New A320 & A321 passenger-to-freighter conversion programmes by EFW and Precision Conversions have the capability to change the game in a Boeing-dominated narrowbody express freight market. The A320/321 are the first narrowbody freighters to utilise lower deck containers.

The status of A320 & A321 P-to-F programmes

The narrowbody freighter fleet today comprises about 700 aircraft in service. With a forecasted 4% growth rate in freight tonne kilometres (FTK) by air, it is expected that 1,200 narrowbody cargo aircraft will be needed by 2037 to cover growth and retirements.

It is predicted that this target will be met by about 750 Boeing narrowbody freighters, and 450 Airbus A320/A321 passenger-to-freighter conversions (P-to-F).

E-commerce growth means that narrowbody freighters will be used to satisfy an increase in demand on express carrier routes. In 2018 it was estimated that the global e-commerce market was worth $2.8 trillion. Over the next three years the value in e-commerce is forecast to rise to $4.8 trillion. World air cargo traffic increased by 4.2% in 2018 as a result of e-commerce growth.

A benefit of the A320/321 series is its ability to carry containerised cargo in the lower hold, which increases operational flexibility, and results in faster and more labour-efficient loading and unloading. Boeing narrowbody freighters do not load containers, which often means that the belly space of 737 and 757 freighters is not used.

"You do not make up time flying faster, you make it up on the ground. In terms of lead time and efficiency, the A321 will be able to make much faster intermediate stops than its competition," claims Peter Koster, head of the cargo conversion business unit at Vallair.

Using lower-deck containers will be especially advantageous to operators that currently use containers between the ramp and fulfilment houses.

Design goals

Typically, the A321 is used as a longer-haul aircraft, so it has accumulated high flight hours (FH) relative to age. It is, therefore, likely that the previous operator will have certified the aircraft with an intermediate service goal (ISG) or an extended service goal (ESG) certificate.

An ISG will extend the design goals of the A321, which are currently set at 60,000FH and 48,000 flight cycles (FC). An aircraft with an ESG can be operated to 120,000FH or 60,000FC, which would return more than 15 years of service in terms of historic utilisation.

Ideally, feedstock aircraft will have previously been certified with either an ISG or ESG before being converted to freighters. Rates of utilisation must be considered if buying feedstock aircraft whose original maintenance design goals have not been updated.

A320/321 weight variants

Two important weights for a freighter are maximum zero fuel weight (MZFW) and operating empty weight (OEW). The difference between the two equates to the aircraft's gross structural payload. Airbus offers different MZFWs for the A320/A321, known as weight variants (WV), and identifiable by a designated WV00 to WV011 code.

Different WVs allow the manufacturer to tune an aircraft's range and payload performance to match operational environment.

MZFW for the A320 is 162,040-169,750lbs, and MZFW for the A321-200 is 196,210-206,132lbs *(see table, page 66)*. Modifications needed to change an aircraft's WV can range from simply updating its operating manual to completing structural modifications via issued service bulletins (SBs).

Vallair

Vallair has signed with both EFW and Precision Conversions to convert its A321 aircraft.

"The EFW and Precision A321 P-to-F conversions have their differences, but we are positive that both will find their place in the express freight market," says Koster. "Both will be brilliant freighters, and will undoubtedly be successful."

Vallair has 10 conversion slots booked with EFW, and four booked with Precision to take Vallair up to 2022/23. Once the first aircraft has been converted, Vallair will closely watch the market reaction before booking more conversion slots.

"At the end of the day we are not the users. The market has to accept the product and see its benefits. Only then can this product establish its place," says Koster.

Engine feedstock is a concern because of limited availability in the market, which has led to high values. In addition, a choice between CFM56-5B- and V2500-A5-powered aircraft could effectively cut engine feedstock in half, if an operator develops a preference for one type. "We have customers interested in both engine types now. But we cannot see if there will be a clear demand for one engine in the future," says Koster.

It is likely that engine choice will entirely depend on feedstock prices. If the V2500 engine is assumed to be less desirable, then lack of demand and low feedstock price will actually make it more attractive.

Many operators prefer the CFM engine, since it is considered cheaper to run, and they typically have established maintenance deals with the original equipment manufacturer (OEM). If there is not enough CFM feedstock, a low-priced V2500 engine may mitigate the gap between operational costs, particularly if the engine has the correct pedigree for a second lease of life.

"Another factor is getting the right engines with the correct amount of green time left, and the right number of engine flight cycles (EFC) and engine flight hours

EFW's A321P2F prototype mid conversion in Singapore. Owned by Vallair, MSN835 is expected to be redelivered and begin operations in early 2020.

(EFH) remaining for the operation. Operators do not want to end up hanging too much capital under their wings," says Koster. "At the end of the day, it will be a matter of the on-ramp cost, operational expenses and the potential for the operator to make money."

Despatch reliability will be extremely important for the new aircraft. If it suffers from frequent aircraft-on-ground (AOG) situations, then operators will disqualify it.

Developing an A320 freighter in 2010 would have been a direct challenge to the 737-400. With launch customers now operating the 737-800, the only way to challenge this programme is to "start with the A321," says Koster. "We are looking deeply into A320 conversion possibilities. But we want to scope one project at a time, and develop the A321 first."

Engine supply

When it comes to powerplant options for P-to-F conversions, many operators will go with whatever engine is available. A factor that is now limiting engine availability is competition from companies that tear down aircraft for engines and salvage the parts. Resellers will often pay a higher market value for an aircraft because they can sell individual components and sub-components at high prices.

"I think that there will be an abundance of V2500-powered aircraft, and their prices will fall. One reason for this is that the V2500 engine is very expensive to overhaul. It is too early to say which direction operators are going to go. The IAE V2500 does get a better fuel burn, but it is also unavailable and very pricey right now," says vice president, sales and marketing, Brian McCarthy. "It is still too early to tell what will happen in the long term."

Fleet retirements are a reliable source of P-to-F engine feedstock. Used engines with life limited parts (LLP) and EFH remaining are ideally suited to low aircraft utilisation rates of freighter operations.

But with today's increasing demand to haul passengers, operators are keeping engines in service longer. This means that when the engine is taken out of service, its remaining useful life is limited.

"Operators are becoming more reliant on the aftermarket for parts. There are many 757s sitting in deserts without their engines," says McCarthy.

As engine specialists are buying all the low-cycled engines as fast as possible, it is expected that this will eventually lead to an abundance of good quality airframes.

According to McCarthy, burning the last of the green time out of an engine means that LLPs will have to be replaced with new parts from the OEM. There are a smaller number of good aftermarket LLPs available.

"Operators run the engines, but do not want to look inside. The minute the aircraft is retired, everything might be completely legal. All signs suggest that the engine is in good condition, but the minute it is borescoped, the engine can be found to be unserviceable," says McCarthy.

Most CFM and V2500 LLP stacks are rated at 20,000EFC. When the engine's 15-year flying period is over and the engine is retired or returned to the lessor, it will often require replacement of LLPs with a full stack. "Then we are back to an engine worth $5-6 million," says McCarthy.

"It makes no sense at all to put $12 million worth of engines on a freighter," says McCarthy. "Airline power-by-the-hour (PBH) managers are going to have to put some nice new engines on their PBH customer airframes so that we can have good quarter-life engines when they retire their engines for freighters."

A quarter-life engine is ideal for a freighter because of a relatively low annual utilisation of 600-700FC. Up to 8,000EFC remaining would be sufficient. It goes from an FH to an FC world very quickly when the aircraft becomes a freighter.

The last two years have seen used engine prices increase by approximately $2 million. A typical value for a CFM56 with around 7,000 EFC remaining is about $5.5 million.

Overhaul expenses for CFM56 are approximately $3.5 million. A full stack of CFM56 LLPs will typically cost around $4 million from an OEM.

Approximate overhaul expenses for a V2500 are $4.5-$5 million. A full stack of V2500 LLPs will typically cost around $5 million from an OEM.

EFW conversions

EFW is in the process of developing an A320-200P2F and a A321-200P2F conversion programme. P2F is the nomenclature for EFW's A320 and A321 P-to-F programmes.

The first aircraft in the programme to be converted is an A321 belonging to Vallair. EFW expects that its prototype will be granted a supplemental type certificate (STC) at the end of 2019. The aircraft is then expected to begin operations at the beginning of 2020.

"Once we have the A321 in the air, we can look at converting an A320 prototype," says EFW vice president, sales and marketing for Airbus freighter conversions, Wolfgang Schmid.

EFW estimates the conversion cost to be $6 million for an A321P2F conversion, and $5.2 million for an A320. These prices include main-deck cargo-loading system (CLS) costs.

Initially the A321P2F will be awarded a European Aviation Safety Agency (EASA) STC. Once awarded, the STC can be easily transferred to a US Federal Aviation Administration (FAA) STC if required. It is also expected that once a European STC has been awarded, the aircraft will be able to get approval from other aviation authorities.

The EFW A321P2F conversion is based on the A321-200 series. The A321-

Precision Conversions' first A321PCF cargo door that was manufactured at its Oregon facility. This door is expected to be installed by July 2019.

200P2F is expected to have a maximum structural payload of 54,445-59,526lbs, depending on the weight variant of the aircraft. The A321-200P2F will be able to carry up to 27 tons of cargo in ULD containers *(see table, page 66)*.

EFW's A321P2F can stow 14 AAA/AAY 88-inch X 125-inch containers on its main deck, and 10 AKH/LD3-45 containers on its lower deck. The aircraft has a total main-deck containerised volume of 6,132 cu ft and a lower-deck containerised volume of 1,270 cu ft. In addition, there is a lower-deck bulk storage hold of 208 cu ft. This translates to a total volume of 7,610 cu ft *(see table, page 66)*.

Tare weight is the empty weight of a ULD. Tare weight is important because it lowers an aircraft's maximum structural payload, which translates to the total weight it can carry. Because the A321 series of freighter is expected to use both upper and lower decks for containerised cargo, its total tare weight will be higher than its competitors'.

Operating with 14 AAA/AAY 88-inch X 125-inch main-deck containers, the A321P2F has a main-deck tare weight of 7,154 lbs *(see table, page 66)*. Operating with 10 AKH/LD3-45 containers on the lower deck increases tare weight by 1,720lbs.

The combined main- and lower-deck tare weights are a total of 8,874lbs. This results in a net structural payload of 45,581-50,652 lbs, depending on the aircraft's WV.

It is accepted that using ULDs on the lower deck to save on transit stop time and ground-handling fees will offset any reduction in the aircraft's maximum structural payload.

"Bulk cargo is not attractive for the express market. With the A321 we have fantastic lower-deck containerised options that offer a great deal of flexibility. This is because the e-commerce freight market revolves around the amount of freight volume that can be carried, not its weight. So, if you have the space on the aircraft to load containers, it makes complete sense that you use it," says Schmid.

As the e-commerce/postal market is based on volumetric capacity rather than weight-lifting ability, EFW wanted to maximise the number of AAA/AAY ULDs on the main deck.

At the request of lessors and integrators to 'volumetrically max-out the fuselage,' EFW has moved the 9G barrier forward from fuselage frame 20 to frame number 16. By doing this, an EFW conversion can accommodate 14 AAA/AAY containers. The installation of a 14th AAA/AAY gives the conversion a 152 cu ft advantage over competing A321 conversions that accommodate 13 AAA/AAY containers and a PAG standard pallet on the main cargo deck.

Moving the 9G rigid barrier forward means that the position-one ULD will restrict access through the original passenger doors, so the forward left-one (L1) and right-one (R1) doors are deleted and blanked. EFW has cut a new crew entry door slightly aft of the cockpit on the port side of the aircraft. To meet safety requirements, external mechanisms are built into the door to allow crew access.

"We relocate the crew-entry door on both of our A320P2F and A321P2F conversions to get more space for commercial use," says Schmid. "Another effect of moving the 9G barrier forward is a smaller galley area. However, if you ask an operator to choose between a larger payload and larger galley, then I believe the answer will be larger payload."

Technical data from Airbus has helped EFW overcome any dynamic changes to the aircraft. According to Schmid this access to OEM data has enabled EFW to "solve problems that our competitors cannot."

One of the solutions has been to balance the aircraft at the request of potential customers that want the ability to fly it when empty. When compared to a Precision Conversions modified aircraft, it is assumed the difference in OEW is balance-related.

"We have not added senseless weight. We have had to balance the aircraft to allow it to be more flexible and useful for our customers," says Schmid.

"We have succeeded in this by using the correct weight in the correct positions, so that there is no requirement for operators to add ballast to the aircraft when they need to fly a sector without any cargo on board," adds Schmid.

A320-P2F

EFW's A320P2F conversion is based on the A320-200 series. Based on a WV aircraft with a maximum take-off weight (MTOW) of 171,958lbs, the converted aircraft is expected to have a maximum structural payload of up to 49,810lbs.

EFW's A320-P2F can stow 10 AAA/AAY 88-inch X 12-inch ULDs plus a single PAG pallet on its main deck, and seven AKH/LD3-45 containers in its lower deck. The aircraft has a total main-deck containerised volume of 4,665 cu ft and a lower-deck containerised volume of 889 cu ft. There is an additional lower-deck bulk hold of 208 cu ft. This gives the aircraft a total volumetric capacity of 5,762 cu ft *(see table, page 66)*.

Operating with 10 AAA/AAY 88-inch X 125-inch main-deck containers and a PAG pallet, the A321-P2F has a main-deck tare weight of 5,260lbs. Operating with seven AKH/LD3-45 containers in the lower deck increases tare weight by 889lbs. Combining main- and lower-deck tare weights together reduces the aircraft's maximum structural payload by a total of 6,464lbs. This results in a net structural payload of up to 43,346lbs, depending on the aircraft WV. This translates to a potential maximum cargo of 19.5 tonnes.

"The A320 is a more complicated aircraft to convert because an angle of attack (AOA) sensor needs to be relocated as a result of installing a cargo door," says Schmid. "It might have been difficult to get

an STC for the type if the AOA sensor remained on the hinged cargo door. But moving the AOA sensor will not be a problem for us."

Data to recalibrate the AOA sensor is completed by EFW shareholder Airbus, because the OEM has all the data required to make the recalibration possible.

Once Airbus has completed the recalibration, it will test-fly the aircraft to ensure that the system is fully functional, and is interfacing correctly with all the flight controls and systems.

The data harvested by Airbus for the AOA sensor relocation work will be shared with EFW so that it can complete all future A320P2F AOA sensor relocations.

It is expected that the A320P2F is a logical way for Airbus A321/330 freighter operators to add to their fleets because of the commonality between types. Another advantage is that all Airbus family aircraft have the same flightdeck. "This is really remarkable," says Schmid. "Typically, the 757 fleet has several systems and avionics fits, which create a lack of commonality that operators do not like. Having the same flightdeck means that Airbus operators can easily switch pilots between the different types. Commonality is key, especially for integrator operators."

If a customer wants the max weight variant aircraft, they may apply for such a SB from Airbus. It will be expected that the aircraft should have the upgrade work completed before conversion. "EFW's relationship with Airbus allows us to make an aircraft that is as close as it can be to an OEM solution," says Schmid. "We are expecting to convert about 90 A321 freighters in the next five years."

Precision Conversions

Precision Conversions is also developing a P-to-F conversion for the A321-200 series of freighter. Nomenclature for aircraft converted with this programme is a PCF suffix. That is, A321PCF.

Prototype aircraft MSN891 is owned by Vallair and is configured to 196,210lbs MTOW WV. New upper and lower sills have been installed and it is likely the cargo door will be fitted by July 2019.

Precision is looking to start flight-testing the aircraft in the final quarter of 2019. The company expects to be granted an FAA STC by early 2020. Precision is processing the FAA STC concurrently with EASA and expects to be awarded both certificates at a similar time.

Once an STC has been granted to the CFM56-5B powered prototype, Precision wants to develop an STC for a V2500-powered aircraft. According to McCarthy, it is unclear which powerplants will be available in meaningful quantities, and which engine will be the preferred choice of operators.

As Precision is completing the prototype, an exact conversion price has not been determined, but the estimated cost is $5 million.

Three years ago, Precision started reviewing the A320 and the A321 to see how suitable they would be for conversion. Precision settled on the A321 because volumetrically it is close to a 757. "We knew that we are in an era where cargo densities are low, and are forecast to remain low. The A321 would, therefore, be a winner because of its great flight efficiency and high volumetric capacity," explains McCarthy.

Precision's A321PCF can stow 13 AAA/AAY 88-inch X 125-inch containers plus a single PAG pallet on its main deck, and 10 AKH/LD3-45 containers in its lower deck. The aircraft has a total main-deck containerised volume of 5,979 cu ft and a lower-deck containerised volume of 1,270 cu ft. In addition, there is a lower-deck bulk storage hold of 208 cu ft. This translates to a total volume of 7,610 cu ft *(see table, page 66)*.

Operating with 13 AAA/AAY 88-inch X 125-inch main-deck ULDs and a PAG pallet, the A321PCF has a main-deck tare weight of 6,793lbs. Operating with 10 AKH/LD3-45 containers in the lower deck increases tare weight by 1,720lbs.

The main- and lower-deck tare weights reduce the aircraft's gross structural payload by 8,513lbs. This means that, depending on the aircraft WV, a net structural payload of 51,167-56,436lbs can be achieved *(see table, page 66)*. This translates to a maximum cargo weight of

ESTIMATED PAYLOAD CHARACTERISTICS OF A320 & A321 FREIGHTERS

Aircraft type	EFW A321P2F WV000	EFW A321P2F WV011	PRECISION A321PCF WV000	PRECISION A321PCF WV011
MTOW - lbs	196,210	206,129	196,210	206,132
MZFW - lbs	157,630	162,701	157,630	162,699
OEW - lbs	103,175	103,175	97,950	97,750
Max structural payload - lbs	54,455	59,526	59,680	64,949
Main deck	14 AAA/AAY	14 AAA/AAY	13 AAA/AAY + 1 PAG	13 AAA/AAY + 1 PAG
Main-deck freight volume - cu ft	6,132	6,132	5,979	5,979
Tare weight - lbs	7,154	7,154	6,793	6,793
Lower deck	10 x AKH/LD3-45	10 x AKH/LD3-45	10 x AKH/LD3-45	10 x AKH/LD3-45
Lower deck - cu ft	1,270	1,270	1,270	1,270
Lower-deck tare weight - lbs	1,720	1,720	1,720	1,720
Lower-deck bulk volume - cu ft	208	208	208	208
Total volume - cu ft	7,610	7,610	7,457	7,457
Total tare weight - lbs	8,874	8,874	8,513	8,513
Net structural payload - lbs	45,581	50,652	51,167	56,436
Max packing density -lbs / cu ft	5.99	6.66	6.86	7.57
Volumetric payload @6.5lbs/cu ft	45,581	49,465	48,471	48,471
Volumetric payload @7.5lbs / cu ft	45,581	50,652	51,167	55,928
Volumetric payload @8.5lbs / cu ft	45,581	50,652	51,167	56,436

Aircraft type	EFW A320 P2F	AEI 737-800SF	IAI BEDEK 737-700BDSF	PRECISION 757-200 PCF
MTOW lbs	171,958	174,200	154,500	255,000
MZFW - lbs	137,789	138,300	121,000	200,000
OEW - lbs	87,979	83,500	75,500	116,000
Max structural payload - lbs	49,810	54,800	45,500	84,000
Main deck	10 AAA/AAY + 1 PAG	11 AAY + LD-	8 x AAY + AYF + AYF	15 AAA/AAY
Main-deck freight volume - cu ft	4,665	4,977	3,697	6,570
Tare weight - lbs	5,260	5,789	4,358	7,665
Lower deck	7 x AKH/LD3-45			
Lower deck - cu ft	889			
Lower-deck tare weight - lbs	1,204			
Lower-deck bulk volume - cu ft	208	1,555	964	1,790
Total volume - cu ft	5,762	6,532	4,661	8,360
Total tare weight - lbs	6,464	5,789	4,358	7,665
Net structural payload - lbs	43,346	49,011	41,142	76,335
Max Packing Density -lbs / cu ft	7.52	7.50	8.83	9.13
Volumetric payload @6.5lbs/cu ft	37,453	42,458	30,297	54,340
Volumetric payload @7.5lbs / cu ft	43,215	48,990	34,958	62,700
Volumetric payload @8.5lbs / cu ft	43,346	49,011	39,619	71,060

23-25.6 tonnes.

The Precision A321PCF can accommodate 14 main-deck stowage positions by using a PAG pallet in the 14th aft-most position and turning it longitudinal. A by-product of turning the PAG pallet sideways and pushing it all the way to the aft of the main deck, is a centre-of-gravity- (CofG-) friendly aircraft.

Capable of being built to a height of 72 inches, a netted PAG pallet is considered by operators to be a legitimate revenue position. "If you go back years before the e-commerce boom, the dominant operators all used pristine ULDs," says McCarthy. "For example, FedEx only used Demi ULDs on their narrowbodies, while DHL flew nothing but AAA/AAY containers."

Today, it is not uncommon for freight aircraft to carry a mix of containers, since the e-commerce boom has led to several sub-service operators now flying for the integrators. So freighters are now being loaded with a mix of ULDs and netted pallets.

Instead of using a PAG pallet, the 14th position can accommodate two AKH/LD3-45 containers that will give the aircraft a total main-deck containerised volume of 5,948 cu ft *(see table, page 66)*.

Compared to a Boeing narrowbody, the A320 family has a slightly taller celling and a wider fuselage profile. Precision is, therefore, going to have one position in the middle of the A321PCF that will be able to accommodate a spare engine for a narrowbody aircraft.

"We are strengthening the floor in the aircraft, but we are not changing the floor beams. This will result in the ability to carry a spare engine on a transverse pallet positioned over the centre of the wing. This will make the A321PCF the only aircraft in its class to have the ability to transport its own engine," says McCarthy.

"Until now, all 757 engines have had to fly on a widebody. If the maintenance unit has the correct cradle, then the facility can call upon a A321PCF to transport the engine at a fraction of the normal cost," adds McCarthy. "At the moment we are developing a low-profile pallet with a cargo-handling company. Therefore, when the need arises to transport an engine, the maintenance facility will not have to take too much off it to make it fit."

Instead of moving the 9G barrier forward, Precision has moved the same bulkhead aft by 33 inches. Relocating the 9G barrier aft of the L1 and L2 doors means there are no crew ingress/egress issues.

In addition, the A321PCF has a large supernumerary area that allows two seats to be installed in the front of the aircraft. Further forward there will be two observer seats, and then seating for the primary flight crew.

Many pilots are frequently transited into and out of their networks of operations, so aircraft must facilitate for a second flight crew. In a world where retention of pilots is becoming crucial, creating a comfortable supernumerary crew area is now considered to be essential.

"These guys are using the system to get to work every week. Pilots are flying in and out on the network, living where they want to live," says McCarthy.

Precision is retaining the front left vacuum-waste system and installing a brand-new, smaller galley complex. "We did not want to waste space by retaining the big cart-galley storage," says McCarthy.

A320/A321 lower deck

The A320/321 will be unique because it will be the only narrowbody freighter on the market that can use ULDs in the lower hold instead of moving just bulk freight.

According to McCarthy, lower-deck bulk cargo holds are only used by operators during seasonal surges, or when they need extra volume. This is because of

Owned by Vallair, the CFM56-powered A321PCF Precision Conversions prototype is expected to begin flight testing in the final quarter of 2019.

the time taken to unload bulk cargo from the lower deck and the cost of the labour.

Typically, 50% of all A321 feedstock aircraft will have the lower-hold CLS installed. Lower-deck CLS-equipped A320s are expected to be less common. Feedstock aircraft with a CLS fitted in the lower hold are expected to be preferred.

It will be possible to retrofit a lower-deck CLS at the point of conversion. EFW uses an Ancra system on the upper deck. If retrofitting the lower deck CLS, the customer can decide between manufacturers such as Telair or Ancra system.

According to McCarthy, feedstock prices for an existing A321 equipped with a lower-deck CLS will command a $200,000 premium, with additional costs incurred to replace and service broken parts.

A new lower-deck Telair CLS, installed by Precision at the point of conversion, will cost about $474,000. Saving money on handling costs and spending less time on the ground, it is thought that the upgrade will likely pay for itself within 12 months.

"The aircraft will need hardpoints to be installed and then mechanical rails and roller rails that enable the ULD containers to quickly slide in and out," says McCarthy.

McCarthy adds that a lower-deck CLS will be essential for operators to European airports, because most ground handlers have plentiful access to mechanical loaders to upload and offload ULDs. Another reason is due to the amount of postal and e-commerce work aircraft are expected to carry out.

Operations to small airports are common when operating on a hub-and-spoke freight network. Yet transit stops are inefficient because of the time taken to load, unload and reshuffle the main-deck containers.

Transit stops are often at airports that service small conurbations, meaning less cargo is offloaded from the aircraft. Therefore, it is expected that any number of the lower deck 438 cu ft AAA/AAY ULDs will be used at these destinations. This will make turnaround times quicker at these historically long stops, and will not interfere with cargo on the main deck.

"The lower deck will give the A320/321 a transit stop capability that no other aircraft will have. "The A321 has got a similar lower-deck capacity to the 757, says McCarthy. "As the 757 does not have lower-deck ULDs, it will take seven ground staff to unload it."

ULD containers also offer postal carriers a secure and weatherproof container to ship goods.

A cheaper alternative to retrofitting a lower-deck CLS is installing a sliding carpet loading system (SCLS). An SCLS will move cargo to the doorway. Using an SCLS to unload a lower hold full of bulk cargo will result in using less manpower than it would take manually. Ground staff requirements are reduced from 12 to six people when using this system.

Packing densities

Both the EFW- and the Precision-converted aircraft are expected to operate in an express freight and integrator network. A typical cargo-packing density in the sector is 6.5 lbs per cubic foot (lbs/cu ft). The low-density cargo will mean that the aircraft is likely to reach volumetric capacity before reaching its net structural payload limit. Higher packing densities of 7.5-8.5 lbs/cu ft are associated with general freight cargo.

"The package density of e-commerce cargo has decreased, which means that this market is no longer about tonnage, and is primarily about volume, "says McCarthy.

The A320P2F (EFW) will reach full volumetric capacity at a packing density of 7.52 lbs/cu ft. Loading a volumetric payload of 6.5 lbs/cu ft, the aircraft will have a maximum structural payload of 37,453 lbs *(see table, page 66)*.

Aeronautical Engineers Inc's (AEI) 737-800SF will reach full volumetric capacity at a packing density of 7.50lbs/cu ft. Loading a volumetric payload of 6.5 lbs/cu ft, the aircraft will have a maximum structural payload of 42,458 lbs *(see table, page 66)*.

Israel Aerospace Industries' (IAI) 737-700BDSF will reach full volumetric capacity at a packing density of 8.83lbs/cu ft. Loading a volumetric payload of 6.5lbs/cu ft, it will have a maximum structural payload of 30,297 lbs.

The A321P2F WV00 (EFW) will reach full volumetric capacity at a packing density of 5.99 lbs/cu ft. Loading a volumetric payload of 6.5lbs/cu ft, the aircraft will have a maximum structural payload of 45,581 lbs.

The A321P2F WV11 (EFW) will reach full volumetric capacity at a packing density of 6.66lbs/cu ft. Loading a volumetric payload of 6.5lbs/cu ft, the aircraft will have a maximum structural payload of 49,465lbs *(see table, page 66)*.

The A321PCF WV00 (Precision Conversions) will reach full volumetric capacity at a packing density of 6.86lbs/cu ft. Loading a volumetric payload of 6.5lbs/cu ft, the aircraft will have a maximum structural payload of 48,471lbs.

The A321PCF WV11 (Precision Conversions) will reach full volumetric capacity at a packing density of 6.86lbs/cu ft. Loading a volumetric payload of 6.5lbs/cu ft, the aircraft will have a maximum structural payload of 48,471 lbs *(see table, page 66)*.

The 757-200PCF will reach full volumetric capacity at a packing density of 9.13lbs/cu ft. Loading a volumetric payload of 6.5lbs/cu ft, the aircraft will have a maximum structural payload of 54,340lbs *(see table, page 66)*. AC