The CFM56-5A/-5B is the second most numerous engine in operation. Its numbers will also continue to increase. The maintenance and support infrastructure for this engine is extensive, with shops and repair facilities on all continents.

CFM56-5A/-5B support & maintenance market

There are 5,246 CFM56-5A/-5B engines in operation, of which 5,078 (97%) are active. These are split between 952 -5As and 4,294 -5Bs. This makes it one of the largest engine fleets, second only to the CFM56-7B.

CFM International (CFMI) states that it has installed a total of 1,070 CFM56-5As since the engine entered service in 1988. It also calculates that there are about 125 spare -5As. According to CFMI, 4,410 -5Bs have been installed, and there are about another 315 spare engines. There is a backlog of orders for about 1,590 -5Bs.

The current fleet of CFM56-5A/-5B-equipped aircraft are likely to operate for up to another 30 years. The ubiquitous A320 family is one of the industry's workhorses, operating at high utilisations in many cases. This means that a stream of a frequent engine shop visits are likely for several decades. A continuous level of service from engine shops and specialist parts providers with good geographical coverage will be required.

The top two owners in terms of number of engines installed on aircraft are GECAS, with 628 engines, and ILFC, with 358. Then the airlines follow with easyJet (260), Delta Air Lines (186), Air France (130), Lufthansa (130) and China Eastern Airlines (126). The next three largest are lessors RBS Aviation Capital (122), The CIT Group Inc (122) and AerCap (102).

The capabilities of maintenance, repair & overhaul (MRO) facilities can include the breakdown of the engine to module or piece-part level, as well as high-tech parts repairs. Providers of these services are discussed here.

CFM56-5A/-5B market

A total of 5,480 CFM56-5A/-5Bs have been manufactured to date, and 5,246 engines are still operational. This difference is accounted for by 12 destroyed aircraft, engines that have been broken down, and engines available from parked and retired aircraft. As already mentioned, CFMI says there are 440 spare engines in addition to these.

The largest CFM56-5A/-5B fleet is in Europe, where there are 2,586 engines. This is reflected in the locations of the larger MRO facilities offering maintenance capability.

The next largest share of the fleet is in Asia Pacific (1,118 engines), followed by North America (926). There are much smaller fleets in the Middle East, South America and Africa, with 250, 218 and 148 engines respectively.

The CFM56-5A is the smaller of the two fleets, with 952 engines. The largest fleets are in North America (408 engines) and Europe (398). Smaller fleets are seen in other locations. There are four variants within this model series. The -5A1 is the most popular, followed by the -5A5 (268) and the -5A3 (220).

A larger number of engines is seen in the CFM56-5B fleet, partly because it has been around for slightly longer, and partly because of its higher thrust. There are 4,294 -5Bs in operation, with Europe again being the most popular location.

Europe accounts for 2,188 -5Bs, and Asia Pacific operates 1,056. There are 518 engines each in North America, the Middle East and South America.

There are nine variants within the -5B series, with each one having at least two variants. The -5B4 accounts for 1,940 engines, representing 45% of the -5B fleet, and 37% of all the -5A/-5B engines. The next largest variants are the -5B6, with 852 engines; and the -5B5, with 642.

With a relatively large range in ages and operational roles, the maintenance requirements will vary. While an original equipment manufacturer (OEM) will stipulate certain aspects of a maintenance plan, there are a number of areas where an operator's needs differ. These affect the maintenance plans, as can the demands of an owner when an aircraft is returned at the end of a lease term. Utilisation ratios of engine flight hours (EFH) to engine flight cycles (EFC) will affect the engine removal intervals, as will the operating conditions.

Engine shop services

Shop visits tend to fall into several categories. A minimum engine workscope can involve a simple external inspection and a borescope inspection.

A repair involves some disassembly and inspection with the module not completely disassembled to piece-part level. Some repairs are carried out.

An overhaul involves a complete disassembly of the module to piece-part level, inspection of all parts and then full repairs of the relevant parts as necessary.

If the shop lacks the required capability for an overhaul or piece-part repairs, the work is sub-contracted. This inevitably increases shop-visit downtime.

To address this problem, large independent engine shops have developed many specialist repairs in-house. For example, the Lufthansa Technik Group has an in-house repair capability for more than 90% of the CFM56-5A/-5B's parts, while Finnair says it has no need to sub-contract parts repairs.

At the same time, many MROs are approved by the European Aviation Safety Agency (EASA) or Federal Aviation Administration (FAA) to develop and certify repairs in-house. Frank Walschot, head of engine services at SR Technics, says that it already carries out 85% of repairs for the -5B, and may develop new ones if there is customer demand, and they are economical for all parties.

Engine shops offer a multitude of services besides engine overhaul, including: engine monitoring and management; spare engine provisioning; and aircraft-on-ground (AOG) assistance.

CFM56-5A/-5B GLOBAL FLEET OF ENGINES CURRENTLY IN OPERATION

Engine Model	Africa Active	Africa Parked	Asia Pacific Active	Asia Pacific Parked	Europe Active	Europe Parked	Middle East Active	Middle East Parked	N. America Active	N. America Parked	S. America Active	S. America Parked	Engine sub-total
CFM56-5A1	30	2	46	2	194	24	10	0	124	14	0	0	446
CFM56-5A3	14	0	12	2	70	10	22	0	84	6	0	0	220
CFM56-5A4	0	0	0	0	18	0	0	0	0	0	0	0	18
CFM56-5A5	6	0	0	0	82	0	0	0	180	0	0	0	268
CFM56-5A Total	50	2	58	4	364	34	32	0	388	20	0	0	952
CFM56-5B1	0	0	0	0	82	0	0	0	0	0	0	0	82
CFM56-5B2	0	0	54	0	46	0	0	0	0	0	0	0	100
CFM56-5B3	12	0	80	2	180	0	14	0	86	12	0	0	386
CFM56-5B4	64	0	504	0	856	18	168	8	142	14	166	0	1940
CFM56-5B5	6	0	30	0	534	2	4	0	66	0	0	0	642
CFM56-5B6	6	2	290	2	344	6	8	0	160	12	22	0	852
CFM56-5B7	6	0	88	0	54	8	2	2	2	0	16	4	182
CFM56-5B8	0	0	0	0	44	0	0	0	10	14	10	0	78
CFM56-5B9	0	0	6	0	12	2	12	0	0	0	0	0	32
CFM56-5B Total	94	2	1,052	4	2,152	36	208	10	466	52	214	4	4,294
Total	144	4	1,110	8	2,516	70	240	10	854	72	214	4	
	148		1,118		2,586		250		926		218		5,246

Source: Flight Global's ACAS system

A full engine management service can include on-wing monitoring, removal and workscope planning, shop-visit planning and repair execution. Walschot adds that SR Technics also offers customers, as standard, a field team support system to prevent engines from having to enter a shop in the first place. These systems enable customers to operate safely, reliably and cost-effectively. Systems ensure that customers comply with EASA Part M, as well as other regulatory authorities that require an operator to have a Continuing Airworthiness Management Organisation (CAMO).

As well as an Engine Maintenance Management Service (EMMS), Lufthansa Technik (LHT) offers Technical Operations Management (TOM), so that all maintenance across a customer's fleet can be integrated into one service package, allowing a fleet manager to organise maintenance simply, from one location. Tim Boldt, marketing manager for Delta TechOps, says that it also uses a data tracking and analysis system. This uses real-time engine health data and information sent by an Aircraft Communications Addressing & Reporting System (ACARS) to its ground stations to give the relevant department time to prepare the corrective action when a contracted aircraft lands and needs maintenance.

If a small airline wanted to improve its maintenance, its lack of experience would limit what it could do. However, Celestino Revuelta, CFM56 programme manager at Iberia Maintenance, says that customers using its health and trend monitoring system, shop-visit management and workscope assessments would benefit from 20 years of CFM56-5 experience, and knowledge of potential operational problems that can arise.

MRO facilities and engine shops often offer a choice of two payment methods: power-by-the-hour (PBH), which is calculated based on the number of flight hours the engine or aircraft has completed between checks; and time and material (T&M), which simply buys the materials and hours that are used in the actual shop visit. "PBH costs can be more easily budgeted, since risks are largely covered in the rates," explains Walschot. "T&M contracts leave more risk with the operator rather than the maintenance organisation, so they do not carry a risk premium, although they do tend to come with not-to-exceed pricing, in which case the risk is partially covered anyway."

As well as the total fleet of engines fitted to active and parked aircraft, there are a number of spare engines. A limited number of these will be owned by airlines, but the remainder will be with lessors and MROs.

Dr. Ralph Petersen, director CFM56 and CFM56 & V2500 engine overhaul at Lufthansa Technik comments that not only are spare engines used on long-term leases and within the engine pool, but also as short ad hoc leases for customers while an engine is in the engine shop. Unavailability can seriously limit aircraft utilisation. This is not unusual and Delta TechOps, Finnair and SR Technics are just a few of the MROs that offer short-term leases. SR Technics can also help customers source spare engines if required, in addition to financing and sale & leaseback transactions through its partnership with Sanad.

Shop module capability

The CFM56-5A is configured with: the fan and three-stage low pressure compressor (LPC); a nine-stage high pressure compressor (HPC); a single-stage high pressure turbine (HPT); four-stage low pressure turbine (LPT); an annular combustor; and the gearbox.

The CFM56-5B is a high thrust version with a few changes such as: an additional LPC stage; the fan in a longer case; and an option of a double annular combustor to reduce emissions.

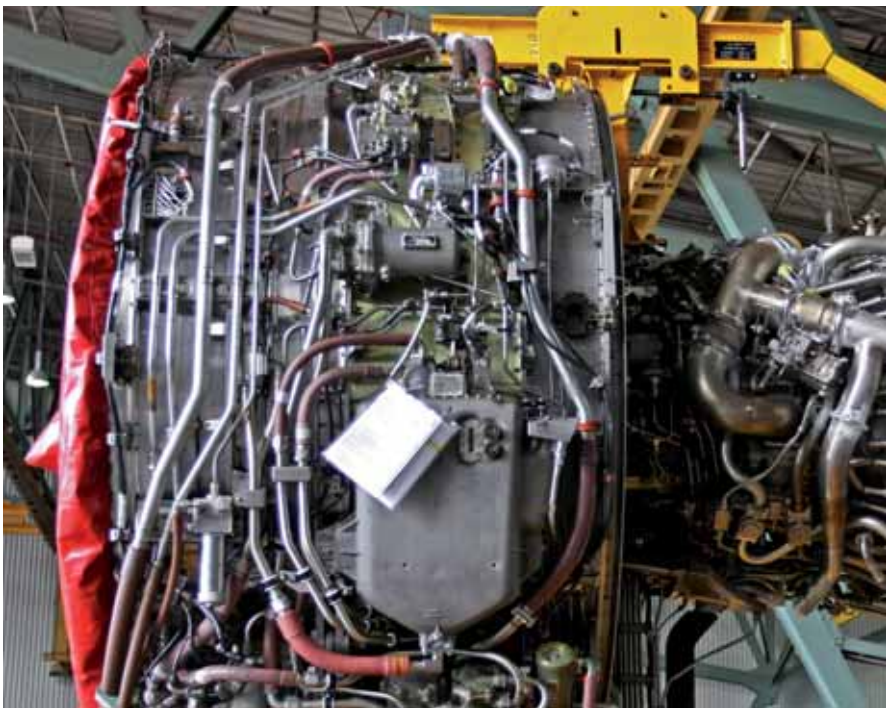
There are four main modules for the CFM56-5 comprising: the fan major module; core major module; LPT major module; and the gearbox. There are also the engine's controls and accessories. The fan module has four sections: fan and booster; No.1 and No.2 bearing support assembly; inlet gearbox & No.3 bearing assembly; and fan frame assembly.

The core module is broken down into eight assemblies: HPC rotor; HPC front stator; combustion case; combustion chamber; HPT nozzles; HPT rotor; and HPT shrouds and stage 1 LPT nozzle.

The LPT module has three assembly parts: the LPT rotor/stator; the LPT shaft; and the LPT frame.

Those facilities that offer engine overhaul (OH) and hot section inspection (HSI) will generally offer capabilities on all four major modules and the parts within. If a particular piece-part repair is required within a major module, for example a bearing, the facility will need to send the part away if they have not developed capabilities. Specialist repairs, be they in-house or sent away, will be factored into the time it takes to overhaul an engine. When a repair time is likely to exceed an engine's allotted downtime, an MRO facility and operator may use a new or reconditioned replacement part.

According to OAG



There are 5,250 CFM56-5As/-5Bs in operation, and a further 1,590 -56Bs on order. Further orders are less likely following the launch of the A320neo, powered by the PW1000G.

Aviation/AeroStrategy, more than 900 CFM56-5A/-5B shop visits are likely to occur globally in 2011, accounted for by 410 -5A visits, and 496 for the -5B. The total number of visits is much higher than in 2010, but not as high as forecast for 2013 (after a little dip in 2012).

The CFM56-5A is forecast to average 350 shop visits per year from 2009 to 2014, with a high of 410 expected in 2011 and a low of 304 in 2012. Global shop visits are forecast to be 284 in 2015, after which the number is likely to reduce drastically as older aircraft retire.

The average number of annual shop visits from 2016 to 2019 is expected to be 200, with 2019 seeing a low of 182.

The CFM56-5B, in contrast, will see an increase in global engine shop visits over the next few years, as deliveries of outstanding orders continue. Up until 2010, more shop visits were performed on -5A engines than -5B engines. This is due to change in 2011, with nearly 500 -5B shop visits forecast.

OAG Aviation/AeroStrategy forecasts a year-on-year increase in shop-visit activity, with 1,140 shop visits forecast in 2019. This is over four times the number undertaken in 2009.

The data emphasise the likely fleet changes as the -5A is retired and the -5B increases in numbers. It also shows how -5Bs are now maturing and requiring more frequent shop visits.

The CFMI Group, which is the CFM56-5A/-5B's OEM, accounts for more than 40% of shop visits, with General Electric Engine Services (GEES) contracted to look after 1,251 engines, Snecma 1,020, and CFMI itself contracted to deal with 29. While the group has 40% of the -5A market, it has nearly 50% of the newer -5B engines, probably because it offers special fixed-rate per-hour care and maintenance packages to new operators.

The next largest shop is LHT, with over 10% of the -5A/-5B market. Although LHT's share of the -5A market alone is higher at nearly 20%, it actually deals with a larger number of -5B engines. While Aveos undertakes 16% of the CFM56-5A shop visit market, it takes less of the -5B market, although again there are more -5B engines contracted to Aveos than -5As.

Older aircraft are likely to transfer to second- and third-tier airlines, or be converted to freighters. This will change the way engine maintenance is managed.

Just 4% of shop-visit contracts are undertaken in-house, which highlights the demand for third-party CFM56-5A/-5B capabilities. As engines get older, they will require more parts to be reconditioned, and/or replaced with new parts, so shop-visit activity will increase.

Africa

Most of the operators of the CFM56-5A/-5B in Africa are located in North Africa, so it follows that EgyptAir Maintenance & Engineering is the only MRO offering capability in Africa, even though the associated airline does not operate any CFM56-5A/-5B engines.

Many other MRO organisations will offer services to airlines located here. Air France Industries, for example, offers services and contracts to Nouvelair Tunisie, which also uses Snecma.

Snecma's facility in France has contracts with Air Arabia Egypt, Air Arabia Maroc and Royal Air Maroc. Afriqiyah Airways and Air Cairo have contracts with GEES, Wales; while Iberia looks after Tunisair, which also has a contract with LHT.

Overall, Africa accounts for just 3% of the fleet, with a much smaller percentage of engine maintenance being completed here, except for line maintenance.

Asia Pacific

Unlike with many other engines, the Asia Pacific operates a small portion of the CFM56-5A/-5B fleet. Traditionally this continent has been known for long distances and high-density markets, making the A320 family less popular.

As far as maintenance is concerned, contracts to Asia-Pacific-based facilities account for about 14% of the global market. MTU Maintenance Zhuhai, Sichuan SNECMA Aero Engine SVS, and P&W Shanghai Engine Center are all the busiest in the region, with each taking over 3% of the global market.

MTU's Chinese operation counts China Eastern, China Southern and Shenzhen Airlines as its customers. China Eastern Airlines also uses P&W Shanghai Engine Center, as does Juneyao Airlines. The OEM facility in China's Sichuan province has Shenzhen, Juneyao Airlines and Air China as its customers.

There are a number of areas geographically within the Asia Pacific region. Within Australasia, Aero Nusantara Indonesia offers engine OH and HSI, while ANA Engine Services and IHI Corporation in Japan offers the same services for the Far East.

As well as the MTU, P&W and Snecma facilities, Gameco also has engine component repair capabilities in China. While China seems to have the biggest market, South-East Asia possibly has the largest selection of facilities. GEES Malaysia, LHT Philippines, SIA Engineering Company and ST Aerospace Engines all do engine OH and HSI, with some also dealing with components.

Airfoil in Malaysia and Singapore, along with Goodrich and ST Aerospace Systems offer engine component maintenance in this region.

Europe

Nearly half the entire CFM56-5A/5B fleet is located in Europe, as are the three MRO facilities with the largest share of the contract market, representing over a

REPAIR FACILITIES WITH SPECIFIC CFM56-5A/-5B CAPABILITIES

Facility	Engine option		Engine	HSI	Accessory drive	Electrical	Fuel	LRU	Lubrication	Thrust
	CFM56-5A	CFM56-5B	Overhaul		gearbox	system	system		system	reverser
Africa										
EgyptAir Maint. & Eng.	Y		Y	Y						
Asia Pacific										
Aero Nusantara Indonesia	Y	Y	Y	Y						
Airfoil Services Sdn Bhd	Y						Y			
ANA Engine Services Co Ltd	Y		Y	Y						
GE Engine Services - Malaysia	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Goodrich Aerostructures - Asia	Y	Y								Y
Lufthansa Technik Philippines	Y	Y		Y						
MTU Maint. Zhuhai		Y	Y	Y		Y	Y	Y	Y	Y
P&W Shanghai Engine Center	Y	Y	Y	Y						
SIA Engineering Company Ltd		Y	Y							
Sichuan SNECMA Aero Engine SVS	Y	Y	Y	Y	Y	Y	Y	Y		
ST Aerospace Systems	Y	Y	Y	Y	Y	Y		Y		
Europe										
Airframe Components Europe	Y	Y								Y
Alitalia Maintenance Systems	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Avio S.p.A.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Barry Controls Aerospace (Eur)	Y							Y		
Chromalloy France	Y	Y						Y		
CRMA	Y	Y					Y	Y		
Finnair		Y	Y	Y						
GE Engine Services - Hungary	Y	Y						Y		
GE Engine Services - Wales	Y	Y	Y	Y	Y	Y	Y			
Goodrich (Prestwick)	Y	Y								Y
Iberia	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Lufthansa Technik AG	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P&W Norway Engine Center	Y	Y	Y	y						
P&W Turkish Technic Eng. Maint.	Y	Y	Y	Y						
SNECMA (MRO Division)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
SR Technics		Y	Y	Y	Y	Y	Y	Y	Y	
TAP Maintenance & Engineering	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Woodward Aircraft Engine Sys	Y	Y					Y			
Middle East										
Abu Dhabi Aircraft Technologies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
AMES	Y	Y						Y		Y
Bedek Aviation (Divn of IAI)	Y	Y	Y	Y						
Jordan Aeronautical Systems Co.			Y							
North America										
AeroThrust		Y	Y	Y	Y	Y	Y	Y	Y	Y
Aveos Fleet Performance Inc.	Y	Y	Y	Y						
Chromalloy Dallas	Y	Y						Y		
Chromalloy Los Angeles	Y	Y						Y		
Chromalloy Nevada	Y							Y		
Chromalloy Windsor	Y	Y						Y		
Complete Turbine Service		Y	Y							
Delta TechOps	y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Flight Test Associates	Y	Y		Y						
GE Engine Services - Strother	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
GKN Aerospace Chem-Tronics	Y	Y						Y		
Goodrich Aerostructures	Y	Y								Y
Patriot Aviation Services		Y	Y							
Snecma America Engine Services	Y	Y	Y	Y				Y		
Westfield Gage Company O&R	Y	Y						Y		
South America										
GE Celma Engine Services	Y	Y	Y	Y	Y	Y	Y	Y	Y	
TAMPA		Y		Y						

Source; ACAS and directly from engine shop facilities

third of all maintenance.

In Southern Europe, just P&W Turkish Technic Engine Maintenance offers OH and HSI capabilities, while 1-Source Aero Services in Greece has component repair capabilities.

SNECMA (MRO division) in France is the busiest engine shop contracted to deal with 851 engines, which accounts for over 17% of the market and offers OH, HSI and component repairs. Its customers include a number of American and European airlines, as well as other MRO providers such as Air France Industries (AFI).

AFI has just over 8% of the market. Customers include Air France and other European airlines, as well as a few African and Middle Eastern airlines. Other facilities in France are Auxitrol, Barry Controls Aerospace, Chromalloy and CRMA offering component repair.

LHT is the second most prolific engine shop with 11% of the contracts market, rising to 18% for the CFM56-5A and falling to 10% for the -5B. Many customers come from Central Europe, with a few from the Middle East and Asia.

SR Technics only deals with the CFM56-5B, of which it has nearly 4% of the contracts market. It deals with a few Central European airlines as well as a number in the Asia Pacific. SR Technics' customers that require -5A maintenance are directed to a sister company, Abu Dhabi Aircraft Technologies (ADAT), in the Middle East.

The United Kingdom (UK) has a number of facilities and engine shops for the CFM56-5A/-5B. The major ones are both GEES shops, one in Wales and one

The number of annual shop visits for the CFM56-5A/-5B is forecast to be about 900. The number for the -5B is forecast to increase from about 500 in 2011 to about 1,200 by 2019.

in Scotland, whose customers include British Airways, Monarch Airlines, Aer Lingus and Afriqiyah Airways. Component repair companies in the UK include Airframe Components Europe, Beagle Aerospace, Goodrich (Prestwick), Nordam Europe and Woodward Aircraft Engines Systems.

Western Europe also has a number of facilities on its southern edge including: Alitalia Maintenance Systems & Avio S.p.A. (both in Italy); TAP Maintenance & Engineering; and Iberia. All these shops offer a wide range of capabilities, and in many cases offer full maintenance coverage. Other component repair companies in Western Europe include Chromalloy Holland, Jet Technology Center, LHT Intercoat, SR Technics Airfoil Services and ST Aerospace Solutions.

P&W Norway Engine Center in Northern Europe is one of PW's major engine shops, but it is not particularly active with regard to the CFM56-5A/-5B engines, although it does offer OH and HSI. Finnair offers engine OH and HSI.

In Eastern Europe there is a GE facility in Hungary and an MTU facility in Poland, which both deal only with line replaceable units (LRUs).

Middle East

Nearly 5% of the global fleet is in the Middle East. ADAT offers a full list of CFM56-5A capabilities, with two customers. AMES also offers engine component maintenance, while Jordan Aeronautical Systems undertakes HSI work for the CFM56 generally. In addition, Bedek Aviation (Division of IAI) completes engine OH and HSI services for China Eastern Airlines.

North America

The North American CFM56-5A/-5B fleet is 926 engines, representing 18% of the fleet. It also has the largest share of parked aircraft.

GE is the most prolific engine shop in this region with two engine shops in the US, in Ohio and Kansas. Together they represent 15% of the global market. As well as many American airlines, customers include easyJet and many Asia Pacific airlines.

Delta TechOps does not have a particularly large market share, since it only deals with CFM56-5B engines, not -5As. Despite this, it offers a relatively full list of capabilities. Aerothrust also offers both engine OH, HSI and component capabilities on the -5B only.

Other American engine OH, HSI and/or component repair facilities are Accel Aviation Accessories, Aero Turbine Inc., Aircraft Ducting Repair, Ascent Aviation Services Corp., Chromalloy (at five locations), Complete Turbine Works, Component Repair Technologies, Eaton Aerospace, First Wave MRO, Flight Test Associates, Fokker Aerotron, GKN Aerospace Chem-Tronics, Goodrich (at two locations), Hawker Pacific Aerospace, JFJ Industries, Middle River Aircraft Systems, P&W (at two locations), PAS Technologies, Patriot Aviation Services, Spirit Aerosystems, TCI, The Fuel Cell, Triumph (at two locations), Twin Manufacturing, Westfield Gage Company and Wood Group Fuel Systems.

Aveos Fleet Performance in Canada accounts for 4% of the market with contracts to maintain 208, mostly CFM56-5A, engines. Another facility is Honeywell's, which deals with the engine's fuel system.

Within Mexico, there are two facilities. Snecma's engine shop counts TAME and Mexicana as customers and undertakes OH, HSI and LRUs. ITR-Turborreactores deals with some engine components for the CFM56 generally.

South America

Just 4% of the global fleet of CFM56-5A/-5B engines are in South America, and all are -5Bs. GE's Celma Engine Services shop in Brazil has 3% of the global contracts with customers. These include Avianca and TAM Linhas Aereas. Two other shops in South America offer HSI: Seman-Peru and TAMPA.

Engine removals

Many different factors can affect an engine's removal rate, including average flight time, thrust rating, operating base temperatures, engine variant and engine age. The hotter the operating location, and the older the engine, the more likely it is to have shorter removal intervals, as well as unscheduled removals.

CFM advises that a fair shop visit interval rate for the older CFM56-5A is 0.086 per 1,000EFH, or one shop visit every 11,628EFHs. With average annual utilisation standing at 2,659EFH, this could mean every 4.4 years.

The shop visit rate advised for the CFM56-5B is lower at 0.032 per 1,000EFH, resulting in less frequent shop visits every 31,250EFHs. Again with average annual utilisation being 2,979EFH, intervals could be every 10.5 years. This large difference in intervals is due in part to the younger age of the -5B engines which can mean advanced technology.

In reality intervals could be more or less frequent, although Petersen agrees with the above interval range. "It is difficult to make a general comment about the mean time between shop visits (MTBSV), since it depends on the utilisation and type of operation," he comments. "The range can be from three years for a heavily used engine in hot and sandy operations, or up to 10 years for a long-range engine operating at a high de-rate and with low rates of utilisation."

"A CFM56-5B4/P, medium-range rating engine, has its first removal around

27,000EFH due to HPC rotor-stator contact," says Revuelta. "The repair is a hospital visit or an on-site top-and-bottom Case repair. The first performance restoration shop visit can occur after as much as 37,000EFH or 20,000EFC, which are the limits of the LLPs of the HPC. Different operations (FH/FC) and environmental conditions may lead to a removal due to performance deterioration (EFH) or LLP limit (EFC). The second visit is determined by management of LLPs at the first shop visit. The performance restoration visit recovers a reasonable margin of EGT, so this is not a critical factor compared with management of the LLPs.

"The highest-rated variant, the -5B3, which operates at average sectors of 1.5EFH and in medium environmental conditions, may have a shop visit after 12,000EFC due to EGT or combustion chamber distress. Something similar happens with the CFM56-5B4/2P (Double Annular Combustor) engines, which have a shorter time between shop visits due to combustion chamber and HPT hardware distress."

The CFM56-5A is a mature engine, the first of the CFM56-5 family. It generally has 13,000EFCs between performance restoration shop visits for average sectors of 1.5 hours. However, at this stage of its life, other aspects affect the engine's condition, such as LLP management or HPT blade life.

"There are three main reasons why engines are removed from the aircraft and inducted in the overhaul shop. The first is the replacement of LLPs when they are reaching their maximum EFH/EFCs," says Petersen. "The second is premature performance deterioration as a result of particularly demanding operations. The final reason is unscheduled maintenance, for example, foreign object damage like a bird strike."

"An additional cause for removals," says Mika Saarinen, manager, CFM56-5B engineering at Finnair Engine Services, "is simple scheduled refurbishments. We have found though that the most common unscheduled removal reason is HPC and LPT distress, but scheduled and LLP removals are more common than unscheduled." This is echoed by CFMI.

Pedroso adds that while the -5B generally follows the CFMI programme for removals, the -5A is much older and now generally removed for convenience and performance.

The LLP limits range from 20,000EFC to 30,000EFC, with parts in the HPC and HPT being 20,000EFC, and the LPT parts being 25,000EFC. The fan is longer at 30,000EFC. With average annual EFCs being 1,665 for the joint CFM56-5A/-5B fleet, the replacement intervals would be up to every 12, 15 and 18 years.

Shop-visit workscopes range from a repair to a full overhaul, with unplanned removals typically addressing the removal root cause within the specific module. Although there are many factors that influence the result, Walschot estimates that for a heavy shop visit (which includes core performance restoration or full overhaul) it typically takes 2,000-2,500 MH. "This would include a significant number of repairs that we perform in-house at SR Technics. It is hard to generalise, since the time taken will depend on the number of repairs that need to be sent to separate repair vendors. This can affect the number of MH by as much as 1,000 on average."

Component repairs

Components are the parts of an engine that often need specialist repairs. Some MROs and engine shops are able to offer repairs on most, if not all, components of an engine.

As the OEMs and leading maintainers of the CFM56-5A/-5B, GEES and Snecma are the main providers of this service. In fact Walschot comments that a significant part of SR Technics' small number of sub-contracted items go to OEM facilities, with the driver being quality, performance and value in terms of repair yield and price. This is echoed by Revuelta, who says that Iberia only sub-contracts specialist part repairs, and then only to the OEMs or other independent repair shops with a long experience and

Engine operators have a choice of fixed rate per flight hour maintenance contracts, or time and material contracts. The members of the CFMI group account for more than 40% of engine shop visits.

proven reliability. Globally, Snecma has three facilities, and GEES has six.

Specialist repairs are also developed and offered by other major shops such as ADAT, AFI, Alitalia Maintenance Systems, ANA Engine Services, Aveos Fleet Performance, Bedek Aviation, Finnair, Iberia, MTU Maintenance, Pratt & Whitney and TAP Maintenance & Engineering.

"LHT is certified as a maintenance, design and production organisation," says Petersen. "This triple expertise enables LHT to develop its own repair procedures, often providing such performance that OEMs incorporate them into their engine manuals. As a cost-effective alternative, LHT also develops proprietary repairs, including high-tech repairs, in its global network. This can allow repairs to be carried out when previously shops had no alternative but to scrap the defective part and offer their customers an expensive new part." This emphasises the pro-active nature of maintenance facilities, whose customers are not restricted to expensive new parts or old repair methods.

Engine modules

There are many parts to each module and, as well as the main facilities, there are many companies that specialise in the overhaul and repair of these parts, which include the blades, vanes and stators for the LPC & HPC, and the fuel nozzles and combustion cans of the combustion chamber.

Chromalloy is one of the market leaders in such repairs, with at least seven relevant locations globally with skills such as HPC blade-tip weld repairs. Including advanced repairs that reduce scrap percentage and improve engine life, Chromalloy calculates that its repairs are as durable as an OEM repair.

Walschot lists SR Technics' specialist repairs as including full LPT and certain HPT airfoil capabilities in Cork, although some HPT airfoils and HPC blades are sub-contracted. A wide range of specialist repairs are completed in SR Technics' Zurich shop, with a focus on cases, frames, rotating seals, disks, shafts, combustion chambers, compressor hardware and other parts. Repairs are developed and certified in-house.

GKN Aerospace Chem-tronics, offers various coatings for blades, vanes, stators and engines cases. It can apply a protective carbide coating to improve the lifespan of the blades and increase durability. The high-velocity oxy-fuel (HVOF) coating is applied robotically to save time, and is OEM-approved.

Airfoil Services in Malaysia also offers this service as part of its LPC blades, and HPC blades and vanes capabilities. Airfoil Services' standard and extended repair service on HPC blades includes: blend repairs; length restoration; dovetail RTV (room temperature vulcanizing) sealant; HVOF coating; repair of coated dovetail; trailing edge fillet/platform blend repair; chord restoration; and blending of the airfoils, including an advanced recontouring process.

GKN Aerospace Chem-tronics' basic repair of a fan blade might include airfoil blending, Cu-Ni-In thermal spray & dry film lubricant coatings on root and blending of the leading edge contour. Additional repairs that are offered are: the replacement of tungsten carbide coatings; reconditioning the blade tips and midspan shroud faces by weld build-up; airfoil straightening; repair of wear marks on shank; and the repair of leading and trailing edges with inserts welded in position.

Snecma itself is the leader in CFM56 combustion chambers and estimates that it deals with over 150 per year. It expects this to rise to 250 per year in the future. Repairs include the restoration of thermal coatings and plasma spray, pulse welding, patch welding and primary swirl nozzle replacement. A full repair is expected to have a turnaround time of about 24 days. LHT offers a fuel nozzle coking repair that identifies and repairs only the damaged areas while still on wing, which has the added benefit of increasing the EGT margin and time on wing. Another on-wing repair is offered by Iberia with the replacement of the fan and booster module.

Honeycomb & knife-edge seals

Honeycomb seals are the non-rotating component in the LPT. Knife-edge seals are the rotating component of seals in the LPT and other parts of the engine.

Major honeycomb seal repair providers include PAS Technologies, LHT and MTU as well as the OEMs and those involved in the specialist repair of seals and blades, such as: Windsor Airmotive Asia; Westfield Gage Company Overhaul & Repair; and Chromalloy's facilities, particularly in Thailand and France.

The same companies that undertake honeycomb repair and replacement will often also offer knife-edge seal repairs, as well as blade, vane and stator repairs.

LLPs

LLPs can be broadly divided into three categories: shafts, discs and rotating airseals.

With the average age of CFM56-5A engines being nearly 16 years old, there is a good chance that most HPC, HPT and LPT LLPs will have been replaced, and the fan's parts will be reaching their limits soon.

The -5B has an average age of nearly six years, so it is likely that most of these engines have not yet reached their limits. They are fast approaching the LLP limits, so therefore there will be an increased demand for new or repaired LLPs.

As well as the capabilities offered by GE and Snecma, the main engine shops and parts repairers, such as Chromalloy

Besides core engine maintenance, operators have a wide choice of vendors for the repairs of turbomachinery parts, accessories & LRUs, cases & frames, seals, and nacelles & thrust reversers.

and Westfield Gage Company Overhaul & Repair, offer cleaning, repair and specialist coating of shafts, discs and rotating airseals.

Cases & frames

Non-rotating parts, cases and frames are some of the simplest parts to repair. The usual major facilities repair these parts are Chromalloy, PAS Technology, GKN Aerospace Chem-tronics and Nordam. Iberia adds that it usually repairs cases as part of a full overhaul.

Accessories & LRUs

The main components mounted on the outside of the engine can be divided between accessories and quick engine change (QEC) kit components. The main accessories are the main engine control (MEC), fuel pump, pneumatic starter motor, variable stator vane actuators and sensors.

Line replacement units (LRUs) are dealt with by all the main shops and a number of specialists. There are no LRU specialists in Africa and only one in South America: GEES Celma.

In North America, apart from OEMs and major MRO facilities, there are: Accel Aviation Accessories, Aerothrust, Ascent Aviation Services, Component Repair Technologies, Eaton Aerospace, Fokker Aerotron, GKN, JFJ Industries, PAS Technologies, TCI, Triumph Accessory Services Grand Prairie, Twin Manufacturing and Westfield Gage Company.

Chromalloy also repairs LRUs at five US locations. Within the Asia Pacific Airfoil Services in Malaysia, and Airfoil Technologies in Singapore are the only non-OEM or MRO facilities to offer this service. In Europe, most that offer this service are OEMs or MRO facilities. The exceptions are 1-Source Aero Services, Auxitrol, Barry Controls Aerospace, CRMA and the Jet Technology Center.

There are also companies involved with the lubrication, fuel and electrical systems of the engines which can be part of the QEC components and accessories. As well as the OEMs and MRO shops, companies involved in these areas are Aircraft Ducting Repair, Fuel Acc Services Technologies, Hawker Pacific Aerospace (LAX), Honeywell Canada, ITR Turborreactores, The Fuel Cell, and Woodward Aircraft Engine Systems.

Nacelles & thrust reversers

Repair of nacelles, cowls and thrust reversers is a specialist capability. Thrust reversers are generally maintained on-condition.

Goodrich repairs and overhauls both nacelles and thrust reversers at four locations: two in the US, one in the United Kingdom, and one in Singapore.

In the Asia Pacific all capability is held by the major engine shops and Goodrich. In Europe, there is an even mix of engine shops and specialist repairers. The same can be said in North America. In South America and the Middle East thrust reversers are only maintained by MRO facilities and OEMs.

PMA parts

The high cost of turbomachinery parts, particularly in the HPT, has led to Parts manufacturer approval (PMA) parts being developed by several suppliers.

Belac is a joint venture between Chromalloy, Lufthansa Technik and United Airlines. Belac makes blades and vanes for several engine types including the CFM56-5A/-5B. The list prices of these parts are 40-75% of the OEM's part. A 30% discount on a HPT blade can save $200,000 or so for a complete shipset of HPT blades.

HEICO is another provider of engine PMA parts for the CFM56. It also manufactures fuel pump gears, bearings and shafts, and expendables.

Other PMA providers manufacture non-core engine parts for the CFM56-5A/-5B. These are parts relating to the fuel controls, starters and various other accessories. Such providers include Aviation Component Solutions and Wencor.

Modifications & upgrades

Modifications and upgrades are developed to reduce the chances of unplanned shop visits, as well as rectifying issues raised on some engines before they affect the whole fleet.

CFMI states that there are no planned upgrades to the CFM56-5A, since it is a very small out-of-production fleet.

In 2007, the CFM56 Tech Insertion was introduced as a production upgrade, and as a retrospective hardware upgrade. Tech Insertion involves improving the durability of the combustion chamber. It now meets the International Civil Aviation Organisation's (ICAO's) CAEP 6 requirements.

Late in 2011, CFMI will offer a Performance Improvement Program (PIP). The PIP offers 0.5% fuel burn improvements, hardware changes to the core in order to improve the aerodynamics, fewer turbine blades and thus reduced maintenance costs. The -5B PIP will become the production standard from the third quarter in 2011.

New modifications that CFMI also offers are new HPT blades with improved aerodynamic efficiency, new HPT discs and new forward outer seals. CFMI also comments that the manufacturing process for fan blades and compressor blades and vanes has been improved to tighten tolerances, thereby reducing performance degradation. AC

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