The first 747-400s are due to be converted. These aircraft will have almost an identical amount of deck space for freight carriage as -400Fs. There are many loading configuration options available to operators, all allow a high packing density so that the aircraft can carry most types of freight.

The revenue carrying capacity of the 747-400

The first 747-400SF will soon be delivered to Cathay Pacific Airways. So far only two companies, Boeing and Bedek, have the necessary certificate and capability to convert 747-400s to freighter configuration. Conversion of more than 30 747-400s has been confirmed for airlines, most of which are based in the Asia Pacific and have a strong need to accommodate a booming cargo traffic. The air freight market is now experiencing a strong recovery around the world, however, and many other airlines have overdue fleet replacement programmes. Demand for more 747-400 conversions is therefore expected to be strong. Closely analysing the 747-400SF's revenue generating capacity is therefore advisable. This capacity varies, however, according to the conversion programme used, the three types of engine powering the aircraft, and the cargo loading configurations available.

Description

The 747-400SF has a strengthened maindeck floor, full maindeck lining, and provision for a new cargo handling system and revised flightdeck system. The floor of the upper passenger deck has been shortened, and a ladder has replaced the passenger stairway. The aircraft receives a side cargo door and an internal layout identical to that of the 747-400F.

This maindeck layout includes 30 pallet positions and a comparable containerised volume to the -400F. The upper deck of the converted freighter is capable of seating up to 19 people, an option found on no other converted freighter.

The -400SF has a maximum take-off weight (MTOW) of 870,000lbs and a maximum zero fuel weight of 610,000lbs (MZFW). Compared to the 747-200SF and 747-300SF, the -400SF's MTOW and MZFW are 37,000lbs and 20,000lbs higher. The -400SF's MTOW is 5,000lbs less than the 747-400F's, but the two aircraft share the same MZFW. The Boeing conversion 747-400BCF has a fuel capacity of 53,765 US Gallons (USG). The aircraft can fly 4,400nm with a full payload.

By comparison, the 747-400F has a fuel capacity of 57,285USG. With an MZFW of 610,000lb, the -400F can fly a full payload over 5,000nm, 600nm longer than the -400SF.

The gross structural payload is the difference between the MZFW and operating empty weight (OEW). Freighters, however, use containers and pallets, and their weight uses some of the gross structural payload. The net structural payload is therefore the difference between the gross structural payload and the total tare weight of all containers and pallets used in the particular freight loading configuration. Although the -400SF's MTOW and MZFW are standardised for Boeing and Bedek conversions, the OEW varies according to aircraft, conversion programme and engine type.

Boeing and Bedek are the only two players in the 747-400 conversion

Converted 747-400s will have virtually the same main deck space for accommodating pallets and containers as -400Fs. The 747-400SF will only have a side cargo door, and not a nose door. There are two conversion programmes and three engine types, resulting in six different structural payloads varying between 247,000lbs and 250,500lbs.

The 747-400SF can utilise many different pallet & container types. These provide a total useable volume of 24,300 to 26,500 cubic feet. The aircraft's net structural payload of 234,000-241,000lbs gives it a maximum packing density of more than 9.0lbs per cubic foot in most configurations. A packing density of 7.5lbs per cubic foot gives it a volumetric payload of 182,300-198,900lbs.

market. Taking advantage of its position as original equipment manufacturer (OEM), Boeing already has got more airline customers confirmed to convert 747-400s than Bedek. Bedek will convert four -400s for Atlas Air and two -400 combis for Guggenheim Aviation Partners. Evergreen Airlines, a Taiwan-based carrier, has also agreed to have Bedek convert four 747-400 Combis into SFs with an option for two more. The work will begin in 2007 and end in 2009. Apart from the price of the conversion kits, the key difference between the aircraft converted by the two companies is their OEW weights. "Boeing is more conservative than Bedek in terms of weight saving. Bedek removes more unnecessary wires and parts from the aircraft, which will make our aircraft lighter than Boeing's proposal," says Steve Huang, junior vice president, business co-ordination department at Eva Airlines.

The engine type powering the aircraft is another contributing factor to the -400SF's revenue potential. The 747-400 is equipped with the 56,700lbs thrust General Electric CF6-80C2B1, the 56,000lbs thrust Pratt & Whitney PW4056 or the 58,000lbs thrust Rolls-Royce RB211-524H. The weight of these engines varies, and so with four engines on each aircraft there are differences in OEW between the three types.

"For the GE models, the OEW varies between 359,000lbs and 361,000lbs. However, in some cases it may be less. Rolls-Royce models have a weight penalty of up to about 3,000lbs over GE-powered aircraft. The Pratt & Witney models are somewhere in between," says Jacob Netz, director of analysis & strategy of freighter conversions at Bedek Aviation Group.

Although the Rolls-Royce engine can provide the highest thrust, it is the heaviest of the three engine types, due mainly to its three-shaft configuration. The operator of the -400SF therefore has to bear an increase of 3,000lbs in the OEW, and proportionate reduction of gross structural payload. The Pratt & Whitney engine also makes the -400SF's OEW slightly higher than the GE engine. making the GE engine the likely choice of freight airlines.

With the CF6-80C2 engine, the OEW of Boeing's -400SF is 359,500lb and Bedek's 360,000lbs *(see first table, page 59)*. Equipped with Pratt & Whitney engines, the Boeing's -400SF has an OEW of 361,000lbs and Bedek's 363,000lbs *(see first table, page 59)*. With Rolls-Royce engines, the OEW for Boeing's -400SF is 361,300lbs and for Bedek's is 361,500lbs *(see first table, page 59)*.

Because these aircraft share the same MZFW, there are six different OEW variants which result in six different maximum gross structural payloads for the -400SF *(see first table, page 59)*. Among the six types of the -400SF types, aircraft equipped with CF6-80C2 engines and converted by Boeing have the highest gross structural payload, which is 3,500lbs higher than for an aircraft equipped with Rolls-Royce engines and converted by Bedek.

Containers and pallets

The cargo volume the -400SF can carry depends on the containers and pallets it uses. Twenty eight types of container and pallet can be used in the -400SF and are suitable to transport goods of different shapes, sizes and densities.

Of the containers and pallets available, the LD-9 pallet (96-inch X 125-inch) and lower deck LD-1 container are most widely used by 747-400F operators.

The LD-9 pallet is a universal general-purpose flat pallet for lower and maindecks. The goods on the pallet can be piled up to 118 inches and produce a maximum volume of 750 cubic feet (cu ft). The LD-9's tare weight is 265lbs.

The LD-7 pallet, which is a universal general-purpose flat pallet for lower and maindecks, is also popular. Its tare weight is 231lbs and can provide a maximum volume of 680 cu ft with a height of 10 feet.

The LD-1 container, whose tare weight varies from 155lbs to 375lbs, is a half-width lower deck container with one angled side, and a canvas or solid. It can provide a maximum volume of 175 cu ft.

The standard cargo configuration for a 747-400SF is 39 LD-9 pallets and a bulk of 835 cu ft. This gives the aircraft a cargo volume of 24,962 cu ft. The maximum cargo volume the -400F can provide is about a cargo volume of 25,200 cu ft; 300 cu ft higher than the -400SF in this configuration.

Different operators use different pallet and container configurations. Dragonair, a Hong Kong-based carrier, which has booked five -400SFs, will allocate 21 ten-foot pallets with 118 inches height (Q7), and nine ten-foot pallets with 88 inches height (X8) or nine AMA containers, and two half-position pallets (PEB) on the main deck. The Q7 is able to provide a cargo volume of 747cu ft. The X8 provides a volume of 494 cu ft. The 21

Q7s, nine X8s and two PEBs together provide a total cargo volume of 20,557 cu ft.

Eight 10-feet pallets with 64 inches height (A2) and four AKE containers can be allocated on the lower deck. Each A2 provides a cargo volume of 402 cu ft and each AKE container 151.8 cu ft, generating a total lower deck cargo volume of 3,824 cu ft.

In total the Dragonair version -400SF will provide a cargo volume of 24,381 cu ft. The tare weight is 231lbs for the ten-foot pallet, 121 lb for the PEB and 231lbs for the AKE container. The total tare weight in this configuration is 8,096lbs.

WEIGHT SPECIFICATIONS OF 747-400SF VARIANTS

Conversion variant	Boeing	Boeing	Boeing	Bedek	Bedek	Bedek
Engine model	CF6-80C2	PW4000	RB211-524	CF6-80C2	PW4000	RB211-524
MTOW lbs	870,000	870,000	870,000	870,000	870,000	870,000
MZFW lbs	610,000	610,000	610,000	610,000	610,000	610,000
OEW lbs	359,500	361,000	361,300	360,000	363,000	361,500
Gross structural payload lbs	250,500	249,000	248,700	250,000	247,000	248,500

747-400SF CONTAINER & PALLET CONFIGURATIONS

Freight configuration	Configuration 1	Configuration 2	Configuration 3	Configuration 4
Maindeck				
Container/pallet type	LD-9	LD-9	LD-7	LD-7
Number	30	30	30	30
Unit volume cu ft	682	682	554-680	554-680
Unit tare weight lbs	265	265	231	231
Total volume cu ft	20,464	20,464	19,487	19,487
Total tare weight lbs	7,950	7,950	6,930	6,930
Lower deck				
Container/pallet type	LD-9 & LD-1	LD-1	LD-1	LD-9 & LD-1
Number	9 + 2	30	30	9 + 2
Unit volume cu ft	407 + 175	175	175	407 + 175
Unit tare weight lbs	265 + 155	155	155	265 + 155
Bulk volume cu ft	810	810	810	810
Total volume cu ft	4,823	6,060	6,060	4,823
Total tare weight lbs	2,695	4,650	4,650	2,695
Total volume cu ft	25,287	26,524	25,547	24,310
Total tare weight lbs	10,645	12,600	11,580	9,625

Revenue capacity comparison

To simplify the analysis, a 747-400SF converted by Boeing and equipped with CF6-80C2 engines is used. This aircraft's revenue capacity is determined by the tare weight and volume of the container and pallet combination it carries.

Since more than 20 containers and pallets are suitable for the aircraft, there are numerous possible configurations. Operators of the aircraft, however, strike a balance between saving operating cost and meeting market demand, and so choose between only a few combinations of containers and pallets. Four key configurations of pallets and containers are analysed here.

Configuration 1

The first combination includes 30 LD-9 pallets on the maindeck and nine LD-9 pallets and two LD-1 containers on the lower deck. On the maindeck the goods on nine LD-9 pallets are piled 86 inches high and the remaining 21 pallets are loaded 118 inches high, giving a total maindeck volume is 20,464 cu ft.

Goods on the nine LD-9 pallets on the lower deck are piled 64 inches high, generating a volume of 3,663 cu ft. The two LD-1s provide another 350 cu ft so, including a volume of 810 cu ft provided by the bulk hold, the total cargo volume on the lower deck is 4,823 cu ft. The total cargo volume provided by this configuration is therefore 25,287 cu ft *(see second table, this page)*.

The 39 LD-9s and two LD-1s result in a total tare weight of 10,645lbs *(see second table, this page)*.

Configuration 2

The second configuration includes 30 LD-9 pallets on the main deck and 30 LD-1 containers on the lower deck. Freight on the 30 pallets is piled up as in the first configuration, producing a cargo volume of 20,464 cu ft. The total tare weight of these 30 pallets is 7,950lbs. The 30 LD-1s on the lower deck generate a cargo volume of 5,250 cu ft and have a total tare weight of 4,650lbs. With the bulk volume of 810lb, the total cargo volume on the lower deck is 6,060 cu ft.

Hence the total cargo volume provided by this configuration is 26,524 cu ft and the total tare weight of the pallets and containers is 12,600lbs *(see second table, this page)*.

Configuration 3

30 LD-7 pallets on the maindeck and 30 LD-1 containers on the lower deck are used in this configuration. Freight on the first two LD-7 contoured pallets at the front of the maindeck is loaded 96 inches high, giving a cargo volume of 493 cu ft and 554 cu ft. Goods on the next five LD-7s are piled up to 96 inches and generate a cargo volume of 2,800 cu ft. Freight on the remaining 23 LD-7s are piled 120 inches high with a volume of 15,640 cu feet. The total cargo volume on the main deck is 19,487 cu ft, and the tare weight of the 30 LD-7s is 6,930lbs.

The 30 LD-1s on the lower deck generate a total cargo volume of 5250 cu ft. With a bulk cargo volume of 810 cu ft, the total cargo volume on the lower deck reaches 6,060 cu ft. The total tare weight of the LD-1s is 4,650lbs.

The total cargo volume provided by this combination is 25,547 cu ft, and the total tare weight incurred is 11,580lbs *(see second table, this page)*.

Configuration 4

Thirty LD-7 pallets on the maindeck, and nine LD-9 pallets and two LD-1s on the lower deck are used in this combination. The height of freight on the LD-7s, is the same as in Configuration three and therefore produces a total cargo volume of 19,487 cu ft. The total tare weight of the 30 LD-7s is 6,930lbs.

The nine LD-9s on the lower deck can

AIRCRAFT VARIANT & CONTAINER COMBINATIONS

Container configuration	Configuration 1	Configuration 2	Configuration 3	Configuration 4
Volume cu ft	25,287	26,524	25,547	24,310
Tare lbs	10,645	12,600	11,580	9,625
Volumetric payload lbs	189,652	198,930	191,602	182,325
Aircraft variant				
Boeing CF6-80c2				
Net structural payload lbs	239,855	237,900	238,920	240,875
Packing density lbs/cu ft	9.49	8.97	9.35	9.91
Boeing PW4000				
Net structural payload lbs	238,355	236,400	237,420	239,375
Packing density lbs/cu ft	9.43	8.91	9.29	9.85
Boeing RB211-524H				
Net structural payload lbs	238,055	236,100	237,120	239,075
Packing density lbs/cu ft	9.41	8.90	9.28	9.83
Bedek CF6-80c2				
Net structural payload lbs	239,355	237,400	238,420	240,375
Packing density lbs/cu ft	9.47	8.95	9.33	9.89
Bedek PW4000				
Net structural payload lbs	236,355	234,400	235,420	237,375
Packing density lbs/cu ft	9.35	8.84	9.22	9.76
Bedek RB211-524H				
Net structural payload lbs	237,855	235,900	236,920	238,875
Packing density lbs/cu ft	9.41	8.89	9.27	9.83

produce a volume of 3,663 cu ft and have a total tare weight of 2,385lbs. The two LD-1 containers generate a volume of 350 cu ft and incur a total tare weight of 310lbs. Thus the total cargo volume on the lower deck is 4,823 cu ft and has a total tare weight of 2,695lbs.

The total cargo volume provided by this combination is 24,310 cu ft and the total tare weight is 9,625lbs *(see second table, page 59)*.

Analysis

Among the four configurations, Configuration 4 has the lowest total volume and tare weight.

Configuration 2 adopts 30 LD-9 pallets on the main deck and 30 LD-1s on the lower deck, which together provide the largest volume of 26,524 cu ft among the four combinations. The arrangement also has the highest tare weight of 12,600lbs.

Configurations 1 and 3 provide similar volumes of about 25,500 cu ft, but Configuration 3 is 930lbs heavier.

Combinations

There are six different aircraft variants, with three engine types and two conversion programmes. For all three engine types, the Bedek-converted aircraft have a small payload disadvantage of 200-500lbs.

The four different container/pallet configurations mean there are 24 aircraft combinations to consider. The net structural payload and maximum packing density of each are summarised *(see table, this page)*. The volumetric payload of each with freight packed at 7.5lbs per cubic foot is also shown.

The highest net structural payload is provided with the CF6-powered aircraft using the fourth container configuration. This option allows freight to be packed at almost 10lbs per cubic foot. Aircraft using the second container configuration have the lowest net payload, although it allows freight to be packed at nearly 9lbs per cubic foot.

The difference between the aircraft that have the highest and lowest net structural payloads is 6,475lbs (about two and a half tons). This is small when typical load factors are considered.

Loading Configuration 3 may be the most desirable, since it is the simplest in terms of using the fewest types of container, and still allows freight to be packed at more than 9lbs per cubic foot.

Considering a probable packing density of 7.5lbs per cubic foot for many freight types, Configuration 2 provides the highest volumetric payload of 198,930lbs, by virtue of it having the highest containerised volume.

Unit cost analysis

Air freight business is a business has a low profit margin. To explore the necessary yield covering the aircraft's operating cost, a sector of 5,000nm is used here. The air freight operators in Asia Pacific often fly the range, about equal to the equivalent still air distance tracked from Beijing to Seattle. A total fuel burn of about 33,500USG is required to fly this sector. Fuel price is assumed to be $1.8 per gallon. The total trip cost, including maintenance, crew, engine inventory, navigation and landing fees, and lease costs is expected to be about $108,000.

This cost divided by the volumetric payload of the four configurations is: 57 cents per lb for Configuration 1, 54 cents per lb for Configuration 2, 56 cents per lb for Configuration 3, and 59 cents per lb for Configuration 4.

Fuel burn is 22,600USG on a 3,500nm sector, which equals a fuel cost of $40,700, and total trip cost is about $77,000. The unit cost is 41 cents for Configuration 1, 39 cents for Configuration 2, 40 cents for Configuration 3, and 42 cents for Configuration 4.

On a sector of 2,500nm, fuel burn is about 15,900USG, which is equal to a fuel cost of $28,600 at a price of $1.8 per gallon. The total trip cost is expected to be about $57,300. In this case, the unit cost is 30 cents per lb for Configuration 1, 29 cents for Configuration 2, 30 cents for Configuration 3, and 31 cents per lb for Configuration 4. The fourth configuration has the highest unit cost because of its lower volumetric payload.

Summary

With either conversion and loading configuration, the 747-400SF has net structural payloads that give it a maximum packing density of 8.9-9.2lbs per cubic foot, which is higher than most types of freight. With a packing density common to most types of freight, the aircraft has a volumetric payload of 182,000-199,000lbs. The aircraft has the ability to carry high-density freight. AC