The on-ramp costs to bring a converted freighter into service can include considerations for aircraft acquisition, maintenance and conversion. The potential build costs for current and future narrowbody conversion candidates are addressed here.

Narrowbody freighter build costs

The number of in-service narrowbody freighters has grown by 13% over the past five years. Narrowbody freighters play an important role in the air cargo market. They are used to serve a variety of missions, including hub-and-spoke integrator operations and point-to-point general freight services.

The main narrowbody freighter options and the related acquisition, conversion and build costs are considered here.

Narrowbody freighter options

There are no new-build options available for narrowbody freighters. An operator or investor therefore depends on aircraft that have undergone passenger-to-freighter (P-to-F) conversions.

In the narrowbody market there are P-to-F conversions for MD-80s, 737-300s, 737-400s and 757-200s. P-to-F conversions have also been launched for the 737-700, 737-800, A320-200 and A321-200, although these are still in development.

Eight organisations have developed or are developing P-to-F conversion programmes for narrowbodies. Some also offer regional or widebody freighter conversions, but these are not considered here.

Aeronautical Engineers Inc (AEI) offers in-production P-to-F programmes for MD-80SFs, 737-300SFs and 737-400SFs. It is developing a supplemental type certificate (STC) for the conversion of 737-800SFs. It expects to receive a Federal Aviation Administration (FAA) STC for the 737-800SF conversion in late 2017, with the programme due to enter the production phase in early 2018.

Three approved facilities perform the touch labour for AEI's P-to-F conversions: the Commercial Jet facilities in Miami, Florida and Dothan Alabama, in the United States (US); and Boeing Shanghai in China.

Boeing is currently developing the 737-800BCF (Boeing converted freighter) P-to-F conversion programme. It expects that the conversion will be available from the fourth quarter of 2017.

737-800BCF conversions will be performed at Boeing Shanghai Aviation Services. Additional sites are also being considered.

EFW is developing its A320P2F and A321P2F conversion programmes in cooperation with ST Aerospace and Airbus. It plans to obtain the relevant STCs for the A321P2F and A320P2F programmes before the end of 2018 and 2019 respectively.

Under the partnership a number of global facilities will be developed to carry out A320P2F and A321P2F conversions. These include EFW's base in Dresden, Germany and ST Aerospace in Singapore. Facilities in Mobile, Alabama in the US and one in China have also been earmarked.

IAI Bedek offers in-production P-to-F programmes for 737-300s and 737-400s. It is also developing conversions for the 737-700 and 737-800. IAI Bedek is the only organisation to have launched a P-to-F programme for the 737-700. All aircraft converted by IAI Bedek are given the suffix –BDSF.

Most of IAI Bedek's conversions are performed at its own facility in Israel, but other facilities can be considered.

PEMCO offers in-production P-to-F programmes for 737-300s and 737-400s. Aircraft converted by PEMCO are designated with an –F suffix.

PEMCO's 737-300F and 737-400F conversions can be performed at its own facility in Tampa, Florida or by approved third-party maintenance, repair & overhaul (MRO) facilities in Costa Rica, Canada and China.

Precision Aircraft Solutions offers P-to-F conversions for 757-200s. Converted aircraft are designated with a -PCF suffix.

757-200PCF conversions can be performed at MRO partner facilities. These are Flightstar in Jacksonville, Florida, HAECO in China and Air China Techniques in Chengdu, China.

ST Aerospace provides P-to-F conversions for 757-200s at its facilities in Singapore, China and the US. Converted aircraft are given an-F suffix. It is also a joint owner of EFW.

In 2014 the PACAVI group announced plans for the P-to-F conversion of A320s and A321s. Unlike traditional conversion programmes, PACAVI's focus is to acquire, convert and lease or sell ready-made freighters. Its initial intention was to make A320 family freighters available by 2017.

A recent communication from PACAVI stated that the group's investors have changed, and it is currently being restructured. This process will see the A320 and A321 conversion programmes transferred into a new entity. It is not yet clear what this entity will be called. A spokesperson indicated that it is still expected that an STC for A320 conversions can be obtained by 2018.

Cost considerations

There are three potential cost areas for operators or investors to consider before they can bring a converted narrowbody freighter into service. In addition to the actual conversion costs, operators may need to acquire feedstock aircraft and decide what level of maintenance to perform during the conversion process.

The basic P-to-F conversion price will include costs associated with parts, labour and certification. Most narrowbody conversion prices will also include the provision and installation of a manual cargo loading system (CLS).

Passenger-configured aircraft are considered suitable feedstock for freighter conversions once there is an optimum balance between market values and remaining economic life. The typical

vintage for freighter feedstock aircraft has been 15-20 years of age. This appears to remain accurate for some types although due to ageing fleets some aircraft are now being converted at 20-25 years of age.

"The typical feedstock age for new narrowbody platforms, such as the A321-200 and 737-800, will initially be 15-20 years," says Adam Rosen, vice president of marketing at ST Aerospace/AEM. "The typical age range for 757-200 feedstock has increased to 20-25 years."

Robert Convey, senior vice president of marketing at AEI, suggests that feedstock for ageing variants such as MD-80s and 737 Classics is being converted at 20-25 years of age. He believes that some of the first 737-800s to be converted could be 12-15 years old. Operators may need to consider potential acquisition costs for 15- to 25-year-old feedstock candidates, depending on their chosen platform.

Maintenance costs are another important consideration. Many operators will perform some form of maintenance check with the P-to-F conversion. In most cases this maintenance event will be a heavy or structural check.

The largest check in an aircraft's base maintenance cycle involves the most invasive structural inspection requirements, and used to be known as a D check. In contemporary maintenance planning documents (MPDs), letter checks have been superseded by assigning each individual task an inspection threshold based on utilisation, calendar time, or a combination of both. Although in most cases tasks are no longer grouped under letter checks, modern aircraft still have a number of large structural inspection requirements that will come due at similar intervals and necessitate a heavy check.

Completing a heavy check together with the P-to-F conversion process can provide several benefits to the operator. "The cost of maintenance will be lower if the aircraft is put through a heavy check during conversion," explains Rosen. The conversion process involves removing the passenger cabin and interior items. This can be time-consuming during heavy checks, when access is required for deep structural inspection tasks. If this access has already been provided as part of the P-to-F conversion, operators will accrue lower man-hours (MH) and related costs against the maintenance check.

Combining a heavy check with the conversion process can lead to MH savings related to aircraft docking and preparation. It will also optimise aircraft downtime, since it avoids the aircraft having to be removed from service twice within a short period.

As well as standard MPD inspections, operators must consider the cost of complying with outstanding service bulletins (SBs) or airworthiness directives (ADs). In extreme cases, the work needed to do this may make the conversion of some feedstock aircraft uneconomic.

Since the average utilisation of a converted narrowbody freighter is less than that of a passenger variant, some operators may bridge aircraft onto a low-utilisation maintenance programme (LUMP) during the conversion. This involves adjusting repeat intervals for inspections to match the reduced utilisation.

Build costs

Operators may choose feedstock aircraft in half-life condition for P-to-F conversion. These are airframes midway through their maintenance cycles, with a window of operation available before they require a heavy check.

In most cases, operators will put the conversion candidate through a heavy check at the time of conversion.

For those aircraft with in-production P-to-F programmes, this analysis accounts for both possibilities. It provides a rough guide to the potential combined acquisition and conversion costs for aircraft in half-life condition. No maintenance assumptions are included

BASIC SPECIFICATIONS FOR CONVERTED NARROWBODY FREIGHTERS

Aircraft Type	MD-82/-88SF	MD-83SF	737-300SF	737-400SF SGW	737-400SF HGW
Engines	JT8D	JT8D	CFM56-3	CFM56-3	CFM56-3
Conversion provider	AEI	AEI	AEI	AEI	AEI
MTOW (lbs)	up to 149,500	up to 160,000	up to 139,500	up to 143,500	up to 150,000
MZFW (lbs)	up to 122,000	up to 122,000	up to 109,600	up to 113,000	up to 117,000
Gross structural payload (lbs)	up to 46,600	up to 45,100	up to 42,900	up to 43,100	up to 47,100

Aircraft Type			737-300BDSF	737-400BDSF SGW	737-400BDSF HGW
Engines			CFM56-3	CFM56-3	CFM56-3
Conversion provider			IAI Bedek	IAI Bedek	IAI Bedek
MTOW (lbs)			up to 139,500	up to 143,500	up to 150,000
MZFW (lbs)			up to 109,600	up to 113,000	up to 117,000
Gross structural payload (lbs)			up to 43,100	up to 44,000	up to 48,000

Aircraft Type			737-300F	737-400F SGW	737-400F HGW
Engines			CFM56-3	CFM56-3	CFM56-3
Conversion provider			PEMCO	PEMCO	PEMCO
MTOW (lbs)			up to 139,500	up to 143,500	up to 150,000
MZFW (lbs)			up to 109,600	up to 113,000	up to 117,000
Gross structural payload (lbs)			up to 43,100	up to 45,750	up to 47,890

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	66,000	70,000/68,000

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	70,000/68,000	70,000/68,000

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). ST Aerospace estimated gross payload for 757-200SF is based on average estimated OEW of 118,000lbs regardless of engine variant. There will be slight difference in OEW and resulting available payload between 757-200s with RR and PW engines.
4). Specifications assume 737 Classics are not equipped with winglets.

for this scenario although it is likely that most airframes will incur some rectification costs.

The analysis also accounts for the total cost of acquiring an airframe that needs a heavy maintenance visit, and of performing a heavy check during the conversion process.

The combined acquisition, conversion and maintenance costs required to bring a converted freighter into service are referred to as the 'on-ramp' costs.

For those aircraft whose P-to-F programmes are still being developed, the analysis estimates potential acquisition and conversion costs, but does not speculate on maintenance costs. *Aircraft Commerce* will revisit the potential maintenance costs for these types once the P-to-F programmes are in production and more reliable figures can be obtained.

Acquisition

The acquisition costs used in this analysis are based on current market values (CMVs) for those aircraft with in-production P-to-F programmes, and future base values (FBVs) for those with P-to-F programmes in-development. In both cases it is assumed that the aircraft have half-life engines, regardless of the condition of the airframe.

The analysis identifies potential acquisition costs for 15-25-year-old feedstock for ageing types including MD-80s, 737-300s, 737-400s and 757-200s. It estimates acquisition costs for 15-20-year-old feedstock for younger variants, such as the 737-700, 737-800, A320 and A321. Since P-to-F programmes for these four types are still being developed, the predicted acquisition costs are based on estimated FBVs for the year in which each conversion programme is expected to enter the production phase. All CMVs and FBVs were provided by Oriel.

Conversion

The conversion costs used here are based on estimated current list prices for the in-production P-to-F programmes. For the P-to-F programmes that are still

BASIC SPECIFICATIONS FOR CONVERTED WIDEBODY FREIGHTERS

Aircraft Type	737-700BDSF	737-800BDSF	737-800SF	737-800BCF
Engines	CFM56-7B	CFM56-7B	CFM56-7B	CFM56-7B
Conversion provider	IAI Bedek	IAI Bedek	AEI	Boeing
MTOW (lbs)	up to 154,500	up to 174,200	up to 174,200	up to 174,200
MZFW (lbs)	up to 121,700	up to 138,300	up to 138,300	up to 138,300
Gross structural payload (lbs)	up to 45,000	up to 52,000	up to 52,000	up to 52,800

Aircraft Type	A320-200P2F	A321-200P2F
Engines	CFM56-5/V2500	CFM56-5/V2500
Conversion provider	EFW	EFW
MTOW (lbs)	up to 169,756	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

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.

in development, current marketed list prices are applied where possible, even where they are based on future value predictions. The conversion costs assume that each variant has already been modified to the highest available original equipment manufacturer (OEM) weight specifications, and does not account for the costs of any OEM weight upgrades.

Maintenance

Maintenance cost estimates are given for those aircraft with in-production P-to-F programmes, and are only applied to airframes where the CMVs assume a heavy maintenance visit is required. The maintenance cost estimates provide a guide to the costs that could be incurred to put an aircraft through a typical heavy check at the time of conversion. These costs are based on estimates for routine and non-routine systems, and structural check MHs with an allowance for materials and some standard AD and SB requirements. It is assumed that the feedstock candidate will not need major AD or SB rectification work, since this could make the conversion uneconomic. Cost requirements for engines and heavy components, including thrust reversers and landing gear, are also excluded. Some converted freighter operators may think it is more economic to source green-time engines and components, rather than put them through the expense of a shop visit.

The maintenance costs used here should only be treated as rough guide, since they will vary depending on the condition of the incoming aircraft. Some older airframes, or those that have been stored for many months, may have a higher number of non-routine requirements and rectifications.

The maintenance cost estimates used for the 737-300 and 737-400 are converted from pounds sterling to US dollars at an assumed rate of $1.5 to £1.0. This exchange rate was chosen based on realistic D check numbers generated before the United Kingdom's (UK's) referendum on membership of the European Union (EU). Since the UK voted to leave the EU the pound has weakened against the dollar and the use of current exchange rates might not provide a true representation of D check costs when converted into US dollars.

The summary has been subdivided between aircraft with active conversion programmes, and those for which a P-to-F modification is in development.

Conversions in production

MD-80

AEI offers the only P-to-F conversion programme for MD-80s. The MD-80 family includes the MD-81, MD-82, MD-83, and MD-88. They all have the same fuselage dimensions, while the MD-87 has a shorter fuselage.

AEI offers conversions for all variants, except the MD-87. The most likely conversion candidates are MD-82s, MD-83s and MD-88s, since only a small number of MD-81s remain.

An MD-80 freighter accommodates up to 12 88-inch X 108-inch unit load devices (ULDs), which may be containers or pallets.

An MD-82/-88SF could have a maximum take-off weight (MTOW) of up to 149,500lbs, a maximum zero fuel weight (MZFW) of up to 122,000lbs and a gross payload of up to 46,600lbs *(see table, page 84)*. A MD-83SF has the same potential MZFW specifications, but can have a higher MTOW of up to 160,000lbs, resulting in more range, but a smaller gross payload of up to 45,100lbs.

According to FlightFleets Analyzer, there are 185 MD-82s, 201 MD-83s and 130 MD-88s in service or in storage. The age profile of these fleets ranges from 20-35 years, 16-31 years, and 19-29 years respectively. MD-80s that are 16-25 years old are the most likely feedstock candidates.

Typical CMVs for MD-80 feedstock candidates in half-life maintenance condition range from $750,000 for an MD-82, to $1.00 million for an MD-83 or MD-88 *(see table, page 88)*. CMVs for aircraft approaching a major base check vary from $500,000 for an MD-82, to $750,000 for an MD-83 or MD-88.

AEI's list price for MD-80 conversions is $2.45 million.

The MD-80 has a reputation for being rugged, and does not suffer from any significant ageing structural maintenance issues. Convey estimates that the cost of performing the equivalent of a D or heavy check during the P-to-F conversion process could be $700,000-800,000. This includes routine and non-routine MH and materials.

The total cost of acquiring and converting 16- to 25-year-old MD-80s in half-life maintenance condition could be $3.20-3.45 million, depending on the variant. The total on-ramp cost for an aircraft needing heavy maintenance could be $3.65-4.00 million depending on vintage and condition *(see table, page 88)*.

737-300

AEI, IAI Bedek and PEMCO all offer full freight conversions for 737-300s.

All three conversion providers offer a nine-position main-deck configuration for the 737-300. This accommodates up to eight 88-inch X 125-inch ULDs, plus a further reduced-size ULD. AEI also markets a 10-position configuration for the 737-300 that can accommodate up to eight 88-inch X 125-inch ULDs, plus two additional reduced-size ULDs.

A converted 737-300 freighter could have an MTOW of up to 139,500lbs, an MZFW of up to 109,600lbs and a gross payload of 42,900 to 43,100lbs, depending on the conversion provider *(see table, page 84)*. "Most 737-300s have had their weights de-rated for passenger operations," explains Convey. "Their MTOW and MZFW will have to be increased before conversion."

This weight upgrade involves a paperwork recertification, and interested parties should contact Boeing for details and any potential cost information.

There are 286 passenger-configured 737-300s in service, and 104 in storage. The fleet ranges from 16 to 31 years of age. The most likely feedstock aircraft are those in the 16-25-year age bracket.

Typical CMVs for 737-300s in half-life maintenance condition range from $1.60 million for a 25-year-old airframe, to $3.25 million for a 16-year-old one. The CMV for a 737-300 approaching a base maintenance check could vary from $950,000 for a 25-year-old aircraft, to $2.60 million for a 16-year-old airframe *(see table, page 88)*.

AEI's marketed list price for 737-300 P-to-F conversions is $2.65 million. List prices for the IAI Bedek and PEMCO conversions were not available. Jacob Netz, senior analyst at the air cargo management group, expressed his own opinion to *Aircraft Commerce* on potential narrowbody conversion costs. Netz speculates that the basic price for an IAI Bedek 737-300BDSF conversion would be $2.60-2.80 million, and that the price of the PEMCO conversion may fall between those of AEI and IAI Bedek.

Typical 737-300 feedstock candidates are likely to be in their second or third base check cycle. The 737 Classic MPD is based on a letter check format with separate corrosion prevention and control (CPCP) tasks. The base check cycle comprises six checks, with the largest being the C6 or D check. It is estimated that the cost of putting a 737 Classic through a typical C6 or D check is $1.05 million, including all MH and materials.

It is estimated that performing this check during the conversion process could reduce the maintenance cost by 20-25%, with savings related to non-duplicated access MH, inspection MH and fewer non-routine defects related to interior items. This would result in an estimated heavy check cost of $790,000-840,000 for a 737 Classic when the check is combined with a P-to-F conversion.

Additional maintenance costs may be incurred for ADs or SBs. The 737 Classic family has suffered from ageing structural maintenance issues. SB 53A1177 details how to replace window skin belts on 737-300s that have been prone to cracking. The cost of such modifications could be prohibitive for some operators. This analysis assumes that any aircraft selected for conversion will be free from any major structural AD or SB modification requirements.

The combined cost of acquiring a 737-300 in half-life maintenance condition and converting it into a freighter could be $4.20-6.05 million, depending on the aircraft vintage and conversion provider.

The total on-ramp cost for an aircraft that requires a heavy maintenance check could be $4.34-6.24 million depending on the aircraft's age *(see table, page 88)*.

Oriel estimates that monthly lease rates for converted 737-300 freighters in half-life condition will range from $85,000 for a 25-year-old aircraft to $125,000 for a 16-year-old airframe.

ESTIMATED ACQUISITION, MAINTENANCE & CONVERSION COSTS - IN-PRODUCTION P-TO-F PROGRAMMES

Aircraft Type	Weight (lbs)	Engine Type	Year built	CMV ($-millions)	Conversion ($-millions)	Acquisition & Conversion Half-life a/c (S-millions)	Maintenance HMV a/c ($-millions)	On-ramp HMV a/c ($-millions)
MD-82	149,500	PW	1991/1995	0.50-0.75	2.45	3.20	0.70-0.80	3.65-3.75
MD-83	160,000	PW	1991/1999	0.75-1.00	2.45	3.45	0.70-0.80	3.90-4.00
MD-88	149,500	PW	1991/1997	0.75-1.00	2.45	3.45	0.70-0.80	3.90-4.00
737-300	139,500	CFM	1991	0.95-1.60	2.60-2.80	4.20-4.40	0.79-0.84	4.34-4.59
737-300	139,500	CFM	1999	2.60-3.25	2.60-2.80	5.85-6.05	0.79-0.84	5.99-6.24
737-400SGW	143,500	CFM	1991	2.45-3.10	2.80-3.20	5.90-6.30	0.79-0.84	6.04-6.49
737-400SGW	143,500	CFM	2000	3.85-4.50	2.80-3.20	7.30-7.70	0.79-0.84	7.44-7.89
737-400HGW	150,000	CFM	1991	2.45-3.10	2.80-3.20	5.90-6.30	0.79-0.84	6.04-6.49
737-400HGW	150,000	CFM	2000	3.90-4.55	2.80-3.20	7.35-7.75	0.79-0.84	7.49-7.94
757-200	250,000	RR	1991	3.30-4.30	4.65-5.03	8.95-9.33	1.50	9.45-9.83
757-200	250.000	PW	1991	3.30-4.30	5.03-5.42	9.33-9.72	1.50	9.83-10.22
757-200	250,000	RR	2001	10.50-11.50	4.65-5.03	16.15-16.53	1.50	16.65-17.03
757-200	250,000	PW	2001	10.50-11.50	5.03-5.42	16.53-16.92	1.50	17.03-17.42
757-200 (W)	250,000	RR	1991	4.10-5.10	4.65-5.03	9.75-10.13	1.50	10.25-10.63
757-200 (W)	250,000	PW	1991	4.10-5.10	5.03-5.42	10.13-10.52	1.50	10.63-11.02
757-200 (W)	250,000	RR	2001	11.30-12.30	4.65-5.03	16.95-17.33	1.50	17.45-17.83
757-200 (W)	250,000	PW	2001	11.30-12.30	5.03-5.42	17.33-17.72	1.50	17.83-18.22

CMV source: Oriel

Notes

1). CMV range accounts for different maintenance conditions. Lower costs are for aircraft in need of heavy check and higher costs for half-life airframes. Half-life engines assumed in both cases.

2). HMV = aircraft in need of heavy maintenance visit/check. Maintenance and on-ramp cost assumptions only apply to HMV aircraft.

3). 757-200 (W) indicates aircraft with winglets.

4). RR-powered 757-200 conversion costs include range from basic to max Precision MZFW upgrade option. For PW-powered aircraft extra cost is added for engine mount replacement.

737-400

Full freight conversions for 737-400s are available from AEI, IAI Bedek and PEMCO.

AEI and PEMCO market 11-position 737-400 freighters. AEI claims it offers the only conversion that can carry 10 full height (82-inch) 88-inch X 125-inch ULDs, plus a reduced-size ULD on the main deck. PEMCO's marketing material indicates that it also offers 10 88-inch X 125-inch loading positions, plus a further position for a reduced-size ULD. IAI Bedek offers a 10-position 737-400 freighter that holds nine 88-inch X 125-inch ULDs with a height of up to 82 inches, and an 88-inch X 125-inch ULD that is limited to 79 inches in height.

Boeing produced standard gross weight (SGW) and high gross weight (HGW) versions of the 737-400. An SGW 737-400 freighter could have an MTOW of up to 143,500lbs, an MZFW of up to 113,000lbs and a gross payload of 43,100 to 45,750lbs depending on the conversion *(see table, page 84)*. An HGW 737-400 freighter could have an MTOW of up to 150,000lbs, an MZFW of up to 117,000lbs and a gross payload of 47,100-48,000lbs depending on the conversion.

SGW and HGW 737-400s were produced simultaneously, so there is no clear line number distinction between SGW and HGW aircraft. Potential operators should note that although an HGW airframe can be certified with lower weights, structural differences mean those built as SGW aircraft cannot be modified to HGW status.

There are 153 passenger-configured 737-400s still in service, and 105 in storage. The age profile ranges from 16- to 28-year-old airframes. The most likely feedstock candidates are the 16-25-year-old aircraft.

Typical CMVs for 737-400s in half-life maintenance condition range from $3.10 million for a 25-year-old aircraft, to $4.55 million for a 16-year-old one. 737-400s in need of a base maintenance check would have CMVs of $2.45-3.90 million depending on the vintage of the feedstock *(see table, this page)*.

AEI's marketed list price for a 737-400SF conversion is $2.80 million. IAI Bedek and PEMCO did not disclose list prices for their conversions. Netz believes the price for IAI Bedek's 737-400BDSF conversion is likely to be $3.00-3.20 million. He adds that the price of the PEMCO conversion is likely to fall between that of AEI and IAI Bedek.

Like the 737-300 series, it is estimated that putting a 737-400 through a D check during conversion could cost $790,000-840,000, including all MH and materials.

The combined cost of acquiring and converting a 737-400 in half-life maintenance condition could be $5.90-7.75 million. The on-ramp cost for an airframe in need of a heavy maintenance visit could be $6.04-7.94 million *(see table, this page)*.

According to Oriel, monthly lease rates for converted 737-400 freighters in half-life condition will range from $130,000-155,000 depending on the vintage.

757-200

P-to-F conversions for 757-200s are available from Precision Aircraft Solutions and ST Aerospace. Both conversion programmes can produce 15-position 757 freighters capable of accommodating up to 15 88-inch X 125-inch ULDs on the main deck.

757-200s produced from line number (L/N) 210 and onwards are the most suitable candidates for conversion, since they offer higher maximum landing weight (MLW) and MZFW options. L/N 210 was delivered in 1989. Since most 757-200 conversion candidates will be 15-25 years old, pre-L/N 210 airframes are unlikely to be converted in the future.

The standard MLWs and MZFWs for 757-200s without winglets and from L/N 210 onwards are 198,000lbs and 184,000lbs respectively. Boeing offers optional weight upgrades, which increase the MLW to 210,000lbs and the MZFW to 188,000lbs for RB211-535-powered aircraft, and 186,000lbs for PW2000-powered examples. Operators should consult Boeing regarding the technical requirements and costs associated with its OEM weight upgrades. Precision can substantially increase the MZFW beyond these OEM-certified weights.

The highest available MTOW for a passenger-configured 757-200 is 255,500lbs, but these variants are downgraded by Precision to 250,000lbs for the best utility and highest payload capability. Precision says it has seen little demand for the highest MTOW since freight operators tend to prioritise payload over range and the 757 already has a significant range capability.

The typical gross payload of a converted 757-200 freighter with standard MLW and MZFW specifications will range from 66,000lbs to 68,350lbs depending on the engine type and conversion provider. Precision claims to offer the lowest operating empty weight (OEW) of any 757 conversion provider. The gross payloads for a 757-200 freighter that has had the OEM MLW and MZFW upgrade will be 70,000-72,000lbs for an RB211-535-powered one and 68,000-70,350lbs for a PW2000-powered one *(see table, page 86)*.

Some passenger-configured 757-200s have been retrofitted with Aviation Partners Boeing (APB) winglets, which are designed to reduce fuel burn. The Precision and ST Aerospace programmes are both certified to convert aircraft with or without winglets.

An installed shipset set of APB winglets for the 757-200 weighs 1,400lbs. The winglet certification allows the MZFW of standard and OEM upgraded 757-200s to be increased by 1,400lbs to compensate operators for the 1,400lbs increase in OEW under a blanket approval as certified. The MZFW of winglet-equipped aircraft therefore increases to 185,400lbs for standard weight aircraft. For those that have had the OEM weight upgrade, the MZFW increases to 189,400lbs for RB211-535 powered aircraft and 187,400lbs for those with PW2000 engines.

Precision Aircraft Solutions offers a higher payload option for converted 757-200 freighters. Together with Leth Associates, it developed a proprietary 12,000lbs MZFW upgrade over an above the maximum OEM-certified weights. This increases the MZFW to 200,000lbs and 198,000lbs for aircraft with RB211-535 and PW2000 engines.

The Precision MZFW upgrade is available for aircraft with and without winglets. Winglet-equipped aircraft will offer 1,400lbs less payload, since the MZFW limits cannot be increased any further to account for the extra weight of the winglets. Typical gross payloads for 757-200PCFs that have had the Precision MZFW upgrade are 82,350-84,000lbs for aircraft without winglets and 80,950-82,600lbs for airframes with winglets.

Before they can undergo Precision's MZFW upgrade, feedstock aircraft must already have had the maximum OEM MLW and MZFW upgrades, and have an MTOW of 240,000lbs or 250,000lbs.

ST Aerospace says that it can increase the MZFW of a 757-200 freighter to the same level as certified by Leth Associates, if required. "So far ST Aerospace has not seen market demand for such weight upgrades," claims Rosen. "OEM weight upgrades are sufficient for cargo densities up to 8.6lbs per cu ft. Most operators do not need higher cargo densities."

ESTIMATED ACQUISITION AND CONVERSION COSTS FOR P-TO-F PROGRAMMES IN DEVELOPMENT

Aircraft Type	Weight (lbs)	Engine Type	Year built	FBV ($-millions)	FBV Year	Conversion ($-millions)	Acquisition & Conversion Half-life a/c ($-millions)	Acquisition & Conversion HMV a/c ($-millions)
737-700	154,500	CFM	1997	7.05-7.85	2017	3.20-3.30	11.05-11.15	10.25-10.35
737-700	154,500	CFM	2002	9.70-10.50	2017	3.20-3.30	13.70-13.80	12.90-13.00
737-800	174,200	CFM	1998	11.20-12.10	2018	3.50-5.00	15.60-17.10	14.70-16.20
737-800	174,200	CFM	2003	14.80-15.60	2018	3.50-5.00	19.10-20.60	18.30-19.80
A320-200	169,756	CFM	1999	8.00-8.80	2019	3.50-4.00	12.30-13.80	11.50-12.00
A320-200	169,756	IAE	1999	8.05-8.85	2019	3.50-4.00	12.35-13.85	11.55-12.05
A320-200	169,756	CFM	2004	12.50-13.30	2019	3.50-4.00	16.80-17.30	16.00-16.50
A320-200	169,756	IAE	2004	12.55-13.35	2019	3.50-4.00	16.85-17.35	16.05-16.55
A321-200	206,132	CFM	1998	9.50-10.30	2018	4.00-4.50	14.30-14.80	13.50-14.00
A321-200	206,132	CFM/IAE	2003	14.10-14.90	2018	4.00-4.50	18.90-19.40	18.10-18.60

FBV source: Oriel

Notes

1). FBV range accounts for different maintenance conditions. Lower costs are for aircraft in need of heavy check and higher costs for half-life airframes. Half-life engines assumed in both cases.

2). 737NG Values assume aircraft are equipped with blended winglets. A320/321s are not equipped with Sharklets.

3). HMV = aircraft in need of heavy maintenance visit/check.

There are 355 passenger-configured 757-200s in active service and 143 in storage. The fleet is split between 273 aircraft with RB211-535 series engines, and 225 with PW2000 engines. The fleet age profile is 11-32 years. The most likely conversion candidates are 15- to 25-year-old aircraft.

According to Oriel, CMVs for 757-200 feedstock candidates in half-life maintenance condition will be $5.10-12.30 million for aircraft equipped with winglets, and $4.30-11.50 million for those without. CMVs for aircraft needing a heavy check will be $4.10-11.30 million for winglet-equipped aircraft, and $3.30-10.50 million for those without winglets.

The list price for Precision's basic 757-200PCF conversion is $4.65 million. This does not include the proprietary MZFW upgrade which costs $32 per lb or up to $384,000 for the full 12,000lbs upgrade. ST Aerospace does not publicly market the list price for its 757-200SF conversion, but Netz believes the price will be similar to the basic figure quoted by Precision. Another cost consideration for converted 757-200 freighters relates specifically to PW2000-powered aircraft. McCarthy explains that as a result of structural changes made during the conversion process, aircraft with PW2000 series engines need a 'hard' engine mount replacement to maintain acceptable flutter margins *(see Cherry Picking 757-200s for conversion to freighter, Aircraft Commerce, February/March 2014, page 60)*. It is estimated that this OEM master change will cost $382,000. Aircraft with RB211-535 engines are not affected.

Taking account of the potential Precision MZFW upgrade and PW2000 engine mount replacement, the conversion costs for a 757-200 could be $4.65-5.03 million for an aircraft with RB211-535 engines, and $5.03-5.42 million for a PW2000-powered aircraft.

The 757-200's traditional base check cycle comprises four C checks. The heaviest check is the fourth in the cycle (C4), referred to as the C4S4C check. Depending on the base check cycle, the C4 may include S8C and S12C structures tasks as well as S4C tasks. Operators may see the conversion process as a good time to perform a C4 or heavy check, since it needs access for deep structural inspections. "The routine labour requirement for a standard MPD heavy check together with a cargo conversion is 5,000-6,000 MH," says Rosen. Brian McCarthy, vice president of sales at Precision Aircraft Solutions, estimates that an C4S4C check performed during the conversion process might cost $1.50 million, depending on past pedigree and total cycles accumulated at conversion.

The total cost of acquiring and converting a 757-200 in half-life maintenance condition could range from $8.95 to $17.72 million.

The total on-ramp cost for an airframe in need of a heavy maintenance visit could range from $9.45 to $18.22 million *(see table, page 88)*.

In both scenarios the final cost will depend on the aircraft vintage, the presence or absence of winglets, the engine variant and whether Precision's MZFW upgrade has been applied.

Oriel estimates that monthly lease rates for converted 757-200 freighters without winglets could be $130,000 for a 25-year-old aircraft and $210,000 for a 15-year-old one, rising to $135,000-215,000 for winglet-equipped aircraft. In both cases these rates relate to aircraft in half-life maintenance condition.

Conversions in development

737-800

AEI, Boeing and IAI Bedek are all developing P-to-F conversion programmes for the 737-800. All three solutions will offer a 12-position freighter that can accommodate up to 11 88-inch X 125-inch ULDs, plus a reduced-size ULD on the main deck. A 737-800 freighter will therefore offer one or two more 88-inch X 125-inch loading positions than a converted 737-400.

Most of the 737-700 and -800 fleet is configured with blended winglets from APB. A new Split Scimitar winglet was certified for the 737-700 and -800 in 2014. AEI, Boeing and IAI Bedek will all offer conversions for 737-800s with APB blended winglets. STCs for converting aircraft with Split-Scimitar winglets will be developed at a later date, since none of these are likely to enter the feedstock age range in the near-to-medium term.

A 737-800 freighter with blended winglets could have an MTOW of up to 174,200lbs, an MZFW of up to 138,300lbs and a gross payload of 52,000lbs to 52,850lbs depending on the conversion programme *(see table, page 86)*. The 737-800 series has lower MTOW and MZFW options, but any airframe can be re-certified at the highest weights without the need for structural modifications. Boeing should be

The used market value of 737-400s has declined to $2.50-4.5 million, meaning on-ramp costs are $6.0-8.0 million.

consulted regarding the costs to increase the certified MTOW and MZFW.

There are 4,142 passenger-configured 737-800s in active service, and 37 in storage. The fleet age profile extends from new aircraft to 19-year-old ones. This analysis assumes that all three 737-800 conversion programmes will reach the production phase by 2018, and focuses on potential acquisition values for that year. The most likely initial feedstock candidates will be 15-20-year-old aircraft.

Estimated FBVs for 737-800 feedstock candidates in half-life maintenance condition in 2018 are $12.10-15.60 million for aircraft with blended winglets. For aircraft that need a heavy maintenance check, estimated FBVs are $11.20-14.80 million.

Boeing's current list price for a 737-800BCF conversion is $5.00 million. AEI's estimated list price is $3.50 million based on 2017 dollars. IAI Bedek did not disclose list prices for its 737-800BDSF conversion, but Netz speculates that it will fall between the AEI and Boeing prices.

The cost of acquiring and converting a 737-800 in half-life maintenance condition in 2018 could be $15.60-20.60 million *(see table, page 90)*, depending on the aircraft age, and conversion provider.

The cost of acquiring and converting an airframe in need of a heavy base check could be $14.70-19.80 million.

No data are available for potential maintenance costs during the conversion process for 737NGs. The heaviest structural checks for this family come due at six-, eight- and 12-year intervals. Some estimates suggest that typical 12-year check costs for a passenger-configured aircraft could be $600,000. The cost of maintenance during the P-to-F process depends on which of the heavier checks the aircraft needs and the percentage of total cost savings that can be realised in terms of MH and material savings.

737-700

IAI Bedek is the only conversion provider developing a P-to-F programme for the 737-700. A 737-700BDSF will be able to accommodate up to eight 88-inch X 125-inch ULDs, plus a further two reduced-size ULDs on its main deck.

IAI Bedek will offer conversions for 737-700s with blended winglets. A 737-700BDSF could have an MTOW of up to 154,500lbs, an MZFW of up to 121,700lbs and a gross payload of up to 45,000lbs *(see table, page 86)*. Lower MTOW and MZFW options are also available for the 737-700, but all aircraft can be certified to the highest weight specifications stated here, without the need for structural modifications. Interested parties should consult Boeing regarding the costs involved in increasing the certified weights.

There are 1,044 passenger-configured 737-700s in service, and 25 in storage. The age profile of the fleet varies from new to 19-year-old aircraft. This analysis assumes that IAI Bedek's conversion will be readily available in 2017 and focuses on estimated acquisition costs for that year. The most likely feedstock candidates will be 15-20 years of age.

Estimated FBVs for 737-700 feedstock candidates in half-life maintenance condition in 2017 are $7.85-10.50 million. FBVs for airframes approaching a heavy check are expected to be $7.05-9.70 million.

IAI Bedek did not disclose the list price for its 737-700BDSF conversion, but Netz believes it could be $3.20-3.30 million.

The cost of acquiring and converting a 737-700 in half-life maintenance condition in 2017 could be $11.05-13.80 million, depending on the vintage *(see table, page 90)*. The cost of acquiring and converting an aircraft in need of a heavy check could be $10.25-13.00 million.

A320-200

EFW and PACAVI have both launched P-to-F programmes for the A320-200 and A321-200. This analysis will focus on the EFW solutions, since PACAVI is undergoing a restructuring process and it is unclear exactly when, and under which entity, its products will eventually be brought to market.

EFW's A320-200P2F solution will offer 11 main-deck positions and seven lower-deck loading positions. An A320-200P2F will accommodate up to 10 88-inch X 125-inch positions, plus a reduced-size ULD on the main deck. Unlike Boeing narrowbodies, the A320 family can also take containers on the lower deck, providing the aircraft has a lower-deck CLS. An A320-200P2F would hold up to seven LD3-45W containers in its lower cargo hold.

Some passenger-configured A320 family aircraft are equipped with Sharklets. These are wingtip devices designed to improve aerodynamic efficiency and reduce fuel burn. EFW does not expect many Sharklet-equipped aircraft to enter the feedstock age range in the near to medium term, and has focused its conversion programmes on aircraft without Sharklets.

An A320-200P2F could have an MTOW of up to 169,756lbs (77 metric tonnes), an MZFW of up to 137,789lbs (62.5t) and a gross payload of up to 46,297lbs (21t) *(see table, page 86)*. The EFW conversion is based on the feedstock aircraft being certified at weight variant (WV) 12. Numerous WVs are available for the A320-200, including some with different specifications. EFW developed its conversion around WV12 due to aircraft performance characteristics. EFW says that any WV can be modified to match its conversion pre-requisites, and to obtain reasonable performance characteristics.

The probable acquisition costs of a 757-200 are $3.3 million for a 1991 example, to $12.3 million for a young 2001-build aircraft. Total on-ramp costs for a converted freighter are $9.5-18.2 million.

Although any A320-200 from L/N 1,081 (manufactured in 1999) onwards can be certified to WV12, the level of required modification can vary from a paperwork exercise to physical structural changes. Interested parties should consult EFW and Airbus for technical details and the related costs.

There are 3,913 A320-200s in active passenger service, with 60 in storage. Nearly 60% of the fleet is equipped with CFM56-5 series engines, while the rest has V2500 family engines installed. This analysis assumes that EFW's A320P2F programme will enter the production phase in 2019, and that early feedstock candidates will be 15-20 years of age.

The estimated FBVs for A320 feedstock candidates in half-life maintenance condition in 2019 will be $8.80-13.35 million. There is a slight premium for aircraft with V2500 family engines. The expected FBV range in 2019 is $8.00-12.55 million for airframes in need of heavy maintenance.

Jacob Netz believes the conversion costs for an A320 are likely to be $3.50-3.70 million. Other sources suggest it could be up to $4.00 million.

Acquiring and converting an A320 in half-life maintenance condition in 2019 could be $12.30-17.35 million depending on the vintage, engine type and maintenance cost, and $11.50-16.55 million for an aircraft that needs a heavy check. Since no conversions have been completed, no maintenance cost data are available for A320 family aircraft during the P-to-F process.

EFW will offer base maintenance checks with an A320-200P2F conversion. "More than 80% of our Airbus widebody conversion customers ordered MRO services in parallel with conversion activities to minimise hangar downtime and maximise the newly converted freighter's revenue potential," says Thomas Centner, director sales aircraft conversion, Asia Pacific at EFW.

A321-200

EFW's A321-200P2F programme will focus on A321-200 series airframes, since older A321-100 series aircraft have lower weight specifications and only 54 remain in service. EFW notes that an upgrade is available to modify -100 airframes to -200 status.

An A321-200P2F will accommodate up to 13 88-inch X 125-inch positions on the main deck. This is two fewer than a 757-200 freighter, but the A321-200P2F's ability to accommodate up to 10 LD3-45W containers in the lower hold means it will offer a higher total containerised volume than the Boeing aircraft. EFW calculates that an A321-200P2F's combined main- and lower-deck container capacity is equal to 16.5 main deck containers, versus 15 on a 757-200 freighter, if the bulk area on the 757-200 is not considered.

EFW's A321-200P2F specifications are designed around WV 11, although all other WVs are feasible for conversion. WV11 offers the highest combined MTOW and MZFW for the A321-200. An A321-200P2F will have an MTOW of up to 206,132lbs (93.5t), an MZFW of up to 162,701lbs (73.8t), and a gross payload of up to 59,525lbs (27t). A321 L/N 1,794 and all aircraft from L/N 1,878 can be certified at WV 11. L/N 1,794 was manufactured in 2002, while L/N 1,878 was built in 2003. Qualifying aircraft will therefore be entering the 15-20-year feedstock age range when the conversion becomes available in 2018.

EFW emphasises that there are plenty of options to fit other WVs to individual operational purposes. Potential investors should consult EFW and Airbus regarding the technical requirements, and any costs related to weight changes.

There are 1,274 A321-200s in passenger service, and 23 in storage. Of these, 63% are powered by V2500 family engines, while the other 37% are powered by CFM56-5B series engines. The A321P2F conversion programme is expected to enter production in 2018, and early feedstock aircraft are likely to be 15-20 years of age.

FBVs for A321-200 feedstock candidates in half-life maintenance condition in 2018 are expected to be $10.30-14.90 million. The FBVs for aircraft approaching a heavy check are expected to be $9.50-14.10 million.

Netz believes the conversion cost could be $4.00-4.50 million.

The potential costs of acquiring and converting an A321-200 in half-life maintenance condition in 2018 could be $14.30-19.40 million, depending on the aircraft vintage and final conversion price *(see table, page 90)*.

OEM support fees

Operators of some converted narrowbody freighters could be subject to annual access charges for OEM aftermarket support.

Aircraft Commerce understands that Boeing charges an annual access fee for support services to operators of 737 and 757 freighters converted by licensed third parties. These fees are paid annually, and amount to $50,000 each for the first four aircraft in a fleet, so the access fee is limited to $200,000 per year even if the operator has more than four Boeing freighters. Industry sources speculate that this fee will not apply to customers for Boeing's 737-800BCF programme, although the Boeing conversion is likely to come at a premium compared to competing solutions.

There are no indications that Airbus plans to introduce an access support fee for converted A320 or A321P2Fs. AC