Twelve months ago, the A321 freighter was considered by many as an untried 757 replacement, and only won interest with the major integrators. Now many investors and airlines are lining up to convert idle A321-200s into the latest narrowbody freighter, that boast large volumetric capacity.

New kid on the block: 4 P-to-F programmes for the A321

There are four companies that are developing passenger to freighter (P-to-F) conversion supplemental type certificates (STCs) for the A321-200. All will be able to achieve a maximum structural payload of 27-28 tonnes.

Three of the STCs accommodate 14 full main-deck container and pallet positions and are differentiated by the size and orientation of the rearmost pallet position *(see table, page 48)*. A fourth STC proposes 14 full-size container or pallet positions, plus a half-size container.

The A321 is the first narrowbody freighter that can take advantage of a containerised cargo solution in its lower hold, which has the capacity for 10 LD3-45W containers. This will increase the A321's versatility and volume, and it is expected to prove popular with express operators and for interlining freight.

Derived from the A321-100, the A321-200 first entered service in 1997 and is available with IAE V2500-A5 and CFM56-5B engines. To date there are about 1,700 operational aircraft in the passenger fleet. Conversion feedstock aircraft can be acquired from about $13 million.

Orders

Qantas Freight became the first carrier to operate the A321 freighter when it took delivery of the Elbe Flugzeugwerke (EFW) P-to-F conversion in October 2020.

Designated the A321P2F *(see table, page 48)*, the EFW-converted freighter is part of a joint venture (JV) with Airbus and ST Engineering. Leased by the asset management company Vallair, Qantas Freight has announced that the A321P2F will eventually replace its ageing 737-300/SF and 737-400/SF freighters.

Operating on behalf of Australia Post, Qantas Freight plans to introduce three A321P2Fs to its fleet to increase its cargo capacity and lower aircraft operating costs.

In January 2021, the aircraft asset management company BBAM leased the second redelivered EFW A321P2F to Titan Airways, which plans to introduce three of the A321 converted freighters to its fleet.

"The phone is off the hook, it is the busiest it has ever been," says Wolfgang Schmid, vice president of sales and marketing at EFW. "Every day is a Black Friday, and this could last for months because there are plenty of feedstock aircraft available at relatively low values compared to last year."

EFW began to convert its latest A321 in December 2020, and is committed to converting 10 aircraft in 2021. It was not expecting to ramp up A321 conversions so quickly. EFW is going to convert the A321 on six lines in Singapore, China and the United States (US). The prototype of the A320P2F will commence conversion on 1st March; the STC is expected for Q1 2022.

Based in Miami, a new ACMI charter operator called GlobalX has signed a letter of intent (LoI) with Vallair for 10 A321 freighters. GlobalX is in discussions with DHL and Amazon, and others, for large airfreight contracts.

Vallair has plans for a second A321 freighter in its inventory, because it is also a customer of the 321 Precision Conversions A321 P-to-F programme. 321 Precision Conversions is a JV between Aircraft Transport Services Group (ATSG) and Precision Aircraft Solutions (PAS), and has much experience with 757-200 P-to-F conversions.

321 Precision Conversions' prototype aircraft is designated A321-200PCF, and completed the first test flight in October 2020. SmartLynx Airlines has signed a lease with Vallair for the prototype aircraft, and expects to be operating a mixed fleet of 10 EFW- and 321 Precision-converted aircraft by 2023.

"We have a very high interest in our programme from operators, leasing companies and investors alike. This is helped by the fact that we have successfully test-flown the prototype aircraft multiple times, and we are now close to the finish line. We are engaged with multiple potential customers," says Zach Young, director of sales, at 321 Precision Conversions. "We are planning to induct three or four A321-200PCF conversions in 2021. Then we could see eight to 10 in 2022, as we expand into Europe and Asia. In 2023 and beyond we will scale up globally to meet the market demand." The current demand for A321-200 freighters is higher than the conversion capacity and this is expected to be the case at least in the near term. The movement by investors and operators into the A321 freighter space is an indication that the 757 P-to-F conversion market is slowing down, and the pool of suitable 757-200 conversion candidates is diminished.

"As a comparison, the 757-200 is a useful and solid freighter but it is becoming obsolete, difficult to operate reliably and increasingly expensive," says Patrick Leopold, director of trading & leasing at Vallair. "Due to coronavirus and non-existent passenger demand, many airlines have started to offload their older and inefficient aircraft, and market them at lower values than previously seen."

The 737-800 has a containerised and total freight volume of 6,532 cubic feet (cu ft); the 757-200 has a total volume of 8,390 cu ft; and a typical A321-200 has a total of about 7,600 cu ft *(see table, page 48)*. The total volumes for the 737-800 and 757-200 include the belly space

volume, which is not containerised.

The 757-200PCF has a gross structural payload of 84,000lbs without any structural modification. It is reported, however, that many freight operators are operating the type with a gross structural payload of no more than 24 tonnes, equal to 24,000Kg or 52,911 lbs, because of the typically low packing densities of eCommerce and express freight.

Challengers

Sine Draco Aviation Development is a company with operations in the US and China. Its US subsidiary, Sine Draco Aviation Technology, located in Bellevue, Washington is developing an STC for an A321-200 P-to-F conversion.

"We have been working hard to develop the technical aspects of the conversion, and getting customers' input. To us this is critical to making the aircraft competitive," explains Alex Deriugin, chief executive officer, at Sine Draco Aviation Development. "Low fuel burn, better maintenance costs, and high yields per container mean the A321 freighter is in the exact 'sweet-spot' between operating economics and cargo capacity."

The Sine Draco Aviation Development aircraft will be designated A321-200SDF *(see table, page 48)*, and is nearing completion of pre-mod-testing. After this, the aircraft will be inducted for conversion at Ascent Aviation Services in Tucson, Arizona. Sine Draco expects to receive a Federal Aviation Administration (FAA) STC in the first quarter of 2022. It will then validate and certify the STC in accordance with Civil Aviation Administration China (CAAC) and European Union Aviation Safety Authority (EASA) regulations.

C Cubed Aerospace is in the final stages of certifying its A320 P-to-F conversion while in parallel progressing with the A321. The 15-position main-deck freighter, designated the A321-CCF *(see table, page 48)*, is expected to be inducted into the conversion facility in the middle of 2021, and be completed by the first quarter of 2022.

"Our major differentiating advantage is that the A321-CCF will have the largest containerised cargo volume in this sector," says Brian Sagi, managing director at C Cubed Aerospace. "The A320-CCF and the A321-CCF are almost identical, with the same main cargo door, installed at the same fuselage station."

C Cubed is currently scheduling its conversion slots and is experiencing much interest. It believes demand for the A321-CCF will be high.

Values

High residual values for younger aircraft rule them out for cargo conversion. It is when an aircraft is 15-20 years old that it is considered to be in the zone of convertibility, and investors then expect it to remain in service for up to 20 years. High demand for A321 P-to-F conversions means that unless investors already have a conversion slot booked during the next 12-24 months, they could be waiting up to two years before one becomes available.

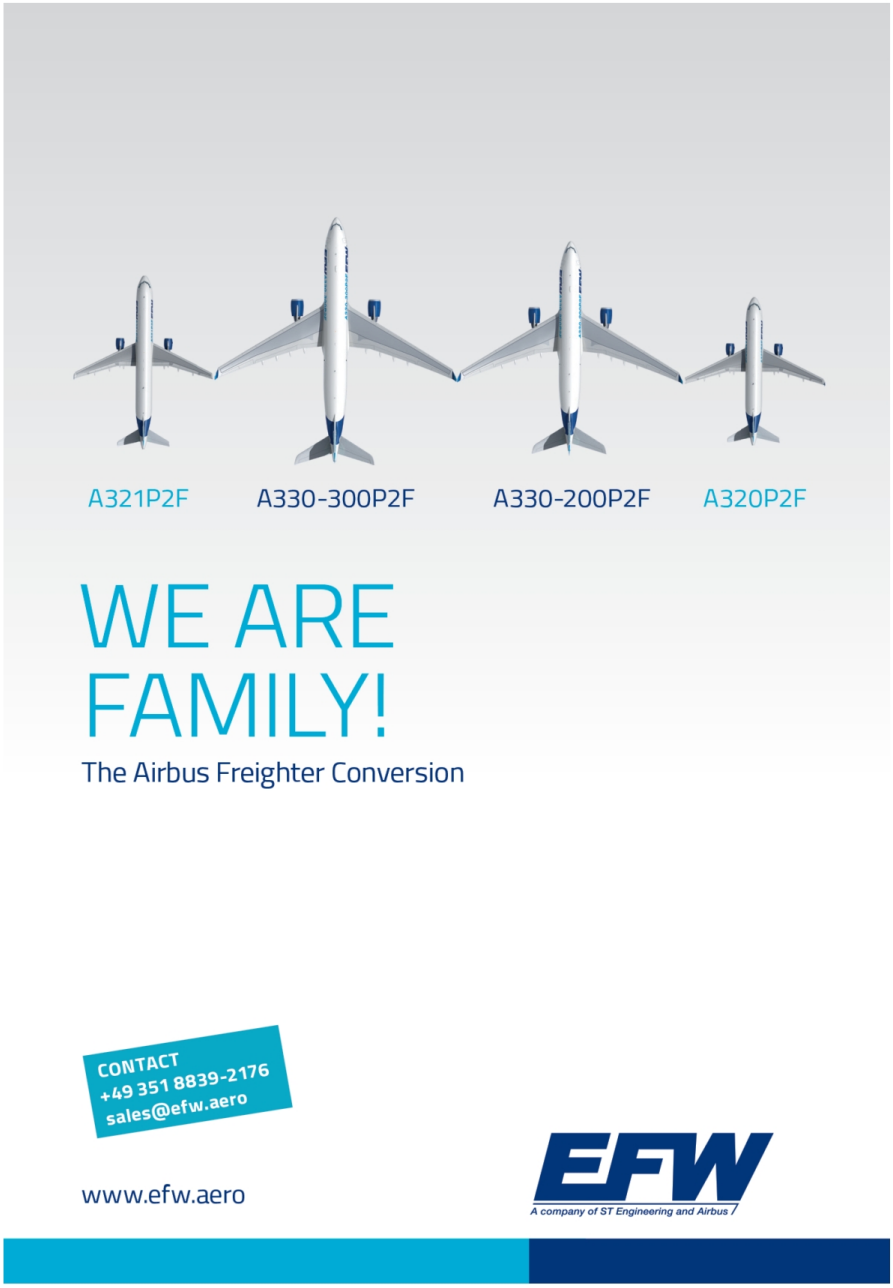
"Investors in A321 P-to-F conversions are price takers rather than price dictators. This is in terms of the actual conversion build cost. The biggest cost driver in the total on-ramp cost will be the initial acquisition cost of the feedstock aircraft and its maintenance condition," says David Yu, finance professor at New York University Shanghai and Chairman of Asia Aviation Valuation Advisors.

There is a lot of demand for cheap narrowbodies for P-to-F conversions, but because the A321-200 is expected to be in demand once passenger traffic returns, prices have not fallen dramatically.

"There are actually more people in the used A321 market looking for aircraft than many have realised. There are many people scouring for these aircraft. In terms of the market, there is a resurgence with part-out vendors that are competitors in this space," explains Yu.

The current market value (CMV) for a 15-year-old A321-200 fell by 27% from $18.9 million to $13.8 million from January 2020 to January 2021. Typical A321 passenger lease rates fell by 42% over the same period, and the values of aircraft that are 'naked' and without leases have dropped more than lease-attached aircraft. CMVs for narrowbodies in 2019 were remarkably high because of soaring passenger demand.

"While there is a direct relationship between the lease rate of the converted freighter and the aircraft value, logistics players that want to lease cargo aircraft



A321 CONVERSION FEEDSTOCK MTOW & MZFW WEIGHT CHARACTERISTICS

WV	WV000	WV001	WV002	WV003	WV004	WV005
MTOW	89,000Kg 196,211lbs	93,000Kg 205,030lbs	89,000Kg 196,211lbs	91,000Kg 200,621lbs	87,000Kg 191,802lbs	85,000Kg 187,393lbs
MZFW	71,500Kg 157,630lbs	73,800Kg 162,701lbs	73,800Kg 162,701lbs	73,800Kg 162,701lbs	71,500Kg 157,630lbs	71,500Kg 157,639lbs
WV	**WV006**	**WV007**	**WV008**	**WV009**	**WV010**	**WV011**
MTOW	83,000Kg 182,984lbs	83,000Kg 182,984lbs	80,000Kg 176,370lbs	78,000Kg 171,961lbs	85,000Kg 187,393lbs	93,500Kg 206,132lbs
MZFW	71,500Kg 157,630lbs	69,500Kg 153,211lbs	69,500Kg 153,211lbs	69,500Kg 153,211lbs	73,800Kg 162,701lbs	73,800Kg 162,701lbs

will generally have an upper limit of how much they will pay to be cost-competitive. This is unlike passenger aircraft where interiors matter more," says Yu.

Airbus plans to deliver about 300 new A321neos to airlines over the next two years. Many investors are refraining from bankrolling A321ceo feedstock just now, because it is believed that their values will drop further once passenger demand returns and airlines take delivery of A321neos to replace their older A321ceos.

"Last August and September, the advice was to hold off until early 2021 to see what happens to the residual values. We are now in the first quarter and there has not been much movement in price," says Deriugin.

Vallair reports that it does not see a big difference in lease rates between EFW- and Precision-converted aircraft because the build costs are similar. Much will depend on the initial acquisition cost of the feedstock aircraft, and lease rates for A321 freighters will fall between the 737F and 757F.

The conversion is expected to cost about $5.9 million. If the initial acquisition price is $13-15 million, and $1-3 million is needed for maintenance, weight upgrades, and repairs, the on-ramp cost for an A321 freighter is expected to be $21-24 million.

Engine types

The A321-200 is available with two main engine types: the CFM International CFM56-5B and International Aero Engines (IAE) V2500-A5. A321-231 and A321-232 sub series aircraft are equipped with V2533-A5 and V2530-A5 that are rated at 30,000lbs to 33,000lbs of thrust.

A321-211, A321-212 and A321-213 aircraft are equipped with CFM56-5B3/, -5B1, and -5B2 engines. These engines also provide 30,000lbs to 31,000lbs of thrust.

Most of the A321 fleet is V2500-powered. "From our perspective, both engine types have their pros and cons," says Leopold. "Sometimes the airline makes its choice simply because it operates a V-powered fleet rather than a CFM fleet. Airlines do not want to overcomplicate things by operating two engine types."

Introducing a new engine type to the fleet will increase operator overhead costs in spare parts and engine inventory, and mechanics with training and experience on both OEM engine types will be needed.

The reason why more A321s are equipped with V2500s is that the CFM56-5B was a development of the 5A, which had 25,000lbs of thrust. The V2500 was designed as a 33,000lbs engine, and was thought to be more capable and better suited to the higher thrust needed for higher gross weight aircraft.

"The older an aircraft is, the higher the portion of the acquisition cost is accounted for by the engines," says Leopold. "In such a (pandemic) situation used engines are readily available. Do you try to acquire the airframe embedded with the engines, or do you source its engines separately? It is possible the lessee will have spare engines. There are several options to go about this."

The market shows a wide variety of engines currently available, and the correct engines will need to fit in with each business case. As engine shops are quiet, few operators are currently buying engines.

The CMV for a V2500-A5 is $5.4-5.6 million, while the CMV for the CFM56-5B is $7.2-7.6 million. The lower the thrust rating, the lower the value of the engine.

According to Simon Mermod, director at Jet Engine Management, "Historically on both those engine types, the higher the thrust, the shorter the life limits on the life-limited parts (LLPs). Now they are fairly uniform". The V2500 is 20,000EFC across all the LLPs for all thrust ratings. The latest CFM56-5B can achieve 30,000EFC for fan stage module LLPs, 20,000EFC for the core module LLPs, and 25,000EFC for parts in the low pressure turbine (LPT) module.

The CFM56-5B engine is more familiar to 737 freight operators, and shop visits are reported to be less costly. Alternatively, the V2500 is considered to return a lower fuel burn. Overhaul expenses for the CFM56-5B are about $3.5 million, and $4.5-5.0 million for the V2500-A5.

To extend the time between performance restorations it is possible to reduce the maximum thrust and de-rate the engine. "The V2500 and the CFM56-5B are both available at lower thrust ratings. If you compare the time on-wing for engines set at high thrust ratings against low thrust ratings, the lower the thrust, the longer its removal interval," says Mermod.

Certifying the A321 freighter at a lower thrust setting will improve its operating economics. It is possible, however, for pilots to adjust the level of thrust available via the flight management computer; effectively de-rating the engine on a per flight basis. Many A320 pilots in Europe will de-rate engine thrust by an average of 15% because they do not need to use full take-off power. This can significantly improve the engine's durability.

Aircraft MSN

EFW's A321P2F prototype aircraft MSN 835 is a V2500-powered example that was built in 1998, and has accumulated 29,500 flight cycles (FC) and 52,280 flight hours (FH). This is operated by Qantas Freight.

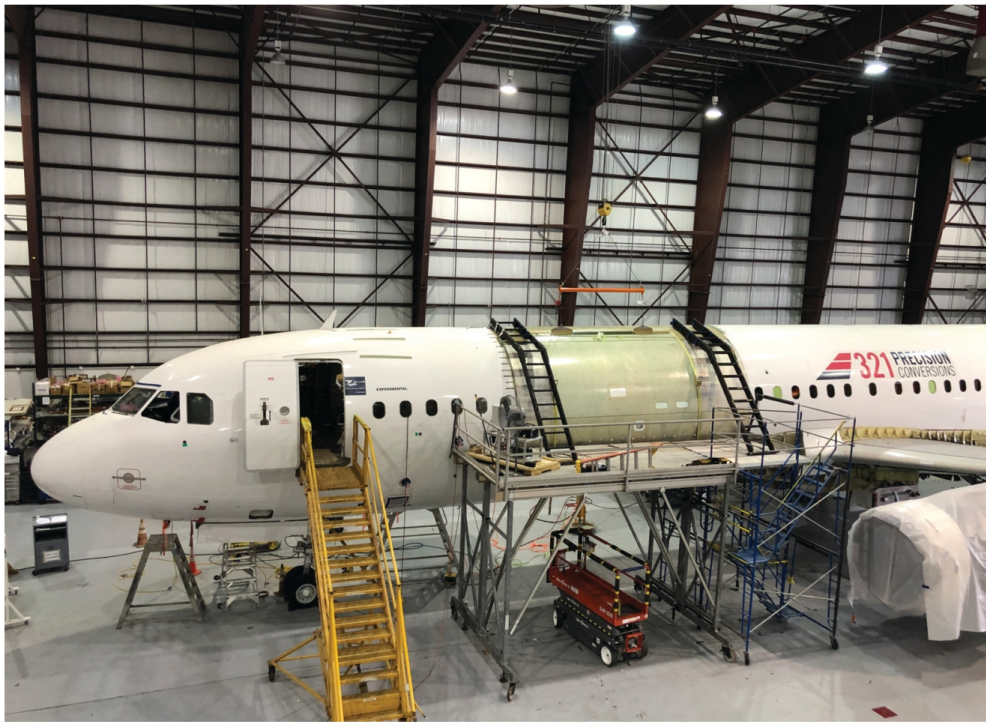
The second EFW aircraft, for Titan Airways, is an A321P2F that was built in 2000. It is equipped with CFM56-5B engines, and has completed 21,220FC and 67,380FH.

A third aircraft, built in 2000, is MSN 1250. This has also been inducted into EFW's conversion facility, and has completed 21,800FC and 69,426FH and has CFM56-5B engines. 321 Precision Conversions' prototype aircraft is MSN 891, and was built in 1998. It has CFM56-5B engines, and has accumulated 14,384FC and 26,622FH.

Sine Draco Aviation Developments' prototype was manufactured in 1999 and has flown 30,400FC and 49,070FH, and has V2500 engines.

Goals

The design service goal (DSG) is the maximum number of FH and FC an aircraft can complete before it is grounded. Investing in an extended service goal (ESG) will increase the DSG of the aircraft, and



MSN 891 was built in 1998 and is a CFM56-5B powered aircraft and 321 Precision Conversions protype. The prototype A321-PCF was test flown in October 2020 and will be redelivered to SmartLynx Airlines. In 2021 321 Precision conversions expects to induct three or four more aircraft into its facility for conversion.

ESG modifications can only begin after all pre-existing repairs have been inspected and approved by Airbus, and any sub-standard repairs have been rectified.

During an RDAS, Airbus charges per repair inspected, so it will cost twice as much for an aircraft that has been repaired 30 rather than 15 times.

Uncertainty and the high cost of an ESG2 mean it is likely to be uneconomic to convert an aircraft approaching a total time of 48,000FC. It is simpler to choose an asset with a higher number of FC and FH remaining, and in times of short supply to choose an asset that requires the ESG1 modification only.

Many operators will not accept an aircraft being grounded for one month for a maintenance check shortly after conversion. Once the aircraft is being converted it is best to zero any letter checks so that the aircraft will be 'on-ramp-ready' for operations without requiring pending maintenance work.

Weight loss

The A321-200 is available in 12 different weight variants (WVs), from WV000 to WV011. This allows airlines to procure the most efficient aircraft for the operation and route network. The characteristics of the WVs include different permutations of maximum take-off weight (MTOW), maximum zero fuel weight (MZFW), and maximum landing weight (MLW).

The greater the difference between the aircraft's operating empty weight (OEW) and the MZFW, then the higher is its gross structural payload. All P-to-F conversion STCs will aim to reduce the aircraft OEW by as much as possible, and to increase the MZFW to its maximum limit.

OEW will vary between aircraft. It is dependent on the aircraft's specification, and the number of repairs and the specification of operating equipment, such as safety items and avionics.

The most common WVs issued to the A321-200 are WV000, WV001, WV002 and WV011 *(see table, page 46)*. Aircraft certified at the other WVs are relatively rare, and in some cases are limited to just four or five aircraft.

The three available MZFW alternatives for feedstock aircraft are 153,221lbs, 157,630lbs, and 162,701lbs. WV001, WV002, WV003, WV010 and WV011 have the highest available MZFW of 162,701lbs, and the WV000 has an MZFW of 157,630lbs *(see table, page 46)*.

Each repair must be inspected in accordance with RDAS guidelines when actioning a WV increase, similar to ESG guidelines. It has been reported that the typical budget set aside for a WV upgrade is about $1 million.

Upgrading the weights of a freighter aircraft is considered worthwhile, since the investment can be absorbed into the conversion cost. Airlines and lessors prefer freighter aircraft that can achieve the highest possible structural payload because it increases their marketability by making them suitable for a range of operations.

Some weight changes only require the aircraft flight manual (AFM) to be updated and others will require some structural modifications. MSN 633 to MSN 1,788, and MSN 1,798 to MSN 1,869 cannot be upgraded from WV000 to a WV011.

"Most of the time some structural reinforcement is required. This does not present a problem, because the aircraft will be opened up for the conversion. This is why we encourage the customer to approach Airbus before we start work on the conversion," says Schmid.

MSN 633 to 1,788, MSN 1,798 to MSN 1,869 and MSN 1,878 may require upgrades to landing gear, wheels and brakes, and other structural pre-requirements, when upgrading WV000 to WV001 and WV002.

321 Precision Conversions

Thanks to a low operating empty weight, 321 Precision Conversions achieves a 27-tonne, or 59,525lbs, gross structural payload on WV000, and can use it across the 14 main-deck and 10 lower-deck positions. The main deck will have a volumetric capacity of 5,990 cu ft when configured with 13 AAY/AAA 88 x 125 containers and one 88 x 125 x 72 PAG pallet in the aft 14th position. Assuming a 65% volume the PAG will have volumetric capacity of 285 cu ft.

The A321-PCF will have a 5,948 cu ft main-deck capacity when it is configured with two LD3-45W/AKH stowed in aft 14th position instead of the PAG.

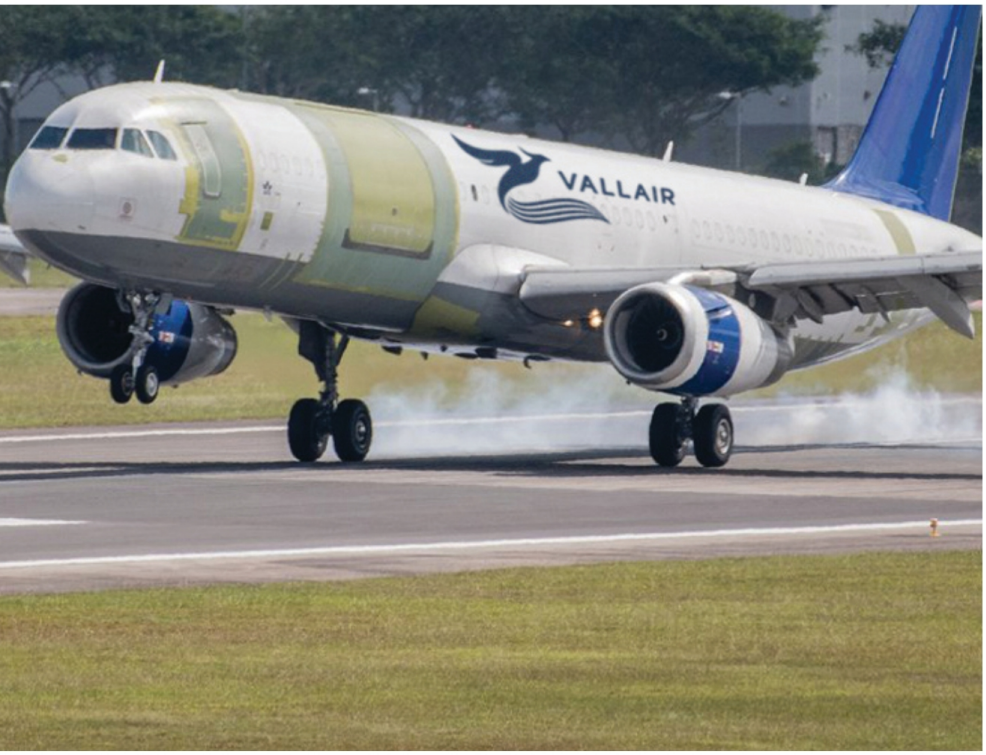
When the A321PCF is configured with 13 AAY/AAA and a PAG, it will have a main-deck tare weight of 3,059Kg/6,743lbs, and a total tare weight of 3,839Kg/ 8,463lbs, when carrying 10 lower-deck LD3-45Ws. This means the A321PCF has a net structural payload of 23,161Kg/51,062lbs *(see table, page 48)*.

At packing density of 6.5lbs per cu ft, the aircraft has a volumetric payload of 21,405Kg/47,190lbs and a maximum packing density of 7.03lbs per cu ft *(see table, page 48)*.

The placement of the 9G barrier means there is no need for additional modification and fabrication of crew access doors because the L1 and R1 doors remain active. The aircraft also has a full-size flight deck, lavatory and galley, plus occupancy for four passengers and two crew.

The A321PCF has an OEW of 98,105lbs *(see table, page 48)*. The 321 Precision deck plan permits a conversion that operates within the original passenger CG envelope and does not require a permanent rear ballast installation. Consequently, the large original flight deck is retained without a penalty in cargo volume. At WV000 with an MZFW of 157,630 lbs, this yields a gross structural payload of 59,525 lbs *(see table, page 48)*.

"We designed this conversion around



To elongate the cargo compartment, EFW moved the 9G barrier forward which means both the L1 and R1 passenger access doors must be deleted, and a smaller crew access door is built. Moving the 9G barrier forward reduced the size of supernumerary area, yet allows for 14 AAA/AAY main deck containers.

the WV000 to carry 27 tonnes, or 59,525lbs, without any costly weight upgrades, knowing very well that when in service it will typically carry no more than 23-24 tonnes or 50,706-52,911lbs. This is because the aircraft will be operating primarily in the lower-density express freight market. Increasing the A321PCF cargo capability above 27 tonnes or 59,525lbs will require more structure, cause higher OEWs and negatively impact the performance and operating costs," says Young.

Typical packing densities in the express market are about 6.5 lbs per cu ft, meaning the aircraft will exceed its volumetric capacity before its structural payload is reached.

Early in the programme, 321 Precision Conversions considered developing an aircraft with a 25-tonne or 55,116lbs gross structural payload, but believed the market was not ready for such a light-density freighter. It is also possible that eCommerce and freight-forwarding companies will pack containers more efficiently to increase average packing densities.

Developing a 27-tonne or 59,525lbs P-to-F STC around WV000 and keeping the OEW lower means the operator will not need to invest in a WV upgrade, while still achieving the payload and range requirements. Upgrading from WV000 to a WV002 will cost about $520,000, while upgrading from a WV000 to WV001 will cost about $1.35 million.

Because the WV000 has lower operating weights, it will be subjected to lower airport charges. Operating at lower certified weights will also save repair and overhaul costs, because ware tolerance limits are higher. This is especially the case with undercarriage components and brakes.

According to 321 Precision Conversions, a higher weight variant aircraft is not practical because the main-deck payload is structurally limited to 59,525lbs regardless of MZFW. Also because of the lower OEW, it is physically impossible to reach an MTOW of 93 tonnes or 205,030lbs without an additional centre tank (ACT) installation. This is one area where 321 Precision Conversion differs from the competition and why it recommends a WV000. If an incoming aircraft is equipped with higher operating weights such as WV002, 001 or 011, it is far more cost-effective to downgrade the aircraft to WV000.

"We took a hard look at how efficient this aircraft is and the type of cargo it will be expected to carry now and in the future. From a performance, operating cost, on-ramp price, weight and balance, supportability and maintainability standpoint, we have the optimum configuration," says Young.

321 Precision Conversions is not yet certifying the ACT, as it negatively impacts the A321's volumetric and structural payload.

"If the conversion candidate is equipped with an ACT, we will require the ACT to be removed either via the aircraft maintenance manual (AMM) or the OEM SB," says Young. There can be provisions for up to two ACTs in the aft lower cargo hold, and a 'cap and stow' removal will typically take eight hours. It is not expensive."

Depending on the fuel reserves required, a 3.5 to 4.0 hour flight time is achievable without ACTs installed. It is not foreseen that operators will fly the A321 further than this. The range of the A321-200PCF is about 2,200nm at max payload, which can vary depending on the seasonal winds or reserve fuel requirements.

Elbe Flugzeugwerke EFW

EFW's STC covers all the available WVs and both engine types. Like all the other STC holders, EFW cannot convert legacy -100 aircraft, which were the first variant of the A321 and built in limited numbers. The A321-200s in the STC make it possible for the operator to choose a WV that best suits their operational requirements.

The difference in engine and WV type does not dramatically influence the price of the base-level conversion. Engineering costs can be lowered, however, by converting a number of feedstock aircraft that have been built in a single batch and same specification. EFW can then pass on the cost saving to the customer.

"If the feedstock aircraft have been ordered by different airlines and have different engines and weights, they will require more engineering work, and there are no savings to be made," says Schmid.

The A321P2F has a structural payload of up to 28 tonnes or 61,730lbs across 14 main-deck and 10 lower-deck positions *(see table, page 48)*. The aircraft has a total containerised volumetric of 7,402 cu ft that is distributed in 14 AAY/AAA 88 x 125 main-deck containers, and 10 LD3-45W lower-deck containers.

The A321P2F has a main-deck tare of 3,245Kg/7,154lbs, and a total tare weight of 4,025Kg/8,874lbs when carrying 10 lower-deck LD3-45Ws *(see table, page 48)*.

Assuming the feedstock aircraft can attain a payload of 28 tonnes/61,730lbs and has a WV of 162,701lbs MZFW, such as WV001/0002/0011, it will achieve net structural payload of 23,975Kg/52,885lbs. At packing density of 6.5lbs per cu ft, the aircraft has a volumetric payload of 21,824Kg/48,113lbs and a maximum packing density of 7.14lbs per cu ft *(see table, page 48)*.

EFW modifies the cockpit and galley area to accommodate 14 containerised positions to maximise the aircraft's volumetric capacity. This is achieved by

To start with Sine Draco is developing its STC around the most numerous weight variants and V2500 engine choice. Sine Draco expects its A321-200SDF to be awarded a Federal Aviation Administration (FAA) STC in the first quarter of 2022, and redelivered shortly afterwards.

installing the ridged 9G barrier forward, deleting the passenger L1 and R1 doors, and building a crew-access door.

EFW has developed the 14-container STC because the airlines wanted a volumetric-focused aircraft that used and 'maxed out' all the available capacity. It also wanted the aircraft to be able to fly empty when required without loading ballast. Fundamentally these demands influence the aircraft's OEW.

To assist in keeping the aircraft within its centre of gravity (CoG) limitations and preserving the payload in the far forward first position, additional 'balancing' weight is installed in the tail. This also allows the EFW conversion to fly empty without adding ballast.

If a feedstock aircraft is certified at WV01/002/011, and has a gross structural payload of up to 28 tonnes or 61,730lbs, its OEW will be 100,972 lbs because it is the difference between gross structural payload and MZFW.

On this assumption, if a lower-weight specification WV000 aircraft was put through conversion it would attain a gross structural payload of 25.7 tonnes or 56,658lbs *(see table, page 48)*.

It will achieve net structural payload of 21,674Kg/47,784lbs and a maximum packing density of 6.14lbs per cu ft *(see table, page 48)*.

"We can convert all WVs. If potential operators are happy with an aircraft that has a payload up to 25 tonnes or 55,116lbs because they do not operate at a high packing density, then we can do it. In the end everybody is going to invest in a weight upgrade if they need it because the higher WV buys flexibility," says Schmid.

EFW's second conversion aircraft achieved the highest gross structural payload of 28.2 tonnes or 62,170lbs.

Sine Draco

The Sine Draco A321-200 SDF flightdeck compartment will have the capacity for up to six occupants and retains the original L1 and R1 passenger doors. The main-deck cargo compartment will support 14 ULD containers with 88 x 125 inch footprint. The larger crew compartment pushes the 14th container position further aft, limiting the position to a 64-inch height pallet or container, instead of a AAA /AAY container.

Carrying 13 full height AAA/AAYs and a single 64-inch '125 x 88' AAP/LD9 will give the SDF a main-deck volume of 6,075 cu ft *(see table, page 48)*. The lower-deck cargo capacity is unchanged at 1,270 cu ft. This gives the A321-200SDF a total volumetric capacity of 7,345 cu ft *(see table, page 48)*. Once the STC has been issued, the A321-200SDF is expected to achieve a gross structural payload up to 28.2 tonnes or 62,170lbs *(see table, page 48)*.

Assuming a 28.2 tonne gross payload, when the A321-200SDF is configured with 13 AAY/AAA and a AAP/LD9, it will have a main-deck tare of 3111Kg/6,858lbs, and a total tare weight of 3,891Kg/8,578lbs when carrying 10 lower-deck LD3-45Ws. This means the A321-200SDF has a net structural payload of 24,309Kg/53,592lbs.

At packing density of 6.5 lbs per cu ft, the aircraft has a volumetric payload of 21,655Kg/47,742lbs and a maximum packing density of 7.29lbs per cu ft *(see table, page 48)*.

"We use an Ancra cargo loading system (CLS) for the main deck. The basic system will support a 14-container configuration, but we can provide a number of options to support several different configurations, layouts and sizes," says Christopher Stafford, senior director of sales and marketing, Sine Draco.

Sine Draco has analysed the A321 fleet to create a product roadmap of late model series aircraft and engine configurations, including weight variants suitable for conversion. As a result, Sine Draco is developing its initial STC for V2500 powered WV000 and WV002 aircraft.

"Ultimately the customer will drive the configurations we develop in the future. The -231 and -232 at WV000 and WV002 are the primary feedstock opportunities," says Stafford. "One of the drivers for the feedstock selection is how the airline wants to operate the aircraft. If it plans to use containers on the lower deck, then the relatively higher container tare weight may mean the WV002 is more appropriate."

Once the STC has been issued, Sine Draco plans to have four conversion lines each completing three aircraft per year. It is believed the A321 freighter will be well received in the market as a good replacement for current mid-size freighters.

C Cubed

C Cubed has been able to accommodate 15 main-deck positions: 14 full-size and one half-size *(see table, page 48)*. The 15th position is the same size as used in the lower cargo hold. C Cubed achieved this by placing the 9G barrier as far forward as possible to accommodate an extra main-deck cargo position. The aircraft is expected to be capable of a gross structural payload of up to 28 tonnes or 61,729lbs *(see table, page 48)*, depending on the WV of the feedstock. C Cubed STC will cover all WV and both engine types.

One benefit of the C Cubed configuration is that the main cargo door is positioned further forward than in other A321 freighters. This allows for greater clearance between ground loading equipment and the aircraft's engines. The flight deck includes a lavatory and three optional supernumerary positions, and a crew entry door replaces the original passenger L1 and R1 access points.

The main cargo deck carries 14 AAA/AAY containers; and either a single LD3-45W, or a 72 x 88 x 125 PAG pallet. The A321-200CCF has a total containerised volume of 7,698 cu ft *(see table, page 48)*. This is split between 6,428 cu ft on the main deck, and 1,270 cu ft in

Operating on behalf of Qantas Freight, Australia Post is the first operator of the A321-P2F. The A321 is the first narrowbody freighter that has the capability to have a lower hold container loading system and lower deck containers. It is expected that the type will typically operate at low express cargo packing densities of 6.5 lbs, and ultimately replace ageing 757Fs.

10 LD3-45W lower-hold containers. The gross structural payload is about 28 tonnes or 61,729lbs, depending on the weight variant of the feedstock aircraft.

When the A321-CCF is configured with 14 AAY/AAA and a PAG, it will have a main-deck tare of 3,290Kg/7,254lbs, and a total tare weight of 4,071Kg/8,974lbs when carrying 10 lower-deck LD3-45Ws. This means the A321-CCF has a net structural payload of 23,929Kg/52,755lbs.

At packing density of 6.5 lbs per cu ft, the aircraft has a volumetric payload of 22,696Kg/50,037lbs and a maximum packing density of 6.85lbs per cu ft *(see table, page 48)*.

C Cube reports the A321 conversion will be straightforward, because it will have more than 90% commonality with the A320-CCF, which it is presently completing. One of the reasons C Cubed believes the A320 will be the more difficult aircraft to convert is because it has a smaller airframe that requires a greater degree of design ingenuity. This ingenuity, carried to the larger A321, is what allowed C Cubed to obtain the extra container position in the A321.

The main cargo deck half-size pallet positions in the C Cubed A230 and A321 freighters are significant. The same size of pallet or container used in the aft-most position is identical to that used in the lower cargo hold.

The C Cubed A321 freighter, for example, will provide 14 full-size positions and a half-size position on the main deck. It is therefore worthwhile for operators to use half-size positions. In contrast, the 737 Classic and NG freighters have provision for a smaller half-size pallet in the last position, but most operators do not use it because there is just one of those containers per aircraft. According to Sagi, the aft-most position and the lower cargo hold are why the C Cubed A320 and A321 freighters have the highest containerised volume in their class.

Cargo loading system

It is expected that 50% of the A321 fleet will have a lower-deck CLS installed. It is likely that many aircraft that were initially delivered to the American market, will not have a lower-deck CLS fitted. Sine Draco is offering an Ancra lower lobe CLS as an option during the conversion. Containerised lower-deck solutions are more popular in Europe and the rest of the world than in the US.

"Narrowbody operators carry bulk cargo in the lower-deck compartments, so we expect operators to take advantage of the availability of the containerised lower deck. Optimising the lower deck with a containerised solution will increase cargo density and volumes and provide shorter load and unload times, critical in express market operations," says Stafford. "Combination carriers that have experience using lower-deck containers are more likely to take advantage of this capability initially."

To add the OEM lower-hold CLS to an existing aircraft could be cost-prohibitive. Aftermarket solutions are available from both Ancra and Telair.

"Many passenger operators are looking to enhance their cargo operations. For this reason we have created an aftermarket solution to retrofit the lower cargo hold CLS to existing aircraft. The OEM system is just not cost-effective," says Sagi.

The lower-hold CLS will help cargo operators interline with passenger aircraft. The ability to take a container from the belly of a freighter and move it quickly to a passenger aircraft for re-distribution to a secondary destination will be key.

"The new feature of the belly containers is that more containerised cargo can be handled on a smaller aircraft. Also integrators may introduce these new belly containers as soon as they operate larger numbers of the aircraft," says Schmid. "It is a fantastic use of the aircraft, because you do not damage as many packages."

When full with containers, the lower hold CLS option also allows for 208 cu ft of bulk cargo. The small size of this space means it is typically used for aircraft spares, such as aircraft tyres, rather than revenue-yielding items.

Summary

The A321's volumetric capacity makes it an ideal replacement to the 757-200F, and provides new entrants and existing operators with a viable alternative to the legacy freighter, with better operating economics.

A321 P-to-F conversion programmes are developing at a time when demand for cargo capacity is high and feedstock aircraft are readily available and acquisition prices are low. Furthermore, A321 values could remain low as A321neos enter service in more meaningful numbers.

The way the STC holders achieve their individual gross structural payloads is different, yet ultimately a gross structural payload between 27 and 28 tonnes will be more than sufficient to meet carriers' eCommerce and express freight requirements, for today and in the future.

Cargo volume and the main deck loading configurations will be a matter of individual preference that could be decided by the operational factors. Some operators will prefer the larger flight deck of 321 Precision Conversions and Sine Draco to the volumetric capacity of EFW and C Cubed offerings. Nevertheless, for the near-term, decisions could be solely made on slot availability alone.

As A321-200 conversion providers are currently facing levels of high demand, it is expected that with four conversion companies competing for business its equilibrium will be soon be achieved. AC

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