aircraft will have volumetric payloads of up to 139,000lbs and 132,000lbs when freight is packed at 8lbs per cu ft, in ULDs and pallets.

The DC-10-30F has a range of about 3,500nm with a full payload, so overall it has good characteristics for carrying general freight. Few were converted, however, because it has higher costs per ton-mile than the 747F.

A300B4-200F

There are only 12 A300B4s left in service, and numbers are due to decline further. The aircraft are 28-36 years old, and there are only six main operators, whose numbers are expected to fall.

The A300B4 has several issues that will force retirement. The first is that the aircraft has an eight-year D check cycle, and aircraft will get retired as they approach a fourth or fifth D check. EAT/DHL operated a fleet, but recently retired its last aircraft. "It requires a certain competence to operate, since industry knowledge of the type is no longer widespread, and it is hard to find technical and engineering support," explains Kehr. "The aircraft's high fuel burn was a main driver for us retiring it, along with its need for a flight engineer."

The A300B4-200F has a maximum gross structural payload of up to 100,000lbs. Its main deck ULD configurations include a combination of AMV and AMA containers, as well as SBS loading of SAA and AYY containers *(see table, page 58)*.

The A300B4 can also carry 19 96 X 125 pallets, and 20 LD-3s in its belly. These two ULD configurations result in net payloads of 85,200lbs and 82,200lbs *(see table, page 58)*. The maximum packing densities are relatively low at 6.4lbs per cu ft and 7.0lbs per cu ft.

With pallets, the aircraft has a higher net payload of 90,642lbs and a packing density of 6.9lbs per cu ft.

The A300B4's payload characteristics, and its relatively short range, limit it to express package operations.

A310-200F/-300F

There are about 16 A310-200Fs still in operation with FedEx, and a similar number of -300Fs. These are all due to be retired, and many A310s have already been replaced with 757-200s.

There are another seven -300Fs in operation with Royal Jordanian and ULS Airlines Cargo. All of these aircraft are equipped with CF6-80A engines, and with most operators retiring aircraft with these engines, it is becoming harder to find parts and materials for them.

The A310-300F can use the same ULDs as the A300B4. Using the same AMV, or mixture of SAAs and AYYs on the main deck, and 14 LD-3s on its lower deck, the A310-300F has a total volume of 10,644 cu ft and 9,092 cu ft. Net payloads are similar at just over 76,000lbs. Packing densities are relatively high at 7.2lbs per cu ft and 8.4lbs per cu ft.

Sixteen pallets can also be carried in two rows of eight, plus four smaller 88 X 125 pallets on the main deck. This results in a higher net payload of 80,000lbs, although packing density is limited to 6.4lbs per cu ft. The aircraft had appropriate payload characteristics for express packages, but poor for general freight.

The A310's overall main disadvantage was a relatively small payload for a widebody, which results in a high unit cost per lb or ton per mile.

767-200F

There are almost 57 767-200Fs in operation, with 53 powered by CF6-80A engines and four with JT9D-7R4 engines.

Airborne Express (ABX Air) has 28 aircraft; while the rest of the fleet is operated in smaller numbers by Air Transport International, Amerijet, Avianca Cargo, Cargojet Airways, and Star Air. ABX Air and Star Air use the 767-200F for express package operations; with Star Air providing capacity under contract for UPS. Atlas Air has five aircraft, which include the four equipped with JT9D-7R4 engines.

Cargo Aircraft Management (CAM) is the owner and lessor of many of these aircraft. "We acquired 767-200s from American, Delta and other carriers. Some have been converted in the past three years," says Bill Tarpley, chief operating officer at CAM. "We have converted them with the expectation that they will operate for 15 years after modification."

Apart from a few of Star Air's fleet, all aircraft are early- and mid-1980s vintage, and the majority have accumulated 25,000-40,000FC.

Most of the fleet is therefore ageing.

FREIGHT ACCOMMODATION CONFIGURATIONS: DC-10-10F/-30F, A300B4-200F, A310-300F & 767-200F

AIRCRAFT TYPE	DC-10-10F ULDs	DC-10-10F ULDs	DC-10-10F Pallets	DC-10-30F ULDs	DC-10-30F ULDs	DC-10-30F Pallets
Gross structural payload-lbs	117,700	117,700	117,700	178,000	178,000	178,000
Main deck						
Type of ULD/Pallet	AMJ	AMJ	96x125x96	AMJ	AMJ	96x125x96
Number	22	22	22	22	22	22
Volume-cu ft	13,508	13,508	13,354	13,508	13,508	13,354
Tare weight-lbs	14,300	14,300	5,896	14,300	14,300	5,896
Lower deck						
Type ULD/Pallet	LD-6	LD-3	96x125x64	LD-6	LD-3	96x125x64
Number	13	26	8	13	26	8
Volume-cu ft	4,082	3,900	3,200	4,082	3,900	3,200
Tare weight-lbs	4,615	5,200	2,296	4,615	5,200	2,296
Total volume-cu ft	17,590	17,408	16,554	17,590	17,408	16,554
Total tare weight-lbs	18,915	19,500	8,192	18,915	19,500	8,192
Net structural payload-lbs	98,785	98,200	109,508	159,085	158,500	169,808
Maximum packing density	5.6	5.6	6.6	9.0	9.1	10.3
Volumetric payload @ 6.5lbs/cu ft	98,785	98,200	107,601	114,335	113,152	107,601
Volumetric payload @ 7.0lbs/cu ft	98,785	98,200	109,508	123,130	121,856	115,878
Volumetric payload @ 7.5lbs/cu ft	98,785	98,200	109,508	131,925	130,560	124,155
Volumetric payload @ 8.0lbs/cu ft	98,785	98,200	109,508	140,720	139,264	132,432

AIRCRAFT TYPE	A300B4F ULD	A300B4F ULD	A300B4F Pallets	A310-300F ULD	A310-300F ULD	A310-300F Pallets	767-200F ULD	767-200F Pallets
Gross structural payload-lbs	100,000	100,000	100,000	88,400	88,400	88,400	102,000	102,000
Main deck								
Type of ULD/Pallet	AMV + AMA	SAA + AYY	96x125x96	AMV + AAX	SAA + AYY	96x125x96	AAX + A2	88x125x96
Number	16 + 3	14 + 12	19	16 + 4	12 + 8	20	18 + 1	19
Volume-cu ft	10,398	8,696	10,216	10,572	6,992	10,376	9,456	9,456
Tare weight-lbs	10,810	11,696	5,358	8,992	9,344	5,532	9,170	4,750
Lower deck								
Type ULD/Pallet	LD-3	LD-3	LD-3	LD-3	LD-3	LD-3	LD-2	LD-2
Number	20	20	20	14	14	14	22	22
Volume-cu ft	3,000	3,000	3,000	2,100	2,100	2,100	2,728	2,728
Tare weight-lbs	4,000	4,000	4,000	2,800	2,800	2,800	4,466	4,466
Total volume-cu ft	13,398	11,696	13,216	12,672	9,092	12,476	12,184	12,184
Total tare weight-lbs	14,810	15,696	9,358	11,792	12,144	8,332	13,636	9,216
Net structural payload-lbs	85,190	82,194	90,642	76,608	76,256	80,068	88,364	92,784
Maximum packing density-lbs/cu ft	6.4	7.0	6.9	6.0	8.4	6.4	7.2	7.6
Volumetric payload @ 6.5lbs/cu ft	85,190	76,024	85,904	82,368	59,098	80,068	79,196	79,196
Volumetric payload @ 7.0lbs/cu ft	85,190	81,872	90,642	88,704	63,644	80,068	85,288	85,288
Volumetric payload @ 7.5lbs/cu ft	85,190	82,194	90,642	76,608	68,190	80,068	88,364	91,380
Volumetric payload @ 8.0lbs/cu ft	85,190	82,194	90,642	76,608	72,736	80,068	88,364	92,784

Moreover, it is becoming harder to support the CF6-80A engine. “The engine is being retired in large numbers by other airlines, and ABX may end up being the only operator of the type,” says Tarpley. “Fewer engine shops have capability for the type, so it may be difficult to acquire parts and materials for it.”

In the 767-200F’s favour is a higher payload capability than the A310. Despite this, most 767-200Fs have been used for express package operations.

The various ULD configurations provide the aircraft with net structural payloads of 88,364lbs and 79,764lbs, and packing densities of 7.3lbs per cu ft and 6.5lbs per cu ft *(see table, this page)*. It has a corresponding range of 3,000nm.

Using pallets, the aircraft has a higher payload of 92,784lbs, and packing density that makes it suitable for many general freight operations. “The 767-200 has good range performance, and we upgraded the MTOW to 351,000lbs during conversion,” says Tarpley. “This gives it a good range performance for transatlantic and trans-US operations. No other aircraft can directly replace it.”

Replacement options

As described, there are five main candidates for replacing the DC-10-10F/-30F, A300B4-200F, A310-300F and 767-200F: the 757-200, A300-600R, 767-200ER, A330-200, and A330-300.

757-200F

The 757-200 is one of the closest freighters in payload and volume to the A310 and 767-200.

The 757-200F is available via two

While the 767-200 has a good payload capacity, long range performance and competitive operating costs, the majority of freighters are equipped with CF6-80A engines. These are being phased out by virtually all passenger aircraft operators, and this could pose a threat to the continued viability of the 767-200F.

passenger-to-freighter conversion programmes.

Precision Conversions' modification provides the 757-200PCF with 15 full-sized narrowbody container or pallet positions. It has the highest possible gross structural payload of up to 80,000lbs.

The Boeing-converted aircraft, the 757-200SF, allows 14 full container, or ULD, and pallet positions. Boeing has modified more than 100 aircraft, most for FedEx and DHL/European Air Transport.

757-200PCF's complex payload

Several complex issues determine the 757-200PCF's gross structural payload, including the aircraft's maximum zero fuel weight (MZFW) and the presence or absence of winglets, which affect operating empty weight (OEW). Precision Conversions is the only passenger-to-freighter modification to convert the 757-200 with winglets.

MZFW is affected by the aircraft's line number and the use of upgrades. Aircraft up to line number (L/N) 210, built in 1989, have a standard MZFW of 184,000lbs. Precision Conversions offers an upgrade to 188,000lbs.

Aircraft from L/N 211 onwards have a standard MZFW of 184,000lbs following conversion. A Boeing upgrade of 4,000lbs or 2,000lbs raises this to 188,000lbs or 186,000lbs, for RB211- and PW2000-powered aircraft.

A further MZFW upgrade offered by Precision Conversions takes this up by another 8,000lbs to 196,000lbs or 194,000lbs, again depending on engine type. RB211-powered aircraft therefore have a 2,000lbs advantage.

The corresponding OEW is determined by the engine type, as well as the presence or absence of winglets. First, the OEW of an RB211-powered aircraft is about 350lbs higher than for PW2000-powered aircraft. Overall, RB11-powered aircraft have a 1,650lbs higher structural payload than PW2000-powered aircraft.

Aircraft with winglets have a 1,400lbs higher OEW than those without, while the OEW of aircraft from L/N 211 is about 500lbs lighter than that of older aircraft up to L/N 210. Few aircraft up to L/N 210 will now be considered for conversion.

For aircraft with winglets, the OEW is 117,400lbs for RB211-powered and 117,050lbs for PW2000-powered aircraft. They are 1,400lbs lighter, at 116,000lbs and 115,650lbs, for aircraft without winglets.

Gross payload is therefore 68,000-80,000lbs for aircraft with winglets, and 66,600-78,600lbs for aircraft without winglets. The highest payload of 80,000lbs is for an RB211-powered aircraft with winglets that has had the Boeing and Precision Conversions MZFW upgrades to 196,000lbs.

The use or otherwise of MZFW upgrades therefore determines the MZFW, gross payload and ultimately the volumetric payloads at higher packing densities *(see table, page 61)*. Even with just the first small MZFW upgrade to 186,000lbs, a PW2000-powered aircraft will have a net structural payload of 63,750lbs with ULDs, rising to 66,765lbs when using pallets. These allow packing densities of up to 7.6lbs and 7.8lbs per cu ft.

The use of SAA ULDs provides a containerised volume of up to 8,390 cubic feet and tare weight of 6,600lbs *(see table, page 61)*.

The aircraft has a range of about 2,500nm with a full payload.

By using pallets with the same base dimensions, the aircraft has a similar total volume but lower tare weight of 3,585lbs *(see table, page 61)*.

The 757-200PCF therefore has high volumetric payloads at a wide range of packing densities, making it suitable for express package and general freight.

Net structural payloads are 6,000lbs higher with the second MZFW upgrade, and packing densities are raised to 8.6lbs and 8.8lbs per cu ft when using ULDs and pallets *(see table, page 61)*.

The 757-200PCF is in a class of its own, and could replace A310Fs and 767-200Fs in some cases, especially where the A310 and 767-200 have been used for express packages. The 757-200PCF may be a good choice where load factors and volumes are low, and reduction in capacity will improve efficiency. Precision Conversions has modified 32 757-200s.

EAT has operated more than 30 757-200SFs converted by Boeing in the late 1990s. "Some of these aircraft are now more than 30 years old, and have 14 main pallet/ULD positions," says Kehr. "We are likely to replace these with younger, converted 757-200s whose modification provides 15 main pallet/ULD positions. The aim is to get about 15 years' operation after conversion to freighter."

One factor favouring the 757-200 is the large supply of passenger-configured aircraft. There are about 530 active, passenger-configured aircraft that are L/N 211 and higher. These are split between 244 PW2000-powered and 285 RB211-powered aircraft. For the PW2000 fleet there are 151 aircraft without winglets, and another 93 with winglets. The PW2000-powered fleet is dominated by large numbers of aircraft operated by Delta and United.

For the RB211-powered fleet there are 75 aircraft without winglets, which are operated in small numbers by a variety of operators; and 210 aircraft with winglets, of which 114 are with American Airlines.

There are 92 parked passenger aircraft, including 18 for FedEx awaiting conversion, and eight parked freighters. Of the 92 passenger aircraft, 67 are L/N 211 and higher. FedEx is only converting aircraft without winglets.

The supply of available 757-200s has

FREIGHT ACCOMMODATION CONFIGURATIONS: A330-200P2F, A330-300P2F, A300-600RF, 767-300BDSF & 757-200PCF

AIRCRAFT / TYPE	A330-300F Payload mode ULDs	A330-300F Payload mode Pallets	A330-200F Payload mode ULDs	A330-200F Range mode ULDs	A330-200F Payload mode Pallets	A300-600F ULDs	A300-600F ULDs	A300-600F Pallets
Gross structural payload-lbs	146,566	146,566	152,076	141,056	152,076	107,370	107,370	107,370
Main deck								
Type of ULD/Pallet	AMV + AMA	96x125x96	AMV + AMA	SAA + AYY	96x125x95	AMV + AMA	SAA + AYY	96x125x95
Number	22 + 4	22 + 4	18 + 4	17 + 14	18 + 4	16 + 4	15 + 13	20
Volume-cu ft	14,220	13,972	12,084	10,444	11,868	11,016	9,346	10,816
Tare weight-lbs	14,788	7,332	12,540	14,032	6,204	11,416	12,574	5,640
Lower deck								
Type ULD/Pallet	LD-3	96x125x64	LD-3	LD-3	Pallet	LD-3	LD-3	LD-3
Number	32	10	26	26	8	22	22	22
Volume-cu ft	4,800	4,000	3,900	3,900	3,200	3,300	3,300	3,300
Tare weight-lbs	6,400	2,870	5,200	5,200	2,296	4,400	4,400	4,400
Total volume-cu ft	19,020	17,972	15,984	14,344	15,068	14,316	12,646	14,116
Total tare weight-lbs	21,188	10,202	17,740	19,232	8,500	15,816	16,974	10,040
Net structural payload-lbs	125,378	136,364	134,336	121,824	143,576	91,554	90,396	97,330
Maximum packing density	6.6	7.6	8.4	8.5	9.5	6.4	7.1	6.9
Volumetric payload @ 6.5lbs/cu ft	125,378	116,818	103,896	93,236	97,942	91,554	82,119	91,754
Volumetric payload @ 7.0lbs/cu ft	125,378	125,804	111,888	100,408	105,476	91,554	88,522	97,330
Volumetric payload @ 7.5lbs/cu ft	125,378	136,364	119,880	107,580	113,010	91,554	90,396	97,330
Volumetric payload @ 8.0lbs/cu ft	125,378	136,364	127,872	114,752	120,544	91,554	90,396	97,330

AIRCRAFT / TYPE	767-300BDSF ULD	767-300BDSF Pallets	757-200PCF ULD	757-200PCF Pallets	757-200PCF Pallets
Gross structural payload-lbs	125,500	125,500	78,350	78,350	70,350
Main deck					
Type of ULD/Pallet	AAX + A2	88x125x96	A2	88x125	88x125
Number	22 + 2	22 + 1	15	15	15
Volume-cu ft	12,034	10,120	6,600	6,750	6,750
Tare weight-lbs	11,550	5,750	6,600	3,585	3,585
Lower deck					
Type ULD/Pallet	LD-2	96x125x64			
Number	30	7			
Volume-cu ft	3,720	3,097	1,790	1,790	1,790
Tare weight-lbs	6,090	2,415			
Total volume-cu ft	15,754	13,217	8,390	8,540	8,540
Total tare weight-lbs	17,640	8,165	6,600	3,585	3,585
Net structural payload-lbs	107,860	117,335	71,750	74,765	66,765
Maximum packing density-lbs/cu ft	6.8	8.9	8.5	8.7	7.8
Volumetric payload @ 6.5lbs/cu ft	102,401	85,911	54,535	55,510	55,510
Volumetric payload @ 7.0lbs/cu ft	107,860	92,519	58,730	59,780	59,780
Volumetric payload @ 7.5lbs/cu ft	107,860	99,128	62,925	64,050	64,050
Volumetric payload @ 8.0lbs/cu ft	107,860	105,736	67,120	68,320	68,320

increased in recent years, as large numbers of aircraft come to the end of their lease terms. Values have fallen to the point that airframes are worth $0.8-1.0 million. The best conversion candidates are those with fewer than 30,000FC.

"The problem is that large 757-200 operators have kept the aircraft as a passenger aircraft, which has kept up lease rates. This means that investing in freighter conversion has not made sense," says Tarpley. "Once retirements start in larger numbers, lease rates and values will drop."

Most of the value in a 757-200 is now in the engines, and values are higher for PW2000s. Demand for RB211-535s is weaker. Mid-life RB211-535s with life-limited parts (LLPs) that have at least 3,000 engine flight cycles (EFC) remaining will have values of $3-3.5 million. This rises to $4.5 million for engines in better maintenance condition.

"The shop visit costs for RB211-535s tend to be high, although they do subsequently have long removal intervals," says Tarpley. "This shop-visit cost is too high for most freight airlines to invest in, and they are showing a preference for PW2000 engines."

Values for PW2037/2040s will be higher than for RB211s, and are about $3.8 million for engines with at least 3,000EFC remaining. This will rise to $4.4 million for a medium maintenance condition, and to $4.8 million for an engine with a large number of EFC time remaining on its LLPs.

This puts a complete aircraft that has

DHL acquired A300-600s from Japan Airlines, converted them to freighter, and used them to replace the A300B4-200F fleet operated in Europe, on a one-for-one basis. With this transaction, there are few A300-600Rs left with the right combination of age, FH and FC that makes them good candidates for freighter conversion.

engines with at least 3,000EFC of LLP life remaining, worth $6-7 million. This is expected to drop to $4-5 million within one or two years.

The list price for conversion to freighter, using Precision Conversions' modification, and the cargo loading system is $4.6 million. The cost of all MZFW upgrades is another $250,000.

The overall cost of acquiring a passenger-configured aircraft, converting it and preparing it for service will thus be $11-13 million, compared to a market lease rate of up to $200,000, in a market where there are few surplus aircraft.

757-300

There is no passenger-to-freighter modification for the 757-300, although one may emerge in the future. Such an aircraft would hold 18 ULDs or pallets with base dimensions of 88 X 125. This would provide 7,920-8,100 cu ft. Added to the belly capacity of 2,382 cu ft, total capacity on the aircraft would be 10,300-10,500 cu ft. Tare weight for this number of ULDs or pallets would be 7,900lbs or 4,300lbs.

It is estimated that gross structural payload would be about 90,000lbs. The aircraft would therefore have a net structural payload of about 82,000lbs or 85,700lbs in ULD or pallet configuration. Packing density would be more than 8lbs per cu ft.

There are 55 active 757-300s, and these are 9-14 years old. Delta has 16 PW2040-powered aircraft it acquired from Northwest. The other 39 aircraft are RB211-535E4-B/-C powered. Condor has 13 -535E4-B-equipped aircraft and United has 21 -535E4-C-powered aircraft it inherited from Continental Airlines.

A300-600RF

There are also 151 A300-600F/-600RFs in active service. These are young, with an average age of just 15 years. Their replacement is therefore unlikely to be considered at this stage, and in fact the A300-600RF is considered a straight A300B4 replacement candidate.

The A300-600RF is available as a converted aircraft through EADS-EFW. It has a gross payload of 107,370lbs.

With ULDs, the A300-600 can carry the same number of AMVs, but one more AMA container in the aft fuselage than the A300B4.

This provides a maximum volume of 14,316 cu ft and tare weight of 15,816lbs. This results in a net structural payload of 91,554lbs, about 6,400lbs more than the A300B4, and a packing density of 6.4lbs per cu ft *(see table page 61)*. It can carry a full payload up to 2,600nm.

When in an interlining mode, the A300-600 can carry 15 SAAs together with 13 AYYs, two more ULDs than the A300B4. This provides 12,646 cu ft of volume, has a tare weight of 16,794lbs, and results in a net structural payload and packing density of 90,396lbs and 7.1lbs per cu ft *(see table, page 61)*.

When using pallets, the lower tare weight of 9,640lbs results in a net payload of 97,730lbs and packing density of 7.1lbs per cu ft *(see table, page 61)*.

In all payload accommodation configurations the A300-600F has low freight packing densities that make it only suitable for carrying express packages. Besides EAT, there are a large number of factory-built and converted freighters in service with FedEx and UPS. Only a small number of converted aircraft are in service with other freight operators.

EAT replaced its fleet of A300B4-200Fs on a one-for-one basis with A300-600Fs. "We bought 18 A300-600s from Japan Airlines (JAL) that it phased out in 2010, and converted them to freighter over the next two years. We operate 16, and the other two are with Air Hong Kong," says Kehr. "The average age of this fleet is 19 years, and the aircraft have mainly accumulated 28,000-32,000FC. Our aim is to get another 15 years' operation from them. Our typical rate of utilisation on our European hub-and-spoke network is about 1,200FC per year.

"The A300-600 has 10% higher payload and lower fuel burn than the A300B4," continues Kehr. "This means it overall has a 20% lower unit cost of fuel per lb of freight than the A300B4. Other advantages are that the A300-600 does not need a flight engineer, and has lower airframe maintenance costs. While engines remain on wing longer than the A300B4's powerplants, the A300-600's engines have higher material costs. The A300-600 therefore has more favourable economics per lb of freight carried."

There are, however, now a limited number of passenger-configured aircraft remaining with the right combination of age and total number of accumulated flight hours (FH) and FC. The first aircraft that are likely to be considered are the 17 operated by China Eastern, Kuwait Airways and Thai International.

767-300ERF

The 767-300ERF is available through two main passenger-to-freighter conversion programmes. These are from Bedek Aviation, Israel; and from Boeing.

Bedek Aviation's passenger-to-freighter modification programme has had an upgrade to the MZFW since 2005. This raised it from 295,000lbs to 309,000lbs, so it raised gross structural payload from 111,000lbs to 125,000lbs for aircraft converted by Bedek Aviation, designated the 767-300BDSF *(see table, page 61)*. It also provides an aircraft with an MZFW of 309,000lbs, and a gross structural payload of 109,000lbs.

The maximum containerised or ULD volume of this aircraft type is 15,574 cu ft, and tare weight is 17,640bs. The resulting net payload is 107,860lbs, and

The 757-200PCF is in a class of its own in terms of payload capacity. The aircraft is a good candidate for replacing A310Fs and DC-8s where a smaller freight capacity is required. Large numbers of passenger-configured 757-200s should come onto the market in the next few years.

packing density is 6.8lbs per cu ft *(see table, page 61)*. This is suitable for express package operations, but is low for general freight. At general freight packing densities the volumetric payload is 107,860lbs, however. This is 16,000lbs higher than the A300-600RF and 20,000lbs higher than the 767-200F.

The use of pallets reduces volume by 2,500 cu ft and increases the net payload to 117,335lbs. Packing density is thus 8.9lbs per cu ft, which is good for most types of general freight. Volumetric payload is up to 105,736lbs *(see table, page 61)*. This is 8,000lbs higher than the A300-600RF.

The 767-300ERF therefore provides additional capacity to 767-200F and A300-600F operators to accommodate growth for several freight types. While the older examples in the 767-300ER fleet are similar in age to the A300-600R, the 767-300ER was built in larger numbers, so there are many potential candidates in the passenger-configured fleet for modification to freighter.

The 767-300ER has the advantage of a two-man flightcrew and, for its size, high capacity and low fuel burn and maintenance costs.

"The 767-300ER is probably our first choice if and when we have to replace the 767-200F for ABX and other carriers, although the airline would need to be able to fill the 767-300's higher payload," says Tarpley. "The 767 has a common type rating with the 757. Pilots therefore only require a differences training course to fly one if they already have a rating to fly the other. This is a fleet strategy that has been adopted by Air Transport International (ATI), which operates the 767-300 and 757-200."

There are 325 CF6-80C2-powered and 153 PW4000-powered 767-300ERs in operation in passenger configuration. The vast majority have accumulated fewer than 20,000FC. Of the total of 478 aircraft, 331 are less than 20 years old.

The largest CF6-powered fleets are operated by Air Canada, American Airlines, All Nippon Airways, Delta, JAL, LAN Airlines and Qantas. The largest PW4000-powered fleets are operated by Air Canada, Delta, Hawaiian and United Airlines.

"The problem with the 767-300ER in recent years has been a low supply of conversion feedstock, because of the delayed 787 deliveries," says Tarpley. "767 leases were extended by passenger operators, but these should start to expire over the next few years as 787 deliveries get underway, and 767-300ERs will start to become available at attractive values."

The list price of conversion to freighter is $13 million for the Bedek modification, while it is $17-20 million for the Boeing conversion. A possible market lease rate up to $300,000 puts a limit of about $10 million on the cost of acquiring a passenger-configured aircraft.

A330-200P2F/-300P2F

The first aircraft types with the payloads and freight volumes closest to the DC-10-10F and -30F are the A330-200F and A330-300F.

While the A330-200F is available as a factory-built freighter, few have been ordered. The -200F and -300F will be available as converted aircraft (designated the A330-200P2F and the -300P2F) from 2016, but only if the passenger-to-freighter programme offered by EADS-EFW is launched.

The A330-200P2F/-300P2F will be configured either in payload mode or range mode. Payload mode allows a higher structural payload. The A330-200P2F will have a gross structural payload of up to 152,076lbs, while the -300P2F will actually be lower at 146,566lbs *(see table, page 61)*.

The maximum containerised freight volume of these two types will be 15,984 cu ft and 19,020 cu ft.

The A330-200P2F can carry a full payload about 3,900nm, while the -300P2F has a shorter range of 3,600nm.

The net structural payloads, packing densities and volumetric payloads of the A330-200P2F and the -300P2F are summarised *(see table, page 61)*.

The A330-300P2F provides about 1,600 cu ft less ULD volume than the DC-10-10F/-30F. The A330-300P2F provides about 1,400 cu ft more ULD volume than the DC-10-10F/-30F.

The A330-300P2F has a high maximum packing density, which makes it suitable for all types of freight *(see table, page 61*. In most cases, the A330-200P2F has a higher volumetric payload than the DC-10-10F, which has a low packing density.

The A330-300P2F has a low packing density when using ULDs, but still has similar volumetric payloads to the DC-10-30F. When using pallets, the A330-300P2F has higher volumetric payloads than the DC-10-30F.

There are about 820 passenger-configured A330s in service that are potential freighter conversion candidates.

Only A330-300s from L/N 256, an aircraft built in August 1999, should be considered for conversion, since they have MTOWs of 506,000lbs and higher. There are, however, 73 A330-300s with lower line numbers and lower MTOWs. These may be considered acceptable aircraft for express package operations. Large numbers are operated by Korean Air, Malaysian Airlines, Philippine Airlines and Thai International.

There are 72 CF6-80E1-, 71 PW4000-, and 241 Trent 700-powered A330-300s with higher MTOWs in service.

All A330-200s have high MTOWs. There are 135 CF6-80E1-, 90 PW4000- and 209 Trent 700-powered aircraft in service.

All A330-300s that are L/N 256 and higher, and all A330-200s, are young

The 767-300F provides a combination of up to 125,000lbs gross payload and long range performance. It is the only aircraft available in large numbers and with the right characteristics as a freighter to replace the A300B4, A300-600, A310 and 767-200.

aircraft, with the oldest only 15 years old. There have been few trades, since there is a general shortage of widebodies. The value of a 1998-built, low gross weight A330-300 in half-life maintenance condition is estimated at $25 million. The value of a younger, high gross weight aircraft is higher, however.

The value of the oldest A330-200s is estimated to be $32 million. The cost of converting it to freighter and installing a cargo loading system is estimated to be $15.5-16.0 million by 2016.

The total cost of building a freighter would be $40-45 million at current values. The supply of conversion candidates will have increased by 2016, however, and aircraft values will have fallen. This could reduce the total cost of producing a freighter by up to $10 million, given that the oldest candidates will be about 18 years old. The supply of retired aircraft should have increased following several years of 787 and A350 deliveries.

Operating economics

Analysing the operating costs of the replacement candidate aircraft compared to the current types will provide some indication of the improvements offered by younger types. As with all freighter aircraft, there is generally a trend between cash operating costs, and lease rentals or depreciation. Low capital costs and lease rentals are pivotal in many cases. With fuel prices at about 330 cents per US Gallon (USG), the relative fuel burn efficiency of many types has become a major factor in aircraft selection.

The fuel burn, direct maintenance and flightcrew costs, in addition to lease rentals, of the A330-300P2F, A330-200P2F, A300-600RF, 767-300BDSF and 757-200PCF have been calculated for short-haul operations for carrying express packages, and medium-haul operations for carrying general freight. The same costs have been calculated for the DC-10-30F, DC-10-10F, A300B4-200F, A310-300F and 767-200F.

The short-haul operation is Miami (MIA) -Memphis (MEM), with a mission length of about 760nm. Flight times are 115-120 minutes for the different aircraft types. The aircraft therefore operate at a FH:FC ratio of 1.92-2.0:1.0. The assumed rates of utilisation are 630FC and 1,200-1,260FH per year.

Aircraft are assumed to carry ULDs that provide the highest possible volume, and also incur the highest possible tare weight. The available volume is assumed to be packed at 6.5lbs per cu ft to result in the volumetric payload for each type *(see table, page 61)*. These volumetric payload capacities are the basis for expressing total costs as rates of cents per ton-mile and per lb.

The medium-haul operation is Istanbul (IST) - Frankfurt (FRA), with a mission length of 1,130nm. Flight times are 162-165 minutes, so the aircraft are operating at an FH:FC ratio of 2.7:1, and at 730FC and 1,970-2,000FH per year. The available volume is assumed to be packed at 7.5lbs per cu ft.

The fuel price used is 330 cents per USG, reflective of current spot prices. This accounts for 45-50% of all the costs that have been included.

The fuel efficiency of modern aircraft is illustrated by the fact that younger types like the 767-300BDSF offset their smaller size compared to the DC-10-10F and -30F, with the 767 having a 3-4 cents per lb lower fuel cost. Even the 757-200PCF, which has a volumetric payload that is 55-60% of the DC-10-10F's and about half of the DC-10-30F's, has at least an equal of better fuel cost per lb.

The full maintenance costs of all aircraft have been included. These include full reserves for engines, base checks, and heavy components such as the landing gear and auxiliary power unit (APU). In reality, freight operators will minimise maintenance costs by not paying reserves for major maintenance events such as heavy airframe checks, engine LLP replacement, engine shop visits, and landing gear exchanges. While this saves cashflow, it is only possible where it is known that the affected airframes, engines or parts will be phased out.

Despite the steady rise of fuel costs and their increasing proportion of total costs over the past five to eight years, lease rentals still account for a high percentage of costs, but they are now the second largest portion of operating costs.

In the case of express package operations, the 767-300BDSF and A300-600RF have the overall lowest per lb, at 25 cents. The A330-300P2F has a marginally higher cost, while the A330-200P2F's is 4.4 cents, and the 757-200PCF's is 7.3 cents per lb higher. The 757-200's main problem is its relatively small payload. Its overall trip cost is $6,000 or 26% less than the 767-300BDSF. The A330-200P2F has a $5,000 or 20% higher trip cost than the 767-300BDSF.

In the case of general freight operations, the 767-300BDSF and A300-600RF again have the lowest costs per lb at about 28 cents. The 757-200PCF's trip cost is about $8,000 less, while the A330-200P2F's trip cost is about $7,000 higher than the 767-300BDSF. This differences have to be considered in relation to the payload capacities of the aircraft, and the possible differences in revenue that they can generate.

In this scenario the 757-200PCF has a cost per lb of 31 cents, which is the same as the A330-200P2F. The A330-300P2F's trip cost is $9,000 or 31% higher than the 767-300BDSF's. The two have a similar cost per lb. AC