

P-to-F conversions will be available for four additional narrowbody types by the end of the decade. The latest P-to-F programme developments are summarised here, including current and proposed specifications. Recent and future demand trends are also discussed.

Narrowbody freighters: options & demand trends

Narrowbody aircraft represent an important element of the global air cargo fleet. There are no dedicated new-build, narrowbody commercial freighters available, so any future capacity requirements will need to be satisfied by aircraft that have undergone passenger-to-freighter (P-to-F) conversions.

There are a number of established narrowbody conversion programmes. In recent years, conversion providers have launched a range of P-to-F solutions for younger aircraft platforms.

The latest status of each narrowbody conversion programme is analysed here, covering those P-to-F programmes that are in production, and those where the supplemental type certificates (STCs) are in development or awaiting final approval. Typical narrowbody freighter loading configuration, payload and volume specifications are identified. Cargo demand and fleet trends are also discussed.

Cargo trends

Air cargo demand trends will have a significant influence on any future narrowbody freighter requirements.

The International Bureau of Aviation (IBA) recently launched a freighter advisory and project management service for investors, lessors and operators. IBA has provided *Aircraft Commerce* with cargo demand data for the past 10 years. This shows that the total cargo carried by air, expressed in freight tonne kilometres (FTKs), was increasing year-on-year before the global economic downturn. From 2006 to 2007, global FTKs grew by just under 5%. The global recession led to two consecutive years of contraction in 2008 and 2009, followed by a return to growth in 2010. Another slowdown occurred in 2011 and 2012 with total FTKs in decline, before the market returned to growth in 2013.

“Air freight demand is driven by global economic and trade growth,” says Moshe Haimovich, head of freighter/P2F cargo conversion advisory services at IBA. “Before the economic downturn, air freight was growing at a rate of 6% per year, twice the rate of global gross domestic product (GDP). Today aircraft manufacturers and industry experts agree that the long-term growth rate is more likely to be 3-4% per year, which is in line with world trade growth.”

“Broadly speaking there has been a shallow recovery in air cargo demand, since the last global recession nearly 10 years ago, but yields have remained relatively low,” explains Kevin Casey, president at Spectre Air Capital, Cargo Aircraft Solutions. “There are a number of macro-economic reasons for the shallower air cargo growth and stagnant yields of the past decade. Immediately following the downturn, these included less emphasis on time-sensitive deliveries of luxury goods, as organisations looked for lower-cost options. Alternative modes of transport, including shipping, road and rail, picked up some demand previously served by aircraft. There were also changes in supply chain strategies with some logistics companies establishing more regional warehouses, which reduced the need for air transportation.

“More recently, in the past 18 months, demand has picked up, mainly driven by e-commerce,” continues Casey. Yields have remained consistently low for all types of air cargo, however. A typical rate for express cargo is \$1.00 per kilogram of freight.

Narrowbody freighters could be used for express or integrator, general freight or mail services. Express freight and mail services typically involve the carriage of small, light parcels. These types of operation have relatively low packing densities of 6.0-7.0 lbs per cubic foot (lbs/cu ft). This type of cargo is often containerised and operations are usually

based on scheduled hub-and-spoke networks.

General freight usually involves the carriage of heavier, bulkier items, including specialist industrial equipment. It has higher packing densities, which would typically be in excess of 9.0lbs/cu ft. General freight is typically shipped on pallets, and operations are more likely to involve point-to-point services and occasional ad-hoc charters.

VX Capital Partners specialises in mid-life aircraft leasing and has recently raised a private equity fund dedicated to narrowbody freighter conversions. More than half of its total portfolio consists of 737-400 freighters. “The express market currently accounts for just over 50% of the worldwide narrowbody freighter fleet,” says Robert Brown, partner at VX Capital Partners. “Express operators are, however driving about two-thirds of the demand for current narrowbody conversions. In the future, we expect about 70% of narrowbody conversion demand to come from the express segment, with general freight and air mail operators accounting for about 15% each.”

E-commerce is one market that has seen expansion in recent years. This could lead to a significant growth in express package demand. “E-commerce is definitely boosting air freight demand, as is intercontinental cargo related to higher-value and time-sensitive goods including pharmaceuticals and perishables,” says Haimovich. “Demand for freighters varies between the regions. In Europe, for example, some of this demand could be satisfied by alternative modes of transport, due to the relatively short distances between population centres, and the continent’s established road and rail infrastructure.”

There is a general consensus that China could see some of the largest growth in air cargo demand. “Chinese integrator SF Express recently announced

NARROWBODY FREIGHTER ULD SPEC ASSUMPTIONS

Container	Internal Volume (cu ft)
88" x 108" x 78"	368
88" x 125" x 82" (AAY)	438
88" x 53" x 64" (AEP)	152
80" x 43" x 57" (AYK)	103
88" x 78.9" x 62.5" (AYF)	193
88" x 125" x 80"	436
88" x 125" x 64" (LD9)	364
60.4" x 61.5" x 64" (LD3)	159
60.4" x 61.5" x 45" (LD3-45)	131
27" x 125" x 80"	156

a joint venture (JV) with UPS which will combine the strengths of SF's Chinese domestic footprint with UPS's global network starting from North America," says Haimovich. "This has been driven by a growth in e-commerce. It is likely that there will be more JVs between the main integrators and local operators in the Far East."

"North-East Asian express carriers could see some of the highest demand for narrowbody freighters in the near to medium term," suggests Casey. "This is mainly due to the expansion of the middle class in this region. There has been an enormous growth in China of middle-class buying power led by young, brand-conscious and technically savvy individuals who buy e-commerce goods via their smartphones and tablets. This has led to demand for high-value and time-sensitive deliveries for products ordered from business-to-business (B2B) e-commerce platforms, like Alibaba.com, business-to-consumer (B2C) platforms like Tmall.com, and consumer-to-consumer (C2C) platforms like Taobao.com, as well as large Western e-commerce platforms like Amazon.com and eBay. There is already a lot of e-commerce demand within China and more developing every day."

Fleet trends

According to Flightglobal's Fleets Analyzer, there are 617 narrowbodies operating primarily as freighters as of 28th June 2017. This excludes Russian types, and represents an 8% reduction in the active fleet since June 2007.

The active fleet consists of 757-200s (282 aircraft), 737-300s (114), 737-400s (108), 727-200s (52), DC9s (25), 737-200s (20), MD-80s (9), 727-100s (2), DC8s (4) and a single 737-700. Most of these aircraft have undergone conversion, although some are actually production freighters, including 79 757-200s that

were manufactured by Boeing from 1987 to 1999. There are also a small number of quick change, Combi and convertible types in operation.

An aircraft in quick change, convertible or Combi configuration is generally indicated by the inclusion of QC, C or Combi in the designation suffix. The suffixes used for convertible and Combi aircraft can vary however. "QC aircraft have their seats installed on pallets, so that they can be quickly converted from all-freight to passenger configuration, and back again," says Haimovich. Convertible aircraft can also be converted between all-freight and passenger configurations, but not as quickly. Narrowbody Combis are designed for dual freight and passenger carriage on the main deck. Cargo is usually loaded at the front with passenger seats configured in a separate rear section.

QC, C and Combi variants are provided with a large main deck cargo door, like a standard dedicated freighter. Very few QC, C and Combi types have been produced. A small number of the 617 narrowbodies operating as dedicated freighters appear to be QC or C variants, including seven 737-200Cs, four 737-200QCs and five 737-300QCs. Fleets Analyzer lists another 28 aircraft with a primary role of 'Quick change/convertible', and 27 more with a Combi role. All 55 aircraft are either 737s or 757s, used for both passenger and cargo requirements, so they cannot be considered as primary freighters.

"Over the past 10 years there has been an evolution in the narrowbody freighter fleet, with older types superseded by 757-200s and 737 Classic variants," says Haimovich. "There have been major fleet retirements of 727s, DC-8s, DC-9s and 737-200s." Flightglobal's Fleets Analyzer shows that the number of these aircraft operating as freighters decreased by 81%, 96%, 64% and 33%

respectively from 2007 to 2017. During the same period, the number of in-service 757-200, 737-300 and 737-400 freighters more than doubled. The 757-200 and 737-300 freighter fleets have increased by 124% and 115%, while the 737-400 fleet has increased from three to 108 aircraft.

"In some cases there was a trend to replace older types with larger aircraft," continues Haimovich. "Some operators replaced 727-200s with 757-200s."

FedEx and UPS have both replaced 727s with 757-200 freighters. FedEx operates a fleet of converted 757-200 aircraft, while UPS opted for the production freighter variant.

Flightglobal's Fleets Analyzer shows that 388 narrowbodies were converted into full freighters in the 10 years from 2007. This excludes conversions carried out for government or military operations. More than half of the 387 conversions took place from 2013 to 2016 as the global economy continued to recover from the downturn, with the highest conversion rates in 2014 and 2016 when 58 and 56 aircraft were modified. Narrowbody conversions were dominated by the 757-200, 737-400 and 737-300 from 2007 to 2016. These aircraft accounted for 47%, 29% and 20% of full-freight conversions, and a combined 96% of the market in total. This dominance has continued in 2017. Up to 27 full-freight conversions were completed on narrowbody types as of 28th June 2017. This included eight 757-200s, 12 737-400s and three 737-300s. In addition, a small number of QC and Combi modifications were performed for commercial operators from 2007 to 2016.

There are no new-build freighters in the narrowbody market. "There is no business sense in developing a new-build narrowbody freighter, since it would involve spreading high capital costs over low units of utilisation," says Haimovich. "It is also unlikely that a new-build freighter would offer a significant advantage in operational performance over a converted freighter."

"Narrowbody freighters typically fly 80-100 flight hours (FH) per month," says Casey. "Few air freight markets can support high capital costs with such a low level of utilisation. Low utilisation also means that operators may not need the incrementally higher level of dispatch reliability offered by a new-build aircraft. The 737NG and 737 Classic freighter's 99.8% or 99.2% reliability rate will be more than adequate for even the most reliability-sensitive operations."

There are active P-to-F conversion programmes for the 737-300, 737-400, 757-200 and MD-80 family. Conversion programmes are also being developed, or are awaiting STC approval, for the 737-700, 737-800, A320 and A321.

NARROW/BODY FREIGHTER SPECIFICATIONS - IN PRODUCTION PROGRAMMES

Aircraft Type	MD-82/-88SF	MD-83SF
Engines	JT8D	JT8D
Conversion provider	AEI	AEI
MTOW (lbs)	up to 149,500	up to 160,000
MZFW (lbs)	up to 122,000	up to 122,000
Gross structural payload (lbs)	up to 46,600	up to 45,100
Main deck positions	12-88" x 108"	12-88" x 108"
Lower deck positions	Bulk only (1,253 cu ft)	Bulk only (1,013 cu ft)
Main deck volume (cu ft)	4416	4416
Total volume inc LD bulk (cu ft)	5,669	5,429

Aircraft Type	737-300SF 9-position	737-300SF 10-position	737-300F
Engines	CFM56-3	CFM56-3	CFM56-3
Conversion provider	AEI	AEI	PEMCO
MTOW (lbs)	up to 139,500	up to 139,500	up to 139,500
MZFW (lbs)	up to 109,600	up to 109,600	up to 109,600
Gross structural payload (lbs)	42,900	42,900	43,100
Main deck positions	9-88" x 125" (8AAY + 1LD3)	8-88" x 125" (8AAY) + 1AEP + 1LD3	8-88" x 125" (8AAY) + 1LD3
Lower deck positions	Bulk only (973 cu ft)	Bulk only (973 cu ft)	Bulk only (1,068 cu ft)
Main deck volume (cu ft)	3,868	3,815	3,663
Total volume inc LD bulk (cu ft)	4,841	4,788	4,731

Aircraft Type	737-400SF SGW	737-400F SGW	737-400SF HGW	737-400F HGFW
Engines	CFM56-3	CFM56-3	CFM56-3	CFM56-3
Conversion provider	AEI	PEMCO	AEI	PEMCO
MTOW (lbs)	up to 143,500	up to 143,500	up to 150,000	up to 150,000
MZFW (lbs)	up to 113,000	up to 113,000	up to 117,000	up to 117,000
Gross structural payload (lbs)	43,100	45,750	47,100	47,890
Main deck positions	10-88" x 125" (10AAY) + 1LD3	1 (27" x 125") + 10-88" x 125"*	10-88" x 125" (10AAY) + 1LD3	1 (27" x 125") + 10-88" x 125"*
Lower deck positions	Bulk only (1,256 cu ft)	Bulk only (1,373 cu ft)	Bulk only (1,256 cu ft)	Bulk only (1,373 cu ft)
Main deck volume (cu ft)	4,539	4,534	4,539	4,534
Total volume inc LD bulk (cu ft)	5,795	5,907	5,795	5,907

Aircraft Type	757-200PCF Standard MZFW	757-200PCF OEM Upgrade	757-200PCF Precision Upgrade	757-200SF Standard MZFW	757-200SF OEM Upgrade
Engines	RB211-535/PW2000	RB211-535/PW2000	RB211-535/PW2000	RB211-535/PW2000	RB211-535/PW2000
Conversion provider	Precision	Precision	Precision	ST Aerospace	ST Aerospace
Winglets	No	No	No	No	No
MTOW (lbs)	250,000	250,000	250,000	250,000	250,000
MZFW (lbs)	184,000	188,000/186,000	200,000/198,000	184,000	188,000/186,000
Gross structural payload (lbs)	68,000/68,350	72,000/70,350	84,000/82,350	67,000	71,000/69,000
Main deck positions	15-88" x 125" (15 AAY)	15-88" x 125" (15 AAY)	15-88" x 125" (15 AAY)	15-88" x 125" (15 AAY)	15-88" x 125" (15 AAY)
Lower deck positions	Bulk only (1,794 cu ft)	Bulk only (1,794 cu ft)	Bulk only (1,794 cu ft)	Bulk only (1,794 cu ft)	Bulk only (1,794 cu ft)
Main deck volume (cu ft)	6,570	6,570	6,570	6,570	6,570
Total volume inc LD bulk (cu ft)	8,364	8,364	8,364	8,364	8,364

Aircraft Type	757-200PCF Standard MZFW	757-200PCF OEM Upgrade	757-200PCF Precision Upgrade	757-200SF Standard MZFW	757-200SF OEM Upgrade
Engines	RB211-535/PW2000	RB211-535/PW2000	RB211-535/PW2000	RB211-535/PW2000	RB211-535/PW2000
Conversion provider	Precision	Precision	Precision	ST Aerospace	ST Aerospace
Winglets	Yes	Yes	Yes	Yes	Yes
MTOW (lbs)	250,000	250,000	250,000	250,000	250,000
MZFW (lbs)	185,400	189,400/187,400	200,000/198,000	185,400	189,400/187,400
Gross structural payload (lbs)	68,000/68,350	72,000/70,350	82,600/80,950	67,000	71,000/69,000
Main deck positions	15-88" x 125" (15 AAY)	15-88" x 125" (15 AAY)	15-88" x 125" (15 AAY)	15-88" x 125" (15 AAY)	15-88" x 125" (15 AAY)
Lower deck positions	Bulk only (1,794 cu ft)	Bulk only (1,794 cu ft)	Bulk only (1,794 cu ft)	Bulk only (1,794 cu ft)	Bulk only (1,794 cu ft)
Main deck volume (cu ft)	6,570	6,570	6,570	6,570	6,570
Total volume inc LD bulk (cu ft)	8,364	8,364	8,364	8,364	8,364

Notes:

- 1). Gross structural payload refers to payload available for ULDs and cargo. These are estimates. Payload will vary slightly by individual aircraft owing to differences in OEWS.
- 2). 737 Classic conversions based on aircraft without winglets
- 3). PEMCO 737-400F can accommodate up to nine AAY containers. Final 88" x 125" main deck position of PEMCO 737-400F conversions limited to 80-inches in height.
- 4). ST Aerospace is developing MZFW upgrades to increase 757 MZFW to 200,000lbs for RR-powered aircraft and 198,000lbs for PW-powered examples.
- 5). ST Aerospace 757-200SF weight specs do not differentiate OEW between aircraft with RB211-535 and PW2000 series engines but Precision does for its 757-200PCF.

Conversion providers

The main narrowbody conversion providers have been summarised. Some also offer widebody or regional jet conversions, but only their narrowbody P-to-F modification activities are shown here.

AEI

Aeronautical Engineers Inc (AEI) has active full-freight conversion programmes for the 737-300, 737-400 and MD-80 family. It is developing an additional programme for the 737-800, for which it is expecting to receive STC approval from the Federal Aviation Administration (FAA) in late 2017. The programme is then due to enter the production phase in 2018.

Aircraft that are converted by AEI are designated by the SF suffix. AEI has already converted five MD-82SFs, four MD-83SFs, 17 737-300SFs and 88 737-400SFs. It has another five MD-83 and 27 737-400 conversions booked, and 101 orders and commitments for 737-800SF conversions.

AEI has five maintenance, repair & overhaul (MRO) partner facilities where narrowbodies can be converted: Commercial Jet Inc in Miami, Florida; Commercial Jet Services in Dothan,

Alabama; FlightStar in Jacksonville, Florida; KF Aerospace in Kelowna, Canada; and Boeing Shanghai in China.

Boeing

Boeing is developing a P-to-F conversion for the 737-800. It expects to receive FAA type design approval in December 2017.

Converted aircraft will be designated with the BCF suffix. "We have 60 orders and commitments for 737-800BCFs," says Kurt Kraft, vice president of modification engineering, engineering, modification and maintenance, Boeing Global Services. "A few conversion slots are available in 2018 and 2019, but the line is filling up quickly. We predict that demand for standard-body (narrowbody) freighters will continue to grow, with more than 40% of demand coming from Asia."

Conversions will take place at two MRO facilities in China: STAECO in Jinan and Boeing Shanghai Aviation Services.

EFW

Elbe Flugzeugwerke (EFW) is developing P-to-F conversion programmes for the A320 and A321 in association with its main shareholders,

ST Aerospace and Airbus. ST Aerospace is developing the STC in co-operation with EFW and Airbus. The STC will then be held by EFW.

Converted aircraft will be given the P2F designation. "We are targeting STC approval from the European Aviation Safety Agency (EASA) in 2019 for the A321P2F and 2020 for the A320P2F," says Thomas Centner director, sales, aircraft conversions at EFW. "We plan to commence serial conversion activities immediately after receiving the STC."

Initial conversions will be completed at EFW's facility in Dresden, Germany, but additional lines will be added at the ST Aerospace facility in Singapore. If demand dictates, conversion lines will also be added in Guangzhou, China and in the US.

"We are introducing potential operators to the latest configuration developments, and we are confident that we will be able to disclose launch customers soon," says Centner.

IAI Bedek

The Bedek Aviation Group of Israel Aerospace Industries (IAI) is developing conversions for 737-700s and 737-800s. In June 2017 it announced a partnership agreement for developing the relevant STCs, with Haite Group subsidiary

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NARROWBODY FREIGHTER SPECIFICATIONS - PROGRAMMES IN DEVELOPMENT

Aircraft Type	A320P2F	A321P2F
Engines	CFM56-5/V2500	CFM56-5/V2500
Conversion provider	EFW	EFW
MTOW (lbs)	up to 171,958	up to 206,132
MZFW (lbs)	up to 137,789	up to 162,701
Gross structural payload (lbs)	up to 46,297	up to 59,525
Gross structural payload (Metric Tonnes)	up to 21	up to 27
Main deck positions	11 - 88" x 125" (10 AAY + 1 LD9)	14 - 88" x 125" (14 AAY)
Lower deck positions	7 x LD3-45 or 1,322 cu ft bulk	10 x LD3-45 or 1,829 cu ft bulk
Main deck volume (cu ft)	4,744	6,132
Total containerised volume (cu ft)	5,661	7,442
Total volume if LD bulk loaded (cu ft)	6,066	7,961

Aircraft Type	737-700BDSF	737-700
Engines	CFM56-7B	CFM56-7B
Conversion provider	IAI Bedek	PEMCO
MTOW (lbs)	up to 154,500	up to 154,500
MZFW (lbs)	up to 121,700	up to 121,700
Gross structural payload (lbs)	up to 45,000	up to 45,000
Main deck positions	8 - 88" X 125' (8 AAY) + 1 AYK + 1 AYF	8 - 88" X 125' (8 AAY) + 1LD3
Lower deck positions	Bulk only (966 cu ft)	Bulk only (966 cu ft)
Main deck volume (cu ft)	3,800	3,663
Total volume if LD bulk loaded (cu ft)	4,766	4,629

Aircraft Type	737-800BDSF	737-800SF	737-800BCF
Engines	CFM56-7B	CFM56-7B	CFM56-7B
Conversion provider	IAI Bedek	AEI	Boeing
MTOW (lbs)	up to 174,200	up to 174,200	up to 174,200
MZFW (lbs)	up to 138,300	up to 138,300	up to 138,300
Gross structural payload (lbs)	up to 53,000	up to 52,000	up to 52,800
Main deck positions	11 - 88" X 125" (11 AAY) + 1 LD3	11 - 88" X 125" (11 AAY) + 1 LD3	11 - 88" X 125" (11 AAY) + 1 LD3
Lower deck positions	Bulk Only (1,543 cu ft)	Bulk Only (1,543 cu ft)	Bulk only (1,543 cu ft)
Main deck volume (cu ft)	4,977	4,977	4,977
Total volume if LD bulk loaded (cu ft)	6,520	6,520	6,520

Notes:

- 1). Gross structural payload refers to payload available for ULDs and cargo.
- 2). Gross structural payloads are estimates. These will vary by individual aircraft due to differences in OEW.
- 3). Specifications assume 737NGs are equipped with blended winglets but that A320 and A321 do not have Sharklets.
- 4). When lower deck loaded with LD3-45W containers A320P2F and A321P2F can accommodate additional 208 cu ft of bulk cargo.

Tianjin Aircraft Engineering Co. Ltd.

Converted aircraft will be allocated the designation -BDSF. IAI Bedek has already completed the conversion of the prototype 737-700BDSF. This aircraft has also completed the necessary flying certification tasks. FAA STC approval is therefore expected in the near future. "We have another two firm orders plus one option for 737-700BDSF conversions from the launch customer," says Rafi Matalon, senior director, general manager marketing & business development at IAI Bedek. Matalon expects to receive STC approval for the 737-800BDSF conversion in late 2017 or early 2018.

IAI Bedek's main facility is in Tel Aviv, Israel, but initial 737-700BDSF and 737-800BDSF conversions will be performed at two MRO partner locations in China: Tianjin Aircraft Engineering; and Bedek Lingyun (Yichang) Aircraft Maintenance Engineering Company Ltd (Belinco) in Yichang. "We can be flexible in terms of the location of MRO conversion partners depending on regional demand," says

Matalon.

IAI Bedek has significant experience of converting 737 aircraft. It previously converted more than 60 737-300s and 737-400s into freight configurations, including 33 full-freight 737-300s seven 737-300QCs and 20 737-400 freighters. IAI Bedek is no longer marketing these 737 classic P-to-F programmes.

PEMCO

PEMCO is a subsidiary of Air Transport Services Group (ATSG), and has active 737-300 and 737-400 conversion programmes. These include full-freight conversions and 737-300QC and 737-400 Combi modification options. In 2017 it launched full-freight and 'FlexCombi' conversions for the 737-700.

Aircraft converted to full freight configurations by PEMCO are designated with the suffix -F. "The first 737-700F has already been inducted at PEMCO's Tampa, Florida facility, and we expect to

receive STC approval in 2018," says Mike Andrews, director of conversion programs at PEMCO.

PEMCO has already converted more than 150 737 classics. Most of these are likely to have been full-freight conversions, although this figure may also include a small number of QC and Combi modifications.

In addition to its main facility in Tampa, PEMCO conversions can be completed at a number of MRO partner locations around the world. This includes Coopesa in Costa Rica, KF Aerospace in Canada, and STAECO and TAECO in China. In early July 2017, PEMCO announced China-based Guangzhou Aircraft Maintenance Engineering Co., Ltd. (GAMECO) as its latest MRO partner facility for conversions.

Precision Aircraft Solutions

Precision Aircraft Solutions offers full-freight and Combi conversions for 757-200s. Aircraft converted to full-

freight status are designated 757-200PCFs, and those modified to Combi are designated 757-200PCCs.

“We generally have five or six aircraft in conversion worldwide at all times,” explains Brian McCarthy, vice president of sales at Precision Aircraft Solutions. Precision’s 757-200 conversions can be performed at any one of three partner MRO facilities: Flightstar in Jacksonville, Florida and HAECO in Xiamen or Air China Techniques in Chengdu, China.

“We have converted about 85 757-200PCFs and one 757-200PCC,” says McCarthy. “Another six PCFs are being converted now, and we will exceed 100 conversions in early 2018. We expect to complete at least 40 more conversions in the next two years, and 20 more spread through 2020-2023.” It is likely that most, if not all, of these future conversions will be for the full-freight PCF variant.

It is expected that Precision will launch a new P-to-F conversion programme for a younger generation narrowbody type in the near future.

ST Aerospace

ST Aerospace offers full-freight and Combi conversions for 757-200s at its facilities in Singapore. Aircraft converted to full-freight status are designated 757-

200SFs.

“ST Aerospace has completed 141 757-200 conversions, including 138 SFs and three Combis,” says Adam Rosen, vice president marketing at VT San Antonio Aerospace, part of ST Aerospace. “We have a backlog of fewer than five aircraft, but expect to secure 30 additional 757-200SF conversions for completion over the next five to 10 years.

In addition to its main facility in Singapore, ST Aerospace plans to establish conversion facilities for 757-200s in China in the near future. These will also convert A320P2Fs and A321P2Fs when these programmes enter production with EFW. ST Aerospace’s controlling interest in EFW means that it will maintain a presence in the narrowbody conversion market when its 757-200 P-to-F programme comes to an end.

Conversions by type

The following analysis identifies narrowbody conversion options by aircraft type. It includes a consideration of basic specifications, including typical loading configurations, structural payloads and cargo volumes. The main focus is on full-freight conversions, since these represent the vast majority of the P-to-F market. QC and Combi conversion

specifications are therefore excluded.

It should be noted that some of the summarised specifications are the result of a series of assumptions. First, it is assumed that the aircraft are loaded with containers, rather than pallets. The loading configurations and container volume specifications used in the analysis are designed to offer realistic industry examples, but in reality, considerable variations are possible. Only one loading configuration is used for each aircraft type, but in most cases multiple options and container sizes are available. In addition, container volume specifications will vary by manufacturer. Operators should also make independent enquiries to confirm if particular container contours are suitable for their preferred conversion option.

The gross structural payloads used in the analysis are based on estimates from the conversion providers. In operational service, operating empty weight (OEW) will vary by individual aircraft, leading to slight differences in structural payload.

Conversions in production

There are active conversion programmes for the MD-80 family, 737-300, 737-400 and 757-200.

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MD-80

AEI offers the only P-to-F conversions for the MD-80 family. Its STC covers the conversion of MD-81s, MD-82s, MD-83s and MD-88s, but not MD-87s, which have a shorter fuselage than the other models. AEI has converted MD-82s and MD-83 since receiving its STC in 2013, but MD-81 conversions seem unlikely, since there are only six active aircraft in a passenger configuration.

All MD-80SF freighters can accommodate up to 12 88-inch X 108-inch unit load devices (ULDs) on the main deck (see table, page 88). When configured with 12 88-inch X 108-inch X 78-inch containers, they would provide a main deck containerised volume of about 4,416 cu ft.

MD-82SFs and MD-88SFs would offer a slight advantage over an MD-83SF in terms of gross structural payload and lower deck bulk cargo volume, but the latter offers a higher maximum take-off weight (MTOW).

An MD-82/-88SF would offer a gross structural payload of 46,600lbs, about 1,500lbs more than an MD-83SF. An MD-82/-88SF would also provide 1,253 cu ft of lower deck bulk volume. This is 240 cu ft of additional volume compared to an MD-83SF. An MD-83SF would, however, offer an MTOW of 160,000lbs which is 10,500lbs higher than that of an MD-82/-88SF. This would provide the MD-83SF with a range advantage.

AEI's list price for MD-8SF conversions is \$2.50 million. The market values of MD-80s and JT8D-200 engines is now low, making total build cost for a converted freighter less than \$5.0 million.

737-300

AEI and PEMCO offer P-to-F conversions for 737-300s. IAI Bedek's 737-300BDSF programme is no longer active. There is an option to retrofit Aviation Partners Boeing (APB) blended winglets to 737-300s to improve operational performance and reduce fuel burn. The AEI and PEMCO conversions are certified for aircraft without winglets, which account for 63% of the active and parked passenger fleet.

A 737-300 freighter can have an MTOW of up to 139,500lbs, and a maximum zero fuel weight (MZFW) of up to 109,600lbs. The available conversion programmes offer gross payloads of 42,900-43,100lbs (see table, page 88). To meet the specifications listed here, some aircraft may need to have their weights upgraded prior to conversion. A weight upgrade is available via a paperwork recertification. Boeing should be contacted for further details.

A 737-300 freighter will accommodate up to eight 88-inch X 125-inch X 82-inch ULDs on its main deck, and one or two smaller ULDs, depending on the conversion option. AEI offers a configuration that can take a ninth ULD with 88-inch X 125-inch base dimensions, although this final position is restricted to a height of 64 inches. The typical containerised volume offered by a 737-300 freighter could be 3,663-3,868 cu ft depending on the configuration and conversion provider (see table, page 88). If lower deck bulk volume is included, the total cargo volume offered by a 737-300 freighter will be 4,731-4,841 cu ft.

AEI's list price for 737-300SF

The narrowbody conversion market has been dominated by 757-200s and 737 Classics in recent years. Asia Pacific is expected to see some of the largest growth in air cargo demand in the near-future. In China, demand for additional narrowbody freighters could be driven by a growth in e-commerce.

conversions is \$2.60 million. PEMCO does not publish its conversion pricing.

737-400

AEI and PEMCO have active conversion programmes for 737-400s. IAI Bedek's 737-400BDSF conversion is no longer available.

There are standard gross weight (SGW) and high gross weight (HGW) variants of the 737-400. These were manufactured simultaneously so there is no line number distinction between SGW and HGW aircraft.

An SGW 737-400 freighter can have an MTOW of up to 143,500lbs, and an MZFW of up to 113,000lbs. The gross structural payload can be 43,100-45,750lbs, depending on the conversion provider. An HGW 737-400 freighter will offer an MTOW of up to 150,000lbs and an MZFW of up to 117,000lbs. The gross structural payload will be 47,100-47,890lbs (see table, page 88).

HGW 737-400s can be certified with lower weights but, due to structural differences, SGW variants cannot be modified to HGW specifications.

AEI and PEMCO market 737-400 freighter configurations that can accommodate 10 ULDs with base dimensions of 88-inches X 125-inches, plus a further reduced-size ULD on the main deck. AEI's conversion is the only one that permits the use of 10 88-inch X 125-inch X 82-inch ULDs, plus a reduced size ULD. The PEMCO configuration accommodates nine 88-inch X 125-inch X 82-inch ULDs, plus a further 88-inch X 125-inch ULD limited to 80 inches in height and an additional 27-inch X 125-inch X 80-inch container or pallet. The typical containerised main deck volume offered by a 737-400 freighter will range from 4,534 to 4,539 cu ft. If lower deck bulk capacity is included, the total cargo volume offered by a 737-400 freighter will range from 5,795 to 5,907 cu ft.

AEI's list price for 737-400SF conversions is \$2.80 million. PEMCO does not disclose its conversion price.

757-200

Precision Aircraft Solutions and ST Aerospace offer conversion programmes for 757-200s.

The Precision and ST Aerospace

conversion programmes both offer up to 15 position-loading configurations. 757-200PCF and 757-200SF freighters can accommodate 15 88-inch X 125-inch X 82-inch ULDs on their main decks. This would provide about 6,570 cu ft of containerised main deck cargo volume. 757-200PCFs and 757-200SFs can also accommodate up to 1,794 cu ft of bulk-loaded cargo in their lower holds. The total cargo volume offered by a 757-200 freighter could therefore be up to 8,364 cu ft (see table, page 88).

The gross structural payload of a 757-200 freighter will vary depending on the aircraft's weight specifications, the conversion provider and whether the feedstock airframe is equipped with winglets.

The highest MTOW available for passenger-configured 757-200s is 255,000lbs. The most likely MTOWs for converted freighters are 240,000lbs or 250,000lbs. Aircraft with an MTOW of 255,000lbs are limited to an MZFW of 186,000lbs. Precision says that it has seen little demand for freighters with an MTOW of 255,000lbs, since operators tend not to favour trading payload for range. It claims that an MTOW of 250,000lbs offers the best balance between range and payload.

Aircraft produced from L/N 210 onwards offer the highest OEM MZFW

and maximum landing weight (MLW) options. All future 757-200 conversion candidates are likely to be post L/N 210 airframes and will therefore qualify for the highest OEM weight options. This is because future feedstock is unlikely to exceed 25 years of age at the time of induction, and L/N 210 was manufactured in 1989.

Aircraft without winglets and manufactured from L/N 210 onwards have standard MLWs and MZFWs of 198,000lbs and 184,000lbs. Boeing offers weight upgrades that can increase the MLW to 210,000lbs. The Boeing upgrades can also increase MZFW to 188,000lbs for aircraft with RB211-535 engines, and to 186,000lbs for those with PW2000 series engines. Boeing should be consulted for further information.

About 64% of the active and parked 757-200 passenger fleet is equipped with APB blended winglets. Precision and ST Aerospace can both convert aircraft with or without blended winglets. Precision does not anticipate converting any variants with split-scimitar winglets. If necessary, split-scimitar winglets can be replaced with blended winglets.

A shipset of APB winglets for the 757-200 adds about 1,400lbs to the aircraft's OEW, but the impact on gross payload can be offset by increasing the APB certified MZFW by the same amount.

The MZFW therefore increases to 185,400lbs for standard weight 757-200s equipped with winglets. The MZFW of winglet-equipped aircraft increases to 189,400lbs and 187,400lbs for RB211-535- and PW2000-powered airframes that have undergone the 'off-the-shelf' OEM weight upgrades.

The typical gross structural payload for 757-200 freighters, from L/N 210 onwards, will vary from 67,000 to 68,350lbs for standard weight aircraft. Payloads for those that have undergone the OEM weight upgrades will range from 71,000 to 72,000lbs for aircraft with RB211-535 engines and from 69,000 to 70,350lbs for PW2000-equipped examples. Precision claims its PCF conversions offer the lowest OEWs and therefore the highest gross payloads.

Precision offers an additional 12,000lbs proprietary MZFW upgrade for 757-200s from L/N 210 onwards, which increases the MZFW to 200,000lbs and 198,000lbs for RB211-535- and PW2000-powered aircraft respectively. The Precision MZFW upgrade is available for aircraft with or without winglets. However, winglet-equipped airframes will suffer a 1,400lbs payload penalty because it is not possible to increase the MZFW any further to offset the weight of the winglets. The gross payload of 757-200PCFs that have

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undergone Precision's maximum weight upgrade could be 82,600-84,000lbs for RB211-535 powered aircraft, and 80,950-82,350lbs for PW2000-powered aircraft. In both cases, the lower end of the scale applies to winglet-equipped aircraft.

ST Aerospace says that it is developing its own proprietary MZFW upgrades over and above the current maximum OEM weights. It adds that these will match the 200,000lbs and 198,000lbs MZFW offerings provided by Precision. ST Aerospace says its MZFW upgrade could be certified within six to nine months pending customer demand.

Precision's baseline conversion list price for a 757-200PCF is \$4.65 million. This does not include the cost of Boeing's MZFW, MLW and MTOW upgrades, or Precision's additional 12,000lbs MZFW upgrade. Aircraft need to have already had the maximum OEM MZFW increase applied, to undergo Precision's proprietary upgrade. The Precision upgrade will then cost a further \$32 per lb, up to a total of \$384,000 for the full 12,000lbs MZFW increase.

McCarthy also highlights that any PW2000-powered 757-200 that undergoes the P-to-F process will require a hard engine mount replacement during conversion. This is an OEM modification required to maintain acceptable flutter margins, and it is estimated that it could cost \$382,000. This modification is required regardless of the conversion provider. Aircraft with RB211-535 engines are not affected.

Conversions in development

There are conversion programmes in development or awaiting STC approval

for the 737-700, 737-800, A320 and A321.

737-700

IAI Bedek and PEMCO have both launched conversion programmes for the 737-700. IAI Bedek has completed a prototype conversion, and expects to receive STC approval in the near future. PEMCO only announced its 737-700F programme in April 2017, and expects to receive its STC in 2018. Both programmes will be certified for aircraft with APB blended winglets, since these account for 88% of the active and parked fleet.

A 737-700 freighter with blended winglets will have an MTOW of up to 154,500lbs, an MZFW of up to 121,700lbs and a gross structural payload of up to 45,000lbs (see table, page 90). Lower MTOW and MZFW options are available and some passenger-configured feedstock will need to be recertified to achieve the highest possible weights. This can be achieved without the need for structural modifications. Boeing should be consulted for details.

Both 737-700 conversion programmes will produce a freighter that can accommodate up to eight 88-inch X 125-inch X 82-inch ULDs, plus smaller containers or pallets on the main deck. The typical main deck containerised volume will be 3,663-3,800lbs. When lower deck bulk volume is taken into account, the typical total cargo volume offered by a 737-700 freighter will be 4,629-4,766 cu ft, similar to that of a 737-300 freighter. PEMCO is marketing the same proposed main deck loading configuration for the 737-700F that it uses for its 737-300F, as the two aircraft

Conversion programmes have been launched for the 737-700 and 737-800. The first 737-800 P-to-F programmes are due to enter serial production in 2017. Some analysts believe that 737 Classics will remain popular conversion candidates until 737NG market values begin to decline.

have identical fuselage dimensions.

No list prices are available for the IAI Bedek or PEMCO 737-700 conversion programmes.

737-800

AEI, Boeing and IAI Bedek have all launched conversion programmes for the 737-800. AEI and Boeing expect to receive STC and type design approval in 2017. IAI Bedek believes its STC will be received in late 2017 or early 2018. All three conversion options are designed for aircraft with APB blended winglets. About 85% of the active and stored, passenger-configured 737-800 fleet has blended winglets installed. AEI, Boeing and IAI Bedek will also offer conversion for 737-800s without winglets.

A 737-800 freighter with blended winglets will have an MTOW of up to 174,200lbs and an MZFW of up to 138,300lbs (see table, page 90). The gross structural payload could be 52,000-53,000lbs, depending on the conversion provider. Some passenger-configured feedstock will be certified with lower MTOWs and MZFWs but, as with the 737-700, these aircraft can be recertified at the highest possible weights without the need for structural modifications. Boeing should be contacted for further details.

All three conversion options will produce 737-800 freighters capable of accommodating up to 11 88-inch X 125-inch X 82-inch ULDs, plus a smaller container or pallet on the main deck. In a typical configuration, a 737-800 freighter could have a containerised main deck volume of 4,977 cu ft, which is 10% more than current 737-400 freighters. If lower deck bulk capacity is also included, the proposed 737-800 freighters will offer a total cargo volume of about 6,520 cu ft.

AEI and Boeing have published list prices of \$3.50 million and \$4.60 million for 737-800SF and 737-800BCF conversions. No list prices are available for IAI Bedek's 737-800BDSF programme.

A320

EFW is developing its A320P2F conversion programme and expects to receive an STC in 2020.

In 2014 PACAVI Group announced

plans to develop STCs for A320 and A321 conversions. Its aim was to acquire, convert and lease or sell A320 and A321 freighters. In late 2016 a communication from PACAVI explained that the group was being restructured, following a change in investors. *Aircraft Commerce* has not received any further news on its A320/321 FreighterLITE conversion developments. As the status of PACAVI's conversion programmes is unknown, they will not be considered here.

EFW's A320P2F conversion will be available for A320-200 series airframes. These now account for the entire A320 fleet with no earlier -100 series models remaining in passenger service. The initial STC will apply to aircraft without Sharklet wing tip devices. About 99% of the Sharklet-equipped A320 fleet is five years old or younger. These aircraft are therefore unlikely to become conversion candidates for another 10 years.

An A320P2F could have an MTOW of up to 171,958lbs, an MZFW of up to 137,789lbs, and a gross structural payload of up to 46,297lbs (21 metric tonnes). There are several weight variants (WVs) available for the A320, and some feedstock candidates will be certified at lower weights. Any A320-200 could be converted to freighter status by EFW. Those produced from L/N 1081 (manufactured in 1999) onwards can be certified at the maximum weights specified in this analysis. This should not prove too restrictive, since the vast majority of conversion candidates are likely to be post-L/N 1,081 examples by the time the A320P2F conversion enters commercial production in 2020.

The extent of modifications required to certify an A320P2F at the maximum possible weights will depend on the WV specifications of the feedstock aircraft. Some might already be certified at the required MTOW and MZFW. Others might require modifications ranging from a paperwork exercise to structural changes. Airbus and EFW should be consulted for technical details and cost information.

EFW has recently amended the proposed main deck loading configurations for the A320P2F and A321P2F. "We have extended the cargo compartments in both types by moving the rigid cargo barrier further towards the flightdeck," explains Centner. An A320P2F will now be capable of accommodating up to 11 ULDs with 88-inch X 125-inch base dimensions, although the rearmost pallet or container will be restricted to 64 inches in height. An A320P2F will provide a typical main deck containerised volume of 4,744 cu ft, somewhere between that of a 737-400 and 737-800 freighter (see table, page 90).

A320 and A321 freighters will be the

only types in the narrowbody segment to offer containerised lower deck volume. The A320P2F will accommodate up to seven LD3-45W containers in its lower deck offering a volume of 917 cu ft. The total containerised volume offered by an A320P2F could therefore be about 5,661 cu ft. This is about 14% more than a 737-800. Alternatively the lower deck can be bulk loaded. In this scenario an A320P2F would offer a total cargo volume of 6,066 cu ft, which is about 7% less than a 737-800 freighter.

EFW does not publish a list price for the A320P2F conversion.

A321

EFW is developing its A321P2F conversion programme and expects to receive an EASA STC in 2019.

The A321P2F conversion will be for A321-200 series aircraft. These represent most of the fleet, since there are only 54 A321-100 series aircraft remaining in passenger service. It is possible for A321-100 series aircraft to be modified to -200 series status. Airbus and EFW should be consulted for further details.

The initial STC for A321P2F

conversions will be designed for aircraft without Sharklets. The oldest Sharklet-equipped A321 is still only four years of age so these aircraft are unlikely to become conversion candidates for more than 10 years.

An A321P2F could have an MTOW of up to 206,132lbs, an MZFW of up to 162,701lbs, and a gross structural payload of up to 59,525lbs (27 metric tonnes). Like the A320, the A321 has various WV options. Although EFW could potentially convert any A321-200 series airframe, some feedstock aircraft will be certified at lower weights. Aircraft from L/N 1,794 (manufactured in 2002) onwards can be certified at the maximum possible MTOW. The extent of work required to increase a feedstock aircraft's weight specifications could vary from a paperwork change to a structural modification. Airbus and EFW should be consulted for details.

EFW's extension to the cargo compartment means that an A321P2F will now be capable of accommodating up to 14 88-Inch X 125-inch X 82-inch ULDs on the main deck. This will provide a main deck containerised volume of 6,132 cu ft, which is 23% more than a



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737-800 freighter but 7% less than a 757-200.

The A321P2F will also be able to accommodate up to 10 LD3-45W containers in the lower hold. In addition to the main deck, this would provide the A321P2F with a total containerised cargo volume of 7,442 cu ft, 13% more than the 757-200. Alternatively the A321P2F's lower deck can be completely bulk loaded. In this scenario the A321 freighter would provide a total cargo volume of 7,961 cu ft, 5% less than a 757-200.

EFW does not publish a list price for the A321P2F conversion.

Future trends

"We believe there will be growth in the narrowbody freighter segment over the next 20 years, with conversions required for replacement and growth purposes," says Haimovich. "One key trend will be a transition away from converting 737 classics and 757-200s to younger generation types including the 737-700, 737-800, A320 and A321."

There will be a transition to younger narrowbody freighters due to decreasing feedstock numbers for the older types, but an additional factor is the import age restrictions imposed on aircraft by certain countries. These include China and India which represent some of the largest potential growth markets for air freight. "Age, pedigree and previous operator/domain restrictions may apply," says Casey. "These can effectively eliminate older aircraft that have had multiple operators from being imported into markets with some of the highest growth potential, like China, India and several other Asian countries."

Haimovich believes that 737NG aircraft will be converted to replace ageing 737 Classic freighters, while A320 family aircraft could find a home as freighters in Asia. "There are a large number of A320s operating in the Far East and China. There is some potential for these to be converted for new entrant cargo operators in the region," says Haimovich.

"The A321 is going to be a success in the long-term as a replacement for 757-200 freighters," adds Haimovich.

Casey believes the A321 is the heir apparent to the 757 in the narrowbody freighter segment, but also expects 737-900 conversions to be launched in the future. "The 737-800 and -900 could take more of the 757-200 market than we expect," says Casey. "A typical freighter flies less than 70% full on average, and 70% of a 757-200's payload and main deck container capacity fits nicely with a 737-800's capabilities."

EFW's A321 and A320 lines are not due to enter serial production until 2019 and 2020 respectively. 737NG conversions will be available in the near term, but Haimovich believes they could take two to three years to gather momentum. "There is already a backlog of 737NG conversions, but I believe some of the first 737-800 deliveries will be deferred," says Haimovich. "737NG freighters will provide greater fuel efficiency than their Classic predecessors, but this is less of an advantage while fuel costs remain relatively low and 737 Classic feedstock remains available. Operators will be more focused on lease rates or capital costs. The high current market values (CMVs) of 737-800s mean that operators might prefer the lower cost option of a 737-400 freighter in the short

EFW has launched conversion programmes for the A320 and A321 in association with ST Aerospace and Airbus. The A321P2F will be capable of accommodating up to 14 88" x 125" x 82" ULDs on its main deck and is seen as the natural successor to ageing 757-200 freighters.

term, even though it would provide one fewer main deck loading position. The current lease rate for a 737-400 freighter is \$130,000-140,000 per month. This is likely to be \$180,000-200,000 per month for the first 737-800 freighters entering service in 2018."

When 737 Classic P-to-F programmes were introduced, the smaller -300 variant was the first to be converted, due to large feedstock availability at the right price. Demand then shifted to the larger -400 model as feedstock became available at suitable prices. Haimovich believes that 737NG conversions will not follow this trend. "There are more than 150 orders or options for 737-800 conversions, and only about 30 for the 737-700," says Haimovich. "At this stage it looks like most of the market is going straight for the larger variant."

"The significantly higher feedstock and conversion cost of 737NGs is expected to temper near-term conversion demand for these types over the next two-to-five years," says Stefan Kageman, senior vice president of marketing at VX Capital Partners. "737 Classics will subsequently remain in demand for now and are likely to be converted up until around 2022."

Casey notes that 737NG capital costs may be a bit high to support significant, near-term conversion demand, but says this situation could change quickly with many leases due to expire and younger models entering the market. "From previous experience, the sweet spot for feedstock market values is reached when an aircraft type has been out of production for six or seven years," says Casey. "This is generally the point at which large numbers of aircraft begin to be retired from passenger fleets, and this has a cascade effect on market values. There are a large number of 737 MAX aircraft on order. More 737NGs will be removed from passenger service as the rate of 737 MAX deliveries increases over the next few years. The potential rate of retirements means there is reason to speculate that 737NG values will drop much sooner than the typical six- or seven-year, post-production timeframe seen for previous-generation types. A similar trend is likely for A320s and A321s as they are replaced by neo variants." - NMP **AC**

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