Lessors, traders and airlines have to strike a balance between acquiring time-continued engines at attractive market values and having sufficient technical support in the industry available to operate them, and their related aircraft. The market dynamics of four engine types are examined.

The market & values for older engines: JT8D-200, CFM56-3, CFM56-5C & CF6-80C2

The aftermarket dynamics of engines powering older generation aircraft types are largely affected by how much of the fleet that has retired, the level of demand for engines in the remaining fleet, and its utilisation. A high availability of time-continued engines with a reasonable amount of remaining maintenance life compared to the active installed fleet will represent an oversupply and reduce market values. This naturally leads to operators exploiting the market situation, by using time-continued engines and modules instead of performing full maintenance. Operators of older aircraft can therefore make savings by avoiding engines' full long-term maintenance costs. The market dynamics, activity and values of older engines, including the JT8D-200, CFM56-3, CFM56-5C and CF6-80C2, are examined here.

Fleet profile

The production of these engine types, and the aircraft they power, ceased 10-20 years ago. The exception to this is the 767-300ERF, powered by the CF6-80C2, which has 61 orders outstanding.

The fleet size and number of each type in operation has therefore reached and passed its peak. Some of the fleet for each type has been retired, parked or written off. Some of the aircraft that have been retired and parked have supplied the aftermarket with engines. Depending on the last operator's engine management and retirement strategy, these engines may have some remaining maintenance life when they become available.

A large number of available engines in relation to the active fleet will keep values low. The value of a time-continued engine in the aftermarket is generally based on the remaining life of its life-limited parts (LLPs), adjusted by a pro-rate factor. The pro-rate factor declines as the engine and aircraft type age and decline in the size of the remaining active fleet. For example, an engine with a full shipset of LLPs that have a list price of $4.0 million, and full lives of 20,000 engine flight cycles (EFC) would be valued at $2.0 million, adjusted by the pro-rate factor. An engine like the CFM56-3, which has seen 60% of the original fleet retire, will have a pro-rate factor of 50% or even less. It will therefore have a market value of $1.0 million, divided between the main engine modules. The high pressure (HP) section of the engine will be in highest demand from the aftermarket, so it accounts for the largest part of the used market value.

The pro-rate factor is almost insignificant for a type like the JT8D-200, with about 75% of the MD-80 fleet having retired. One of the lowest rates of retirement for these older engine types is the sub-fleet of CF6-80C2s with full authority digital engine control (FADEC), with about 21% of the aircraft it originally powered having been retired or in storage, and 78% still in active service.

JT8D-200

The MD-80 went into mainstream production in 1979, and continued until 1999. A total of 1,194 aircraft were built, of which almost 900 have been retired or are in storage, and 49 have been written off. This leaves 246 aircraft in active service at the start of 2019, split between 232 passenger- and 14-freighter configured aircraft. The freighters were converted under the Aeronautical Engineers Inc (AEI) programme.

The MD-80 was popular in the US and Europe, and operated in large numbers by American Airlines and Delta Airlines. Major European carriers were SAS, Swissair and Alitalia. It only had 11 major airline operators, and few MD-80s were operated elsewhere in the world.

The active fleet of MD-80s has declined from about 1,045 units in 2005, at an average rate of 57 aircraft per year, with 67 aircraft retired over the past year.

The remaining fleet includes 29 aircraft operated by American Airlines and 88 by Delta. Both these fleets are in decline, having been at 362 and more than 120 aircraft. The remaining 120 active passenger-configured aircraft are operated by a mix of airlines that utilise mainly used aircraft.

The MD-80 is exclusively powered by JT8D-200 series engines. The three main variants are the -209, -217A/C and -219. The -217A and -217C power 67 of the aircraft left in service, and the -219 powers 165 active aircraft that include the remaining American and Delta fleets.

"From the start, the MD-80 was only operated by a limited number of airlines. Most original major MD-80 operators are no longer involved with the type, and many airlines using it are small, secondary carriers. These have used many of the time-continued engines that were available," says Mario Abad, chairman of the board, at Aerothrust. "It has therefore become very difficult to find good quality time-continued engines with a reasonable amount of LLP life remaining.

"There are now only a few shops left with JT8D-200 capability. It has also become difficult to acquire parts. Pratt & Whitney no longer manufactures airfoils or LLPs for the engine," continues Abad. "The remaining fleet is therefore very dependent on the aftermarket. Aerothrust buys material, partly to provide warranties for our customers. We bought the American Airlines fleet to acquire parts so that we can support our contracts."

Aerothrust has a power-by-the-hour (PBH) maintenance contract with Delta Airlines. "This is for 116 engines. We also own a portfolio of engines, and lease 10 to Delta, 15 to American and 29 to other smaller customers," says Abad. "We are not just in the maintenance and technical support market for the JT8D-200, but also in the leasing and trading market.

American and Delta are due to retired their MD-80 fleets by 2021. Moreover, there are few providers of specialist repairs for the JT8D-200, Aerothrust is scheduled to shut down its shop visit line for the engine, and Pratt & Whitney no longer manufactures parts. It will become increasingly difficult to support the aircraft engine after 2021.

On average we sell one engine per month.

"We have been active in securing core engines on the aftermarket, because fewer airlines want to perform hi-tech and complex parts and airfoil repairs. This makes it difficult to support the engine," explains Abad. "We therefore do 75% of the required repairs in-house, and have to repair other parts such as the seals and turbine airfoils. The repair providers that are left in the JT8D-200 market are Chromalloy, Turbochrome in Israel, and MTC in Japan. These all perform specialist airfoil repairs. Turbochrome, for example, repairs fan blades and turbine airfoils. If these companies shut down their JT8D-200 capabilities, then time-continued engines will be the only source of airfoils and other parts. The JT8D-200 market could no longer exist by 2021."

Aerothrust is shutting down its engine repair and shop visit (SV) line in 2021. It currently performs about 12 engine SVs per month. "These are not all full SVs, however," says Abad. "About five per month are minor visits performed under warranties, up to seven are engines that require some sort of repair or restoration between leases or that are due to be sold, and three per month are proper SVs."

American Airlines, which has kept its JT8D-200 capability, is shutting down its line, and its MD-80 fleet will be fully retired by the end of 2019. Delta maintains a hospital shop for the JT8D-200, but Abad says it has not performed full or heavy SVs for several years.

There are still a large number of engines on aircraft parked in Roswell, and Aerothrust has bought the retired aircraft. "All of these engines can support any remaining JT8D-200 activity," says Abad. "Although the active MD-80 fleet has declined fast, with 67 retired during 2018, the market value of engines is actually climbing because of a shortage of parts and difficulties acquiring them.

"Of the 232 passenger aircraft left, 30 are with American and 88 with Delta. We bought 185 retired aircraft from American and have first refusal to buy its last 30," says Abad. "These aircraft have good engines, which have the equivalent of three years' LLP operating life left in them. The 86 Delta aircraft include the 116 engines we have under PBH contract which Delta will retire by the summer of 2021. We know that by then the engines we manage will only have 300-600 engine flight cycles (EFC) of LLP life remaining, so they will contain little material worth salvaging. Moreover, new LLPs are no longer being manufactured."

Abad estimates the market value of an MD-80 with time-continued engines with up to 3,000EFC left at about $1 million, with each engine being about $400,000.

CFM56-3

The 737-300, -400 and -500 series are powered exclusively by the CFM56-3 family. A total of 1,988 aircraft were built from 1984 to 1999. About 59% of the fleet has now been retired and stored, and 37 aircraft have been retired in the past year.

The CFM56-3 has four thrust ratings, and three variants of 18,500lbs, 20,000lbs, 22,000lbs, and 23,500lbs. The -3C1 can be rated at all four ratings, while the -3B2 can be rated at the three ratings up to 22,000lbs. The -3B1 can only be rated at the two lowest ratings.

The thrust ratings have implications for exhaust gas temperature (EGT) margin, and therefore time on-wing between removals for SVs. When a -3C1 engine is rated at the highest rating of 23,500lbs and has had maintenance SVs and performance restoration, recovered EGT margin is about 25 degrees centigrade. "The engine can then have removal intervals of 4,000-6,000EFC

when operated in a temperate environment, depending on the previous shop visit," says Chris Grey, principle at Aer Auster. "The -3 series engines have high rates of EGT margin erosion, and EGT margin and performance loss are the main removal drivers.

"The highest rating of 23,500lbs is desirable for the 737-400, especially when operated in a passenger configuration, and for aircraft operating where there are performance restrictions, such as high temperatures and short runways," continues Grey. "A -3C1 engine rated at 23,500lbs therefore needs to have at least 25 degrees centigrade EGT margin so that it can achieve a reasonable removal interval. A used and time-continued -3C1 rated at 23,500lbs taken from an aircraft will not necessarily be able to stay on-wing for 4,000-5,000EFC just because it has this life remaining in its LLPs. A -3C1 operated at 23,500lbs requires some maintenance and performance restoration. Remaining LLP life is not enough on its own, and it would be risky to buy a time-continued engine and operate it without performing any SV maintenance."

A -3C1 or a -3B2 engine rated at 22,000lbs or lower has higher EGT margins, and so can achieve reasonable removal intervals that most airlines need.

Of the 745 aircraft in service, 276 are freighters, and 30-35 aircraft are being converted to freighters each year. Some of these are stored or retired aircraft that are being reactivated and put back into active service. This compares to 470 passenger-configured aircraft.

Of the active aircraft, 535 are equipped with -3C1 engines, the most desirable CFM56-3 variant. There are also 90 aircraft with -3B2 engines and another 121 with -3B1 engines. There are 277 active 737-400s, and 255 are equipped with -3C1 engines. A smaller portion of 192 of the 319 active 737-300s have -3C1 engines fitted.

A large number of the 1,164 retired and stored aircraft were equipped with -3C1 engines, numbering 478 aircraft or 41%. There are another 253 retired and stored aircraft with -3B2 engines.

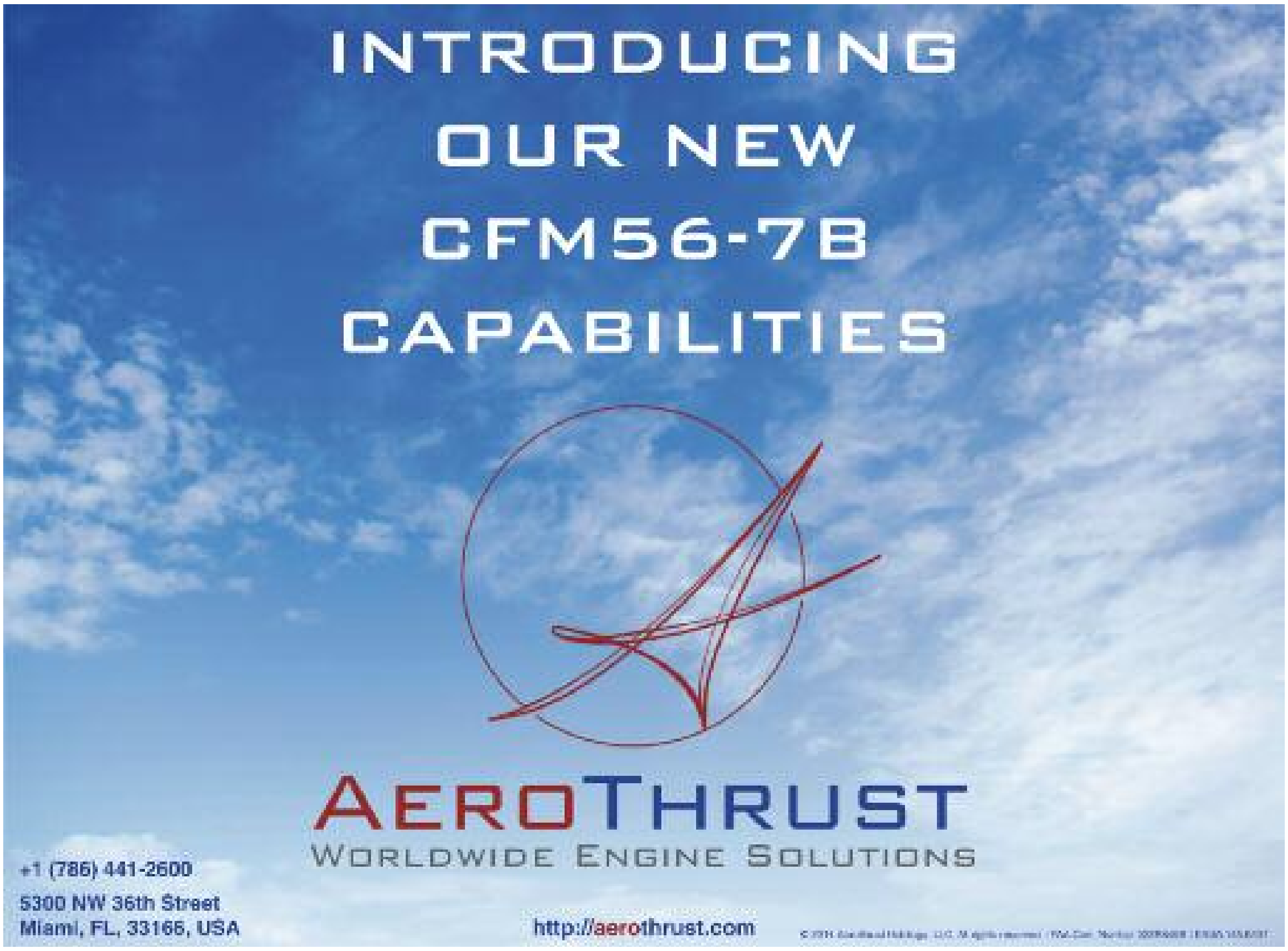
"Although a -3C1 allows the highest possible thrust rating, a -3B2 rated at 22,000lbs should be sufficient for many freight operators with the 737-300 or -400," says Grey. "The lower rating of 22,000lbs means the engine should have sufficient EGT margin remaining when an operator is aiming to keep the engine on-wing for 4,000-5,000EFC."

The CFM56-3 series market benefits from the large number built compared to another type, such as the JT8D-200. "There are a lot of time-continued engines available," says Abad. "This is especially the case with engines that had been operated by Southwest Airlines. There are now a lot fewer shops repairing CFM56-3s. We are prepared to buy in used or time-continued cores and trade them for repaired engines with LLP life and warranties. This is generally the trend with a lot of operators. Many airlines, including small passenger and freight carriers, prefer to acquire time-continued engines with a small SV, rather than do full maintenance.

"The supply of time-continued -3C1s has increased with on-going retirements, and there are several hundred aircraft in operation that are using these engines at a fast rate," continues Abad. "We find that we can put a -3 into an SV induction and fairly quickly we have received a letter of intent (LOI) to buy the engine. There is always someone ready to buy. We recently bought 21 ex-Southwest 737-300s, and we have already sold or leased the engines."

The demand for CFM56-3s is coming from South American airlines, smaller US carriers such as Swift, firefighting operators in Canada, and small passenger and freighter fleets of up to 10 aircraft.

Freight airlines operate at relatively low frequencies of 50EFC per month, so time-continued engines with 4,000-5,000EFC can last on-wing for eight or 10 years. It is also helped by these airlines



having lower take-off ratings.

The market value of used and time-continued CFM56-3 engines can be based on the value of remaining LLP life as a portion of the full LLP life, then adjusted by a pro-rate factor. A shipset of new LLPs for the -3C1 has a list price of $3.1 million, although from 2019 the manufacturer stated that buyers should request a quote for new parts. This is due to the demand for new LLPs diminishing as the number of active engines declines.

The life of new parts varies with thrust rating. The highest rating of 23,500lbs thrust results in lives of 20,000EFC and 30,000EFC in the fan and low pressure compressor spool, 15,000EFC and 20,000EFC in the high pressure compressor rotor, 15,000-20,000EFC in the high pressure turbine, and 19,000EFC and 25,000EFC in the low pressure turbine.

As a broad guide, a time-continued engine with remaining lives that are 50% of full life would have a value of $1.5-1.6 million, but then adjusted by a pro-rate factor. Many engines are being bought with 4,000-9,000EFC remaining, and operators aim to build engines with remaining LLP life that is likely to match the engine's on-wing life. The -3s are generally being built to shorter lives, partly because of the probable retirement age and timing.

With just 4,000-5,000EFC left, it would be about 25% of LLP shipset cost, while an engine with 9,000EFC LLP life remaining would be about 45% of LLP shipset cost.

"You have to remember that about 20% of the parts in the engine account for about 80% of its value," says Grey. "The pro-rate factor paid for an engine will roughly be based on remaining LLP life. Many operators now look to build engines for 4,000-5,000EFC. An engine with this many EFC remaining on its LLPs may be valued at a pro-rate factor of 70-80%, so it would have a value of $650,000. An engine with 8,000-9,000EFC remaining will have a lower pro-rate factor of 50% because fewer airlines are looking for this amount of LLP life. This engine's market value would be slightly higher at $700,000."

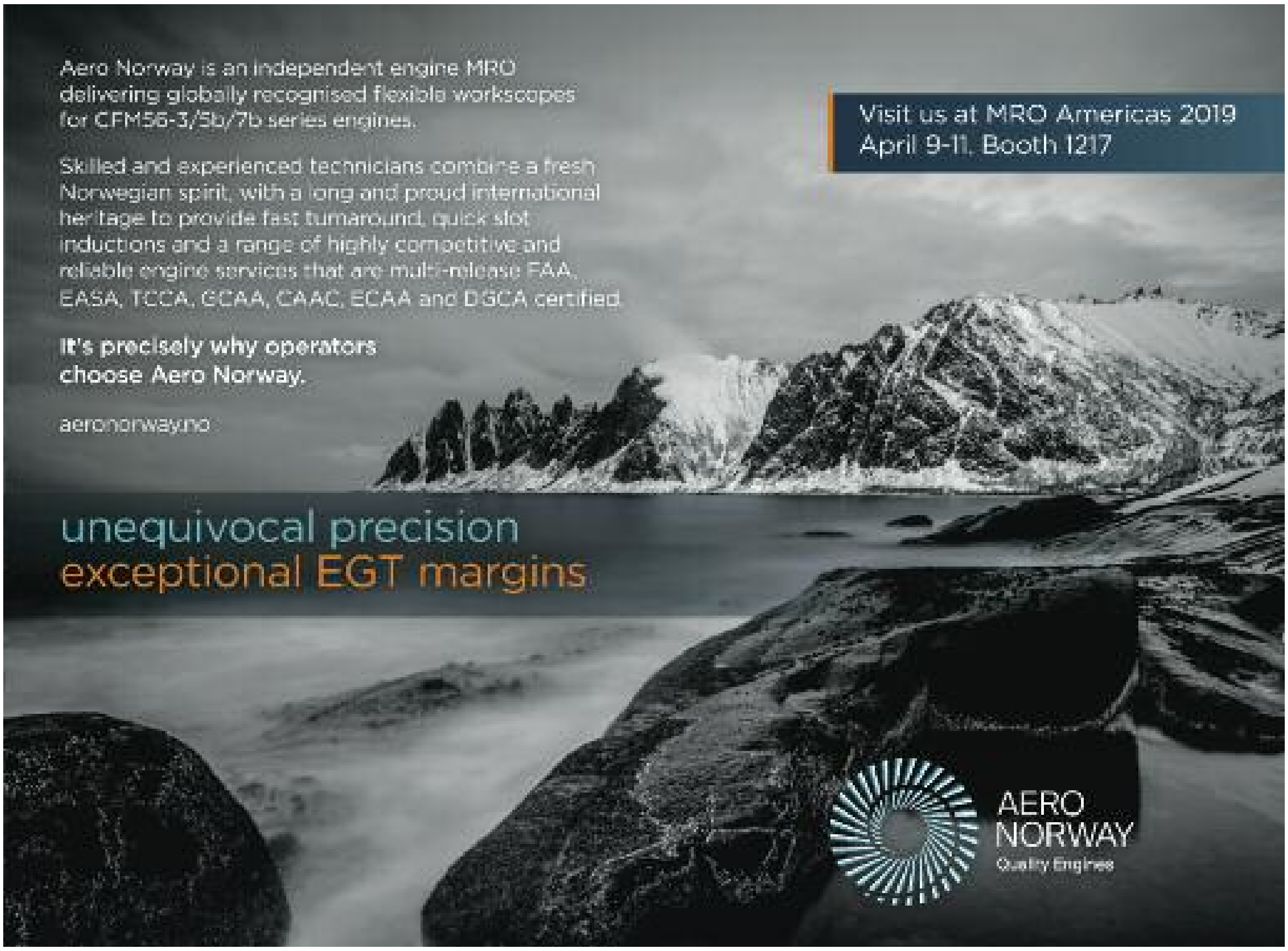
Abad puts the value of time-continued -3C1 $400,000-750,000, depending on its remaining LLP life and EGT margin. "An engine fresh from an SV should have about 8,000EFC or more left, but such engines are harder to value," says Abad. "These might be $750,000 to $1.3 million. There are many LLPs on the aftermarket, and CFM will still make them if requested. The cost of a full shipset cannot be justified, however. A used engine could be valued in proportion with its remaining LLP life, and then pro-rated at a factor of 60%. There is also now a trend for airlines to use parts manufacturer approval (PMA) parts if they are available, since this lowers the cost of maintenance."

CFM56-5C

The CFM56-5C series exclusively powers the A340-200 and -300. There are three main variants: the -5C2 rated at 31,200lbs, the -5C3 rated at 32,500lbs, and the -5C4 rated at 34,000lbs. There were 247 A340-200s/-300s built from 1992 to 2008. The active fleet has declined more quickly than other types. There are 140 aircraft that have retired or are in storage, which is 57% of the fleet; the same as the 737-300/-400/-500.

Another five aircraft have retired, leaving 102 in active service, including one experimental aircraft operated by Airbus. These are 41% of the aircraft built. The rate of retirement has been fast in recent years, with 21 aircraft retired in 2018, equal to 15% of the number built.

The three -5C variants originally had different red line EGT limits, the -5C2 having the lowest at 950 degrees, and the -5C3 originally being 965 degrees. Both had upgrade kits available to increase their red line limits to 975 degrees as used by the -5C4. This increased the EGT margin of the -5C2 and -5C3.



Only about 100 A340-200s/-300s out of 247 built are in operation, and aircraft are retiring at about 20 per year. This has increased the supply of CFM56-5Cs, and there are several shops in Europe that have maintained capability for the type.

The -5C is the highest-rated of all CFM56 family engines, and like the -3 series the -5C is particularly sensitive to EGT margin and performance erosion. Recovered EGT margins following an SV are 35-40 degrees for the -5C4 variant, and about 60 degrees for -5C2 engines. This allows mature removal intervals of about 10,000 engine flight hours (EFH) for the -5C4 and up to 14,000EFH for the lower rated -5C3 and -5C2 when they are operated at about 7.0 EFH per EFC.

The active and retired fleets can be sub-divided by engine variant, and the -5C4 accounts for most of the fleet. These engines have the advantage of the flexibility of three thrust ratings and so have the scope to de-rate take-off power.

The active fleet of 102 aircraft includes 84 airline-operated examples with -5C4 engines. Operators include Lufthansa, Swiss, Edelweis, SAS, South African Airways, Aerolineas Argentinas and Air Mauritius which have all kept their fleets operating. Many of these aircraft are due to be retired over the next five years, however, and so should increase the supply of used and time-continued engines on the aftermarket.

Most of the 140 retired aircraft also have -5C4 engines, with 89 aircraft being equipped. Another 26 retired aircraft were fitted with -5C3 engines.

"Any -5C4 engines on the market are attracting good values, because airlines are more interested in acquiring time-continued engines and performing small SVs, than in putting engines through full SVs," says James Bennett, director sales and marketing, at Aerfin. "The A340-200 and -300 have been kept going in remaining fleets with problems and delays of replacement aircraft."

Philippine Airlines, for example, kept its A340-300 fleet going until late 2018. There are also several airlines that have acquired used aircraft for mainstay long-haul operations. Examples are HiFly, Joon, Kam Air, Plus Ultra, Mahan Air, and Iran Asseman Airlines.

A few air forces and governments have also acquired some aircraft.

Another market for used -5Cs is to tear down engines to support SV activity for the -5B and -7B, since these two have a lot of parts commonality with the -5C, including some of the LLPs and airfoils.

"The premium pricing or market values for engines will not last forever," says Bennett. "The rate of retirement will increase to about 20 aircraft per year. The number in 2019 will be similar to 2018. This will put a lot of engines on the market. The fleet will therefore decline to an increasing number of smaller operators.

"Engine values should come down, but there will also be fewer shops with CFM56-5C capability," continues Bennett. "SR Technics and Lufthansa Technik still get a lot of -5C business, but they may drop their capability if the volume of work declines too much."

Bennett says lease rentals in the current market are $60,000-90,000 per month. The demand for time-continued engines in the future, however, will depend on which shops reduce or dispense with their capability, the rate of fleet retirement, and the price of fuel. The A340-300 and CFM56-5C can clearly represent a lot of capacity and capability for relatively low investments.

"Airlines are definitely using used serviceable material (USM) in SVs when they perform maintenance," says Bennett. "They are also more readily using PMAs and designated engineering representative (DER) repairs for airfoils when they own the assets. They are also buying time-continued modules and engines. This is preferred to a full SV, and engines can be acquired for about $2 million. Typical rates of utilisation mean that an engine only needs about 3,000EFC of LLP life and other probable maintenance time to operate for another four to five years. The -5C4 at the highest rating is, however, sensitive to EGT margin, since it never had a lot because it is one of the highest-rated CFM56 variants. A core restoration or some level of SV is probably required if an operator wants some EGT margin."

Bennett comments that if the pro-rate factor system is used to estimate the purchase value of an engine or material, then a pro-rate factor of 100% can be used for parts that are common to the CFM56-5B or -7B. A pro-rate factor of 25% is more appropriate for material unique to the -5C. Overall, however, if an engine has 10,000EFC LLP remaining, it will still have the same market value as an engine with 3,000-4,000EFC. In this condition, a possible market value is $1 million. This should be considered against the monthly lease rentals and desired lease term.

CF6-80C2

The CF6-80C2 is one of the most successful widebody engines, powering 1,365 aircraft to date, including the five main types of the 747-400, MD-11, A300-600/-600R, A310 and the 767-300ER. The 767-300ER is still being manufactured, with orders outstanding for freighter variants. The four other main types ceased production from 1994 to 2009.

Care has to be taken when considering CF6-80C2 engines. There is a large number of variants and sub-variants, with 18 applications. They all have the same basic internal configuration and turbomachinery hardware, but they are not all completely interchangeable.

First, there are three main groups of engines with A, B and D suffixes. The A1, A2, A3, A5 and A8 engines power the A300-600/A310. The B1, B2, B4, B5, B6, B7 and B8 power the 747-400 and 767. The D1 engine powers the MD-11.

There are three different sets of quick

engine change (QEC) kits and accessories for the A, B and D engines which are mounted on the outside. The QEC kits determine the aircraft to which the engines can be fitted.

Another main difference in hardware and configuration is that earlier-built engines have power management controls (PMC) for thrust and power setting. Engines built from 1989 onwards have full authority digital engine control (FADEC) units to set thrust and power. Engines with FADEC units have more precise control over thrust settings, and so have higher EGT margins.

"It is possible to interchange between a PMC and FADEC engine by using the internal hardware of one type, and then equip with the appropriate control unit," says Rodrigo Montero, vice president of purchasing at CTS Engines. This is rarely done and expensive, however. The fleet is therefore subdivided between those with PMC engines and FADEC engines.

In addition to differences in external hardware, FADEC engines were also configured with high-thrust parts and airfoils. The high-thrust configuration is for 60 degrees EGT margin, which applies to most FADEC engines. PMC engines are often referred to as having an EGT margin configuration of 45 degrees. Care must be taken not to install 45-degree configuration parts in a FADEC engine. This difference in configuration is part number (P/N) based, affecting LLPs, external parts and basic engine parts.

There were 356 aircraft built with PMC engines, of which 181 have been retired and 15 have been written off. This equals 55% of aircraft built. Only 767s, A300-600s and A310s were fitted with PMC engines. There are 104 passenger-configured and 56 freighter aircraft still in active service with PMC engines. It is possible to swap A and B engines between Airbus and Boeing aircraft, but these require a modification kit via a service bulletin (SB).

Despite being less popular, Montero says that there is a lot of demand for both types, because there are few surplus engines available to support the fleet.

To date, 1,009 FADEC-equipped aircraft have been built, and just over 60 767-300ERFs are on order. To date 209 aircraft have been retired or stored and eight written off, equal to 21% of the fleet.

Again, it is possible to swap between A, B and D engines but it requires different QECs and kits via SBs. An example is SB 72-1470 which changes a -D1 engine powering a MD-11 to a -B6F engine for a 767-300ER.

Modifications and SBs are also required to change thrust ratings within the same A or B group. This is SB 72-0389, which converts between different B engines for Boeing aircraft.

The 767-300ER accounts for the largest number of aircraft in the fleet, with 503 built to date. A small number of 44 have been retired or stored. There are 459 still in active service, split between 244 passenger aircraft and 215 freighters. The freighter fleet is split between 64 converted aircraft, and 151 factory-built aircraft that are mainly operated by FedEx and UPS. Most of the passenger fleet are operated in large fleets by Air Canada, All Nippon Airways, Delta Airlines, JAL, LATAM and United.

The 747-400 is the second largest fleet, with 335 built. A large portion has been retired, with 129 aircraft representing 38.5% of the fleet. There are 80 passenger aircraft and 122 freighters in service. The passenger fleet is expected to continually diminish as aircraft retire, with 16 retiring in 2018. The passenger aircraft are operated partly in large fleets by KLM, Lufthansa, Qantas, Thai International and Virgin Atlantic Airways. There are also smaller fleets.

While it is known that a lot of aircraft are due to retire over the next five years, conversion of 747-400s to freighters ceased in 2012, although Bedek Aviation has said it could re-open its conversion line if freight operators required. There is therefore likely to be a large number of

-B1F engines coming on to the market as these aircraft retire.

The freighter fleet of 122 is split between factory-built and converted aircraft, powered by a mix of -B1F and -B5F engines.

The third largest FADEC fleet is the -D1F engines on 119 MD-11s. All 79 active aircraft are freighters, and are 18-29 years old. Another 36 aircraft have been retired, and four aircraft were written off. The active MD-11 freighters will retire at a steady rate, increasing the supply of -D1F engines on the market.

There are only 52 A300-600Fs built with FADEC engines, and all are in operation. Except for two, 50 are in service with FedEx and Air Hong Kong. These are still relatively young, so will not increase the supply of engines on the market.

"There is strong demand in the aftermarket for serviceable -80C2 engines and parts," says Montero. "Values are therefore high, which sometimes makes it uneconomic to buy serviceable engines for teardown purposes. It was expected that market values would fall following a large number of retirements, but changes in the industry mean it did not happen. Unlike other used engine types the market value of a serviceable and time-continued engine is based not just on the pro-rated value of LLPs, but also on the estimated yield of usable airfoils and other hot parts."

Stratton Borchers, president of True Aero, comments that there is still demand for PMC engines, especially from cargo carriers. "Demand for FADEC engines is much higher. Most airlines try to acquire serviceable and time-continued engines to avoid performing SV maintenance.

"The large number of MD-11 and 747-400 retirements over the next few years is expected to reduce the market value of parts, due to the increased availability," adds Borchers. "It will not, however, have a significant impact on engine values and leasing because it is too expensive to convert engines between A, B or D, or upgrade the thrust rating. This will reduce the market availability of each variant, since the fleet will be split into a lot of smaller sub-fleets, and airlines will be looking for particular variants. These conversion costs represent cost barriers between the different variants."

Borchers explains that the main factor that determines an engine's market value is the amount of serviceable life it has remaining. In the case of unserviceable engines, because of lack of EGT margin for example, the main factors that affect market value are the remaining LLP life and particular P/Ns for the airfoils in the engine.

The CF6-80C2's LLPs have life limits of 15,000EFC and 20,000EFC. HP modules have shorter lives. A full shipset of new HP LLPs has a list price of $1.43 million, and the LP parts have a list price of $6.31 million. Total for a complete shipset is $7.75 million. Estimates for a pro-rate factor in the industry for estimating a used engine's market value is about 50%. An engine with about 50% of LLP life remaining costs $1.94 million. This will be split into $0.45-0.50 million for the fan/LPC, HPC and LPT modules; and about $0.4 million for the HPT.

Mature removal intervals for engines operated on medium- and long-haul missions are 2,200-2,500EFC. These are also affected by the thrust rating. These are long enough to keep the engine on-wing for five to seven years in the case of most long-haul operations, and even longer for some freight operators. An engine with up to 5,000EFC can therefore be acquired for up to $1.2-1.5 million. A performance restoration on the HP modules can cost $3.0 million, but a saving of $0.5 million is possible when using USM. A lighter visit may be all that is needed to achieve the desired on-wing time. Acquiring time-continued fan/LPC and LPT modules on the aftermarket is more economic than putting them through SVs. AC

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