Narrowbody aircraft are suited for short to mid-length routings, and so are evident in the fleets of almost all operators. Their popularity has led to a competitive variety of choices in the engines able to power these aircraft. A selection of these engines, alongside some examples of those able to perform specialist parts repair on their components, is examined here.

Narrowbody engine hi-tech & specialist parts repair providers

The main narrowbody fleet includes the 737 Classic and 737NG families, the 757-200/-300, the A320 family, and the Embraer E-Jet family. Three of these families are powered by three variants of the CFM56, and the V2500-A5. The E-Jet family is powered by the CF34-8E & -10E series. The RB211-535E4 and PW2000 power a declining number of 757s. The majority of the narrowbody fleet is therefore powered by five main series of engines.

The shrinking 737 Classic and 757 fleet, and the introduction of the 737MAX and A320neo families, will see CFM International, IAE, Pratt & Whitney (PW), and General Electric (GE) engines dominate the narrowbody fleet, and engine maintenance market.

Due to the changing shape of the engine aftermarket, it can be expected that new generation engines will not offer the same number of options in repair providers that has been available for previous engine types. It has been recognised in recent years, for example, that original equipment manufacturers (OEMs) are keen to ensure that a high percentage of the repair and overhaul work carried out on their engines and associated parts and components is either performed in their facilities, or remains under their control.

This is somewhat balanced by the general industry expectation that new designs and materials seen in modern engines will increase the time between shop visits, costly overhauls, and so limit the requirement to renew expensive parts. The emphasis is on repairing expensive and hi-tech parts and components, rather than replacing them.

To strengthen this market perception, OEMs have now adopted similar approaches. They now include a select group of global specialised engine repair and shop visit facilities to focus on specific engine modules and parts, usually under the OEM's endorsed banner, using its repair techniques and with the engine shops in its network being granted the necessary endorsements and licences. This strategy applies to all new generation, developing engines, and will become more prevalent over the next five years.

Types of specialist repair

OEM versus DER versus PMA

The divide between OEM, designated engineering representative (DER) and parts manufacture approved (PMA) repair techniques has led OEMs to influence the market, such that service providers and operators in the market are wary of repair processes that are not approved by the manufacturer. An OEM will often argue that OEM-supported engines retain the highest residual value, and maintain higher performance levels than those that undergo DER repairs.

The main difference between OEM repair processes, and PMA parts, is that OEM repairs are developed by the manufacturer using approved, proprietary data while DER and PMA have been approved by leading aviation authorities such as the FAA and EASA. The main attraction that these types of repair have typically held for operators is that they have the potential to offer a substantially lower-cost alterative to some expensive repair and parts replacement using OEM repair techniques.

DER repair techniques may vary from those endorsed by the OEM. "For example, unique stripping, welding, coating and machining techniques can all be applied to DER repairs," explains Mike Moore, vice president of engine and component maintenance at Delta Tech Ops.

The trend is now for repair providers to become 'OEM friendly'. This means being willing to be partnered and supported by an OEM. This contrasts to a provider that works separately from the OEM and adopts separate repair techniques that do not get approved at manufacturer source. This approach is arguably more achievable for large-scale airlines with established maintenance facilities, and with large aircraft orders to use as leverage. It may be relatively simple for these airlines to negotiate maintenance and repair capabilities if they have placed large orders for engines with an OEM. Even so, freedom may only be provided for the maintenance of its own fleet, rather than being free to truly offer a fully independent maintenance capability to third-party customers. These airlines may still be referred to the OEM for the major engine maintenance processes.

Other than this, independent repair providers that have been long-term

affiliates of the manufacturers may also be able to continue providing repair services on new and emerging engines.

Parts manufacturers are also able to develop mutually beneficial relationships with OEMs due to the services they can offer in parallel to the production of new generation engines.

Key repair techniques

Repair processes seen in narrowbody engines reflect those mentioned in widebody engine hi-tech repair processes. Examples include:

CNC Shot Peening: a technique designed to relieve tensile stress in materials and increase material integrity and life. This tensile stress can arise through manufacturing processes such as heat treating, grinding and welding; and can lead materials to crack. Shot peening is used to replace tensile stress with compressive stress, manipulating the surface of the material to prevent fatigue and stress-based cracks.

Plasma Spray coatings: These coatings provide a thermal barrier for components that undergo high temperatures in the engines. Zirconia and ceramic coatings are two examples commonly used. Alongside heat resistance of up to 1,000 degrees celsius, plasma-sprayed coatings allow lightweight and composite materials used in current-generation engines to become even more durable and hard wearing.

Electron Beam Welding (EBW): EBW is a high-strength fusion-welding process. It joins two materials together via a beam of high-velocity electrons. It is widely used in the engine repair process, and is considered to be the most reliable type of welding.

High velocity oxygen fuel coatings (HVOF): Commonly used in turbofan engine bearings, HVOF is a thermal spray process where tungsten carbide powder particles are injected through a nozzle via a high pressure and temperature gas stream. Materials coated using this technique have a dense and durable coating. HVOF is most commonly applied using robotics to direct and hold the spray nozzle.

There are many other types of coating, and adaptive machining and milling processes used by repair providers and OEMs, including chemical vapour deposition (CVD) coating; airfoil chord width restoration (CWR); and chromium and nickel plating and stripping. All repair techniques require approvals, and in most cases hi-tech repairs involve very high cost equipment, access to manuals, and licences. To differentiate which processes apply to each engine, we must expand on the different capabilities seen across the narrowbody engine selection below.

Pratt & Whitney

The PW2000 series and V2500 are the key products offered by PW for narrowbodies. The V2500 will be expanded on separately in its own section below. The repair facilities owned by Pratt & Whitney provide repair services for both the PW2000 and V2500 and are predominantly located in Asia and America. These are:

- Asian Compressor Technical Services, Taiwan: Its repair capabilities focus on the engine compressors, stators, shrouds and HPC seals.
- Component Aerospace Singapore: CAS's repair services extend to the combustion chambers, fuel nozzles, and fuel nozzle guide vanes (NGVs).
- Connecticut Rotating Parts, USA: repair focus is on PW2000 and V2500 major rotating parts.
- Connecticut Stators and Components, USA: A sister facility specialising in HPC stator and honeycomb seal repair.
- Dallas Airfoil Repair Operations, USA: components in the exhaust gas path

form the repair basis here, including HPT/LPT blades and vanes, alongside airfoil coatings.

- International Aerospace Tubes, Singapore: repairs tubes, ducts and manifolds.
- North Berwick Part Repair Operations, USA: capabilities include airseals, shrouds, ducts, vane supports and bearing components.
- Pratt & Whitney Auto Air, USA: Thrust reversers, nacelle components and composites repair.
- Pratt & Whitney Component Solutions, Singapore: PW's facility in Asia focusses on stators, variable vanes, ducts, airseals, split cases.
- Repair Supplier Logistics, USA: Provides repair logistics.
- Turbine Overhaul Services, Singapore: HPC, HPT and LPT airfoils, and transition ducts.
- 1-Source Aero, Greece: main focus is accessory repair.

PW2000 engine parts repairs are also performed at the PW engine overhaul facility at Columbus engine centre, Columbus, Georgia, USA.

PW applies the same processes used in OEM engine design and development between its PW2000 and V2500 engine part repairs. PW specialises in high-tech repairs such as: multi-layer abradable coating for blade outer airseals; drum rotor disk replacements for rotating parts; and electron beam welding for flange replacements (for example cases) and Turbofix™ for all engine turbine blades.

PW2000

The PW2000 engine series is a turbofan with an eight-stage axial turbine, annular combustor, and an axial compressor. It powers all models of the 757 family, alongside various military aircraft.

The PW2000 engine entered revenue service in 1984 as the first commercial engine with FADEC (Full-Authority Digital Electronic Control) technology. PW later introduced a revised version of the PW2000, with reduced temperature configuration (RTC) in 1994.

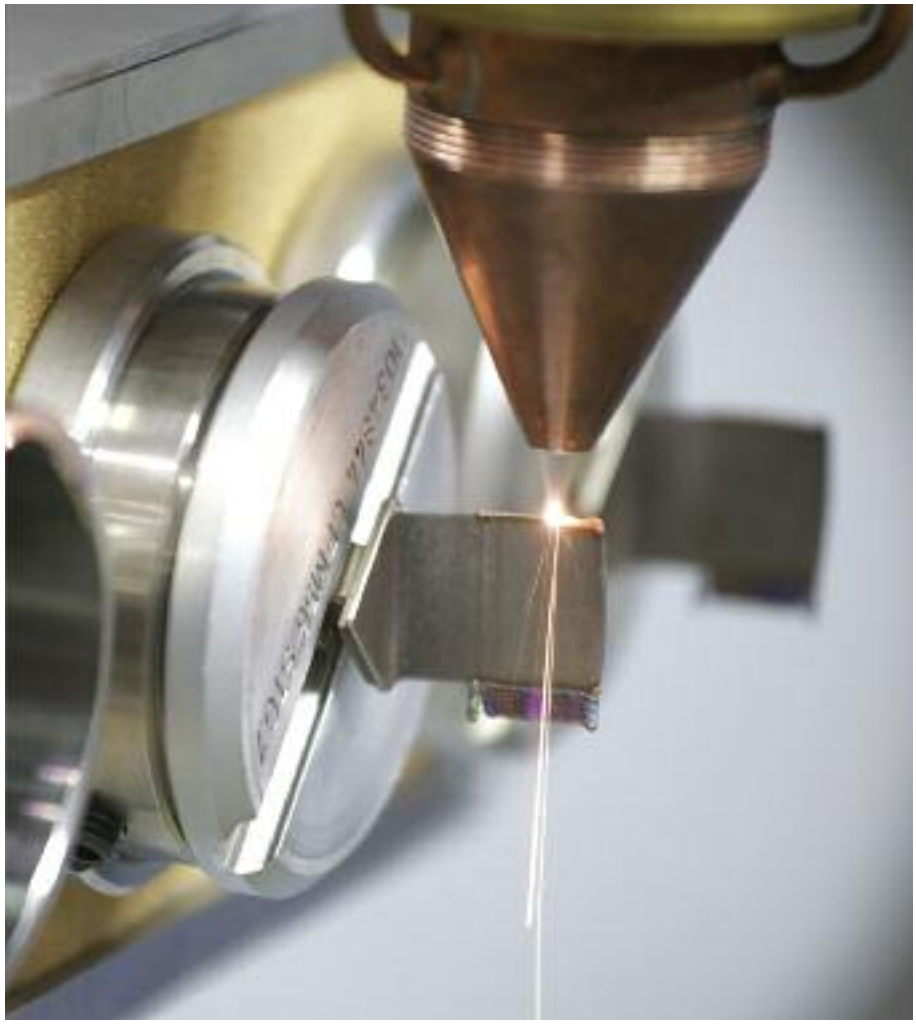
PW2000 repair providers

MTU Aero Engines both developed and designed critical elements of the PW2000. As such, it holds more than a 21% stake in the PW2000. Headquartered in Hannover, Germany MTU's sister company MTU Maintenance specialises in the maintenance of commercial engines, alongside creating repair solutions for the engines it supports. Subsequently, MTU Maintenance offers full module and parts repair capability for the PW2000, including: the fan; low pressure compressor (LPC) and high pressure compressor (HPC) airfoils; the combustor; high pressure turbine (HPT), and low pressure turbine (LPT) airfoils; cases; gearbox; and accessories.

The first PW2000 series engine, the PW2037, entered service with Delta Air Lines. Delta's narrowbody current fleet includes 717-200s, 737-700s & -800s, A320-200s and A319-100.

Delta's designated maintenance facility, Delta Tech Ops, is headquartered in Atlanta. "We provide modification, repair and overhaul, and full restoration across all engine modules for the PW2000," explains Moore. "We also carry out performance restoration to certain components, including those used in the gas path. We can perform repairs for the fan, bearing housings, LPT seal segments, HPT shroud hangers, liners, engine mounts, HPC airfoils, LPC airfoils, combustor, frames, gearboxes, cases and hundreds of other parts," continues Moore.

"We use a wide range of hi-tech repair technics, such as plasma spray,



The main high-tech engine repair techniques include CMC shot peening, plasma spray coatings, electron beam welding (EBW), and high velocity oxygen fuel (HVOF) coatings.

HVOF, anti-friction and thermal barrier coatings, laser welding, tip welding, electron beam welding, laser cladding, heat treatment, high pressure waterjet stripping, CNC shot peening, as well as silver, chrome and nickel plating capability," highlights Moore regarding Delta's OEM repair capabilities. Alongside OEM endorsed repair, Delta is able to provide DER repair on the PW2000 series. "We can provide DER repairs on a range of narrowbody engines, including the PW2000, the CF34 and CFM56 series" confirms Moore. "In our opinion, there are more DER repair options available on the older models than the new."

PW1000G 'PurePower' series

The PW1000G series is due to enter service to exclusively power Embraer's second generation E-Jets, alongside the Bombardier C Series. It is a high-bypass ratio, geared turbofan engine family.

It will also be an engine option on the A320neo. "PW's Geared Turbofan (GTF) engine aftermarket approach is all about providing customer value and supporting customer choice," begins Marc Meredith, director, aftermarket & commercial development at Pratt & Whitney. "Initial maintenance and repair for the GTF engine will be performed by PW and its OEM partners, MTU and JAEC. Over time, as the maintenance, repair and overhaul (MRO) network grows, we expect it to include engine partner shops, airline shops and independent MRO facilities. This will lead to a competitive marketplace, providing a variety of service options for narrowbody operators," continues Meredith. Much like the PW2000, MTU Aero Engines is manufacturing the PW1000G's high-speed LPT and various stages of the HPC. As such, MTU Maintenance plans to provide repair services at its Hannover facility in the first quarter of 2016.

MTU Maintenance offers high-tech repairs, which are developed in house, approved by the European Aviation Safety Agency (EASA) and Federal Aviation Administration (FAA), and marketed as MTUPlus repairs. They increase the cost-effectiveness of a maintenance workscope, as opposed to the replacement with new parts.

MTU Maintenance provides MTUPlus repairs on the CFM56, the CF34 and V2500 engines. Prominent examples include its erosion-resistant nano technology coating, now called MTUPlus ERCoateco. This is appropriate for HPC airfoils, which are prone to erosion in certain environments.

ERCoateco provides particle and fluid erosion and corrosion resistance. MTU Maintenance also offers MTUPlus Tip Protection, where blades can be repaired for one-tenth of the new part price. This allows for increased parts life (10% less scrap), higher engine efficiency and longer on-wing times. "In terms of processes, DER repairs do not differ much from OEM repairs," Reinhard Schuetz, director sales support repair services at MTU Maintenance.

"With our hi-tech repairs, we focus on operational success, which means that we have developed repairs i) for a specific type of damage, ii) which are optimised for a certain operation, and iii) which are an alternative to replacement parts," explains Schuetz.

IAE

International Aero Engines (IAE) is a consortium backed by four aero engine manufacturers, formed in 1983 to produce the IAE V2500. The V2500 is a two-shaft high-bypass turbofan engine which powers the A320 family (A320, A321, A319 and the Airbus Corporate Jet), the McDonnell Douglas MD-90, and the Embraer KC-390.

Rolls-Royce (RR) designed the HPC, while PW developed the combustor and the two-stage air-cooled HPT. Japanese Aero Engine Corporation (JAEC) provided the LPC system, and MTU was responsible for the 5-stage LPT in the V2500.

PW provides V2500 engine part repairs at its engine overhaul facilities at Christchurch Engine Center, Christchurch, New Zealand; Columbus Engine Center, Columbus, Georgia, USA; and Turkish Engine Center, Istanbul, Turkey.

V2500 engine part repairs are also performed in the following IAE network engine overhaul facilities: IHI in Tokyo, Japan; MTU Maintenance in Hannover, Germany and Zhuhai, China; and RR in East Kilbride, Scotland.

Repair providers

PAS Technologies Inc., backed by KRG Capital Partners, is a provider of OEM-licensed MRO solutions for a broad range of commercial and military aerospace applications, including a strong specialism in aerospace propulsion components.

Since its inception in 2006 as an

There are many types of coatings and adaptive machining, and milling processes used by repair providers and OEMs. These include chemical vapour deposition (CVD) coating, airfoil chord width restoration (CWR), and chromium and nickel plating and stripping.

aerospace MRO application provider, PAS has undergone significant growth and development through its OEM partnerships. PAS offers an expansive range of process capabilities, including vertical integration. This allows PAS to offer solutions from its five global plants located in Kansas City, MO; Hillsboro, OH; Phoenix, AZ; Romania and Singapore.

PAS provides repair support on the V2500 engine. PAS is a designated service provider (DSP) to PW. This means it is closely affiliated to the OEM to provide aftermarket support for this engine. This DSP affords PAS the right to operate under the PW brand, with access to PW engineering resources. This includes engineering documentation and EA/IEN in support of repair development requirements for customers. PAS can repair the HPT Stage 1 cooling (TOBI) ducts and bearing housings, seals and supports, and LPT shroud seal segments and inner duct segments. These repairs require high-tech processes that include thermal spray coatings, honeycomb brazing, EB welding, machining and other speciality processes.

"PAS Technologies Inc has capability to support repairs in all V2500 modules from the fan to the turbine exhaust," explains Daniel Adamski, vice president of business development at PAS Technologies Inc. "Our repairs include cases and frames, TOBI ducts, segmented honeycomb seals and shrouds, HPC stators and outer shrouds, airfoils, bearing housings, seals, supports and many more components that align with a broad range of technical process capabilities. PAS Technical process capabilities include: grinding, milling, turning, metal forming, honing, lapping, plating, painting, coating, heat treatment, shot peen, inspection & non-destructive testing (NDT), assembly, welding and joining/brazing," continues Adamski.

As co-manufacturer of the V2500, MTU Maintenance again holds capability for the full range of engine module parts repair for the engine, in equal scope to the PW2000 series.

An airline-related MRO that can provide repairs on the V2500 engine is Lufthansa Technik (LHT). Headquartered in Hamburg, its parent airline Lufthansa, and its group members, has a broad range of narrowbodies that include the A320, A319, E-190, and 737. Lufthansa Technik has developed capabilities to support both its in-house fleet and also third-party customers for the V2500-A5 series, among other narrowbody engines expanded on later. LHT is also preparing for the introduction of parts repairs for several new generation engine types.

The Lufthansa Technik parts repair division known as engine parts and accessories repair (EPAR) has a broad range of high-tech repairs for the V2500. These are in addition to the CFM56-5A/-5C/-5B/-7BE, and CF34-8/ -10, which will be expanded on throughout the article.

LHT's EPAR repairs are performed within the global network at the following locations: LHT Hamburg for the repair of fan blades, rotating and stationary-airfoils, engine components and cases; LHT Berlin for the repair of engine tubes and ducts; LTTS (Lufthansa Technik Turbine Shannon) Shannon (Ireland) for the repair of LPT vanes and HPT shrouds; ASSB (Airfoil Services) Kuala Lumpur (Malaysia) for the repair of HPC and LPT blades; and lastly Bizjet in Tulsa (USA) for the engine teardown process.

"Lufthansa Technik is constantly increasing its high-tech parts repair capabilities, and also investing in new innovative technics to allow it to provide new hi-tech parts repairs in the future," explains Thorsten Prehn, head of product sales & customer support EPAR at Lufthansa Technik. "The typical EPAR techniques that Lufthansa Technik is using are EB welding, laser welding, adaptive machining, laser applications, thermal spraying applications, 3D measuring and parts digitising for inspection."

General Electric (GE)

The CF34 series of engines, which entered into service in 1992, has long been GE's primary offering of narrowbody engines. The CF34 family includes: the CF34-8C5, which powers the Bombardier CRJ-900; the CF34-8E, which powers the 70- to 90-seat E-170 and E-175; the CF34-10E engine, which powers the E-190 and E-195; and the CF34-10A, which powers the COMAC ARJ21 family.

The CF34-8 and -10 series of engines are overhauled at the GE Strother facility in Kansas, while the CF34-10s are also overhauled at the GE Celma facility in Brazil. GE's global repair shops in Cincinnati, Ohio; Singapore; McAllen, Texas; and Veresegyház, Hungary provide repairs for its GE network and third-party overhaul providers. GE's overhaul shops at Strother and Celma also offer a range of parts repair capabilities.

These GE repair shops focus on

specific product types for each engine:

- In Cincinnati, repairs are available for rotating parts and structures across the CF34 family, alongside HPT airfoils.
- In Singapore, the focus is on combustors, HPT airfoils, HPC airfoils and LPT airfoil repairs.
- The McAllen facility specialises in LPT airfoils.
- In Hungary, honeycomb and composite repairs are performed.

GE's repair technologies for each component include:

- HPT & LPT airfoils: stripping, FPI, eddy current, x-ray, welding, brazing, grinding, EDM, laser drilling, and coatings (Pl Al, VPA, EBPVD).
- Combustors: waterjet stripping, welding, brazing, coatings, and laser drilling.
- Rotating parts: cleaning, FPI, eddy current inspection, ultrasonic inspection, metal spray (HVOF), grinding, machining.
- Structures: welding, metal spray (HVOF), and heat treatment.

Much like the DSP arrangement, GE focuses on offering maintenance and repair providers the opportunity to become part of the GE brand. This is known as the GE Branded Service Agreement (GBSA). "Our network overhaul providers with GBSAs include MTU (Berlin, Germany), Standard Aero (Winnipeg, Canada) and IHI (Mizuho, Japan)," explains Lorna Hyman, repair marketing manager at GE Aviation. "GE also has broad repair capability with its component repair facilities, together with a large network of licensed repair providers."

Repair providers

MTU Maintenance, as a holder of a GBSA with GE, is an inherent part of its repair network for the CF34 family. It can repair the fan, HPC airfoils, combustor, HPT airfoils, gearboxes, and cases and frames for the CF34. It cannot repair the LPT airfoil, or engine accessories.

Similar to its capabilities on the PW2000, Delta Tech Ops can carry out performance restorations to certain components, including those used in the gas path modules of the CF34. Delta Tech Ops can also repair the fan, bearing housings, LPT seal segments, HPT shroud hangers, liners, engine mounts, HPC airfoils, LPC airfoils, combustor, frames, gearboxes, and cases throughout the engine. As one of the earlier produced narrowbody engines, Delta observes a shift in acceptance of DER and PMA repair techniques. "For our CF34-8 customers, we see a high percentage of them opt for DER and PMA repairs; over 90%, even if it is only for a limited number of parts," highlights Moore. "For our PW2000 and CFM56-5/-7 engines, only about one-third opts for DER and PMA solutions to control costs."

CFM International (CFM)

CFM International is a 50:50 joint-owned company of Snecma (Safran) and GE Aviation (GE). As such, both companies produce components for the CFM56 family. GE produces the HPC, combustor, and HPT. Snecma manufactures the fan, gearbox, exhaust and the LP system, including the LPT. Some components are made by Avio of Italy. The engines are assembled by GE in Evendale, Ohio; and by Snecma in Villaroche, France. The completed engines are subsequently marketed by CFM.

The CFM56 first ran in 1974 and has become the most numerous commercial engine in service. It is most widely used on the CFM56-7B-powered 737NG, and the CFM56-5B-powered A320 family. The -5C series is the only engine used to power the A340-200 and -300 series.

The CFM56's design includes a fan and three-stage LPC, followed by a nine-stage HPC, annular combustor and single-stage HPT, four-stage LPT.

Conversely, the CFM LEAP is an emerging new generation engine that CFM has developed. It is due to formally enter service in 2016. The LEAP-1A is an option on the A320neo, while the LEAP-1B is the exclusive powerplant for the 737 MAX; and the LEAP-1C is the sole western powerplant for the COMAC C919.

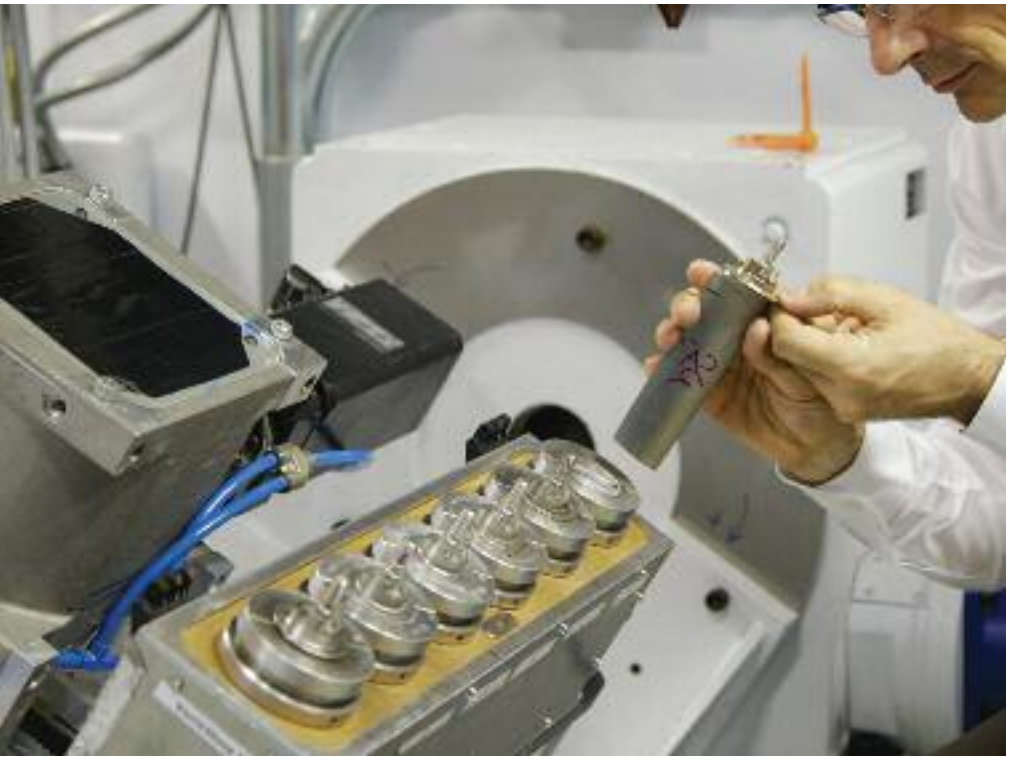
The LEAP engine family is manufactured using breakthrough processes, such as additive layer manufacturing (ALM); a technique derived from 3D-printing. It is therefore to be expected that the aftercare for the LEAP engine will require further specialised, hi-tech repair processes in some modules that are perhaps different to older generation predecessors.

There is an open network of more than 30 service providers that overhaul the CFM56-7B. As an emerging new generation engine, the service network for the LEAP programme is being developed.

"The two parent manufacturers compete for overhaul work as GE Aviation Services and Snecma Services. Customers are free to select a CFM option or other third-party providers, however" explains Hyman. "For the LEAP engines, all aftermarket support will be provided by CFM, leveraging the network and infrastructure in place with the two parent companies."

The CFM56 engines are overhauled by GE in Brazil, Wales, Malaysia, and Kansas; and by Snecma in France, Belgium, Mexico and Morocco.

GE repair shops located in Ohio, Texas, Singapore, and Hungary; and Snecma repair shops located in Chatellerault, Saint Quentin, Villaroche and Brussels all provide repairs to the global network of overhaul providers that services the CFM56-7. The CFMI LEAP engines will initially be overhauled by CFM Services in Lafayette, Indiana; Brussels, Belgium; and Saint-Quentin,



Lufthansa Technik parts repair division is known as engine parts and accessories repair (EPAR). It has a range of repairs for parts used in the V2500, CFM56-5A/-5B/-5C/-67BE and the CF34-8/-10.

France.

Much like the CF34 series detailed, GE's repair shops focus on specific product types:

Cincinnati - rotating parts and structures.

Singapore - combustors, HPT airfoils, HPC airfoils, and LPT airfoils.

McAllen - LPT airfoils, and HPT shroud hangers.

Hungary – honeycomb and composites.

Additionally, the services provided by Snecma as part of the 50:50 joint venture include:

Snecma Services Belgium – combustors.

Snecma France – HPT airfoils, LPT airfoils, rotating parts and structures, HPT shroud hangers, and honeycomb repairs.

Propulsion Technologies International (PTI) – which is a joint venture between GE and Snecma, performs repairs on fan blades, platforms, booster vanes, spinner cones, and rotating parts.

Much like other engines, repair techniques differ between each module, as pressure, temperature and material component demands vary. For the CFM56, current repair techniques include:

HPT & LPT airfoils: stripping, FPI, eddy current, X-ray, welding, brazing, grinding, EDM, laser drilling, coatings (Pl Al, VPA, EBPVD).

Combustors: waterjet stripping, welding, brazing, coatings, laser drilling.

Rotating Parts: cleaning, FPI, eddy current inspection, ultrasonic inspection, metal spray (HVOF), grinding, machining.

Structures: welding, metal spray (HVOF), heat treatment.

"The LEAP engines have new technologies incorporated to achieve significant performance improvements compared to CFM56 engines," explains Hyman. "These include carbon fibre composite fan blades and fan cases, ceramic matrix composites, blisks, advanced twin-annular pre-swirl combustor with advanced cooling, titanium aluminide LPT blades, and additive manufacturing techniques. New repair processes are in development to support this technology," adds Hyman.

Repair providers

As a repair provider for the CFM56-5A/-5C/-5B/-7B types, Lufthansa Technik is concentrating on the entire engine and is offering repairs on the entire gas stream, except for HPT blades.

Airfoil Services (ASSB) is a specialist repair source for the HPC and LPT blades, whereas LTTS is concentrating on the HPT shrouds and LPT vanes. The Hamburg shop is completing this with HPT vane repairs. Besides this, EPAR is also providing repairs on all the cases, stationary and rotating parts. This level of capability is similar to its range of repair capabilities on the V2500 engine, with the exception that LHT does not perform LPT vane repairs on the V2500.

PAS Technologies also has extensive repair capability on the CFM56. Current PAS repair support includes the LPT case, HPC rear case, LPT stationary outer airseals, HPT aft outer airseals, HPT shroud hangers, compressor stator shrouds, HPC vane sectors, and fan outlet guide vanes. "High-tech repairs rely heavily on PAS Technologies' vertically integrated process capability that includes machining, milling, turning, vacuum brazing, honeycomb, EB and TIG welding, and thermal spray coatings," explains Adamski. "Different OEMs incorporate a different array of speciality process applications into their repairs. Through its OEM partnerships, PAS is licensed to perform many OEM-specific, source-demonstrated speciality process applications and can perform a broad array of OEM-approved processes from multiple major OEMs."

For the LEAP series, PAS anticipates further repair developments, as the aftermarket takes shape once the engine progresses in service.

Air France Industries (AFI), alongside its industry partner KLM Engineering & Maintenance (KLM E&M), also has significant repair capabilities for the CFM56 family. Alongside CRMA, the designated centre of excellence for repair development, AFI KLM E&M offers extensive repair capabilities on all parts of the CFM56-7B series, excluding gas path hardware elements. These include blades, stator vanes and shrouds. AFI KLM E&M is also building up capability for the CFM56-7BE engine, which will power the Boeing next generation single-isle family of 737 and BBJ aircraft. This capability is due to be finalised in operation by the end of 2015.

AFI KLM E&M works together with OEMs to offer OEM repair solutions, instead of DER repairs. On occasion, if customers require DER repairs AFI KLM E&M can offer tailor-made solutions with partners. AFI KLM E&M estimates a maximum 20% of customers might consider to opt for DER repairs.

MTU Maintenance provides almost all repair capabilities across the CFM56 family. With the exception of CFM56-3 HPT airfoils, it has full repair provisions on the CFM56-3/-5B and -7 variants from fan to LPC and HPC airfoils, through to the combustor, and LPT airfoils and remaining engine components. MTU Maintenance's overall portfolio of specialist part repairs include:

MTU Maintenance provides a wide range of parts repairs for narrowbody engines. Techniques include atmospheric plasma spraying (APS), wire-feed plasma spraying, laser drilling and welding, and low-pressure plasma spraying.

adaptive machining and milling; application of anti-friction and thermal barrier coatings; atmospheric plasma spraying (APS) and wire-feed plasma spraying; CVD coating; CWR; chromium and nickel plating and stripping; electron-beam physical vapor deposition coating (EB-PVD); electron-beam welding; laser drilling & welding; low-pressure plasma spraying (LPPS); plasma spray coating; tip welding; ultrasonic inspection for fan blades and other weld repairs.

Established in 1997 and headquartered at Zurich Airport, SR Technics was formerly the Technical Department of Swissair, initially founded in 1931. The company performs hi-tech repairs on the CFM56-7 variants. Its main hi-tech processes include: plasma coatings, various plating processes, precision machining, automated TIG welding, and high speed grinding.

The CFM56 parts that SR technics can provide hi-tech repairs for include: fan cases; compressor cases; turbine cases; LPT airfoils; combustion chamber; life limited parts (LLPs); knife edge seals; electrical harnesses and accessories.

Examples of SR Technics' repair processes and capabilities include: i) crack repairs: manual or automated TIG/micro plasma welding; ii) combustor repairs: strip and recoating; iii) airfoil repairs: non-destructive testing, automated or manual blending; iv) frames: patch repairs; and v) LLPs: coatings, and automated machining processes.

Alongside the above OEM repairs that SR Technics can provide, some DER repair options are available subject to customer request and approval. In some cases, the techniques employed may differ slightly from the OEM repairs. "Generally inspection criteria (dimensions and repairable limits) and welding processes can vary," says Jean-Marc Lenz, senior vice president of engine services at SR Technics. "Applying existing technologies to areas which are not being covered by the engine manual is another example."

Market perception of DER repairs, however, seems to be consistent across repair providers, with only a fraction of customers opting for this type of repair on the CFM56 engine series instead of OEM endorsed repair. "We estimate about 5% of customers look at DER as an option (over OEM repair and in addition to the OEM)," summarises Lenz.

Lufthansa Technik is a repair provider for both the CF34-8/-10, and CFM56-5A/-5C/-5B/-7B series of engines, alongside the V2500 as referenced earlier. Lufthansa Technik EPAR is using the synergies in repair methods to constantly expand its capabilities and to introduce new repairs in future. This will enable it to further prepare for repair introduction on the upcoming new generation engine types.

Delta Tech Ops' capabilities for the CFM56-5 & -7 models are equal to its repair capabilities on the PW2000 and CF34 engine types. That is, it can carry out modification, repair and overhaul, alongside full restoration across all engine modules. This is in addition to its ability to carry out performance restoration to certain components in the engine, including those located in the gas paths. Lastly, Delta can perform repairs for the fan, bearing housings, LPT segments, HPT shroud hangars, liners, engine mounts, HPC airfoils, LPC airfoils, combustor, frames, gearboxes and cases for the CFM56 engine.

It is interesting to note that there seems to be little option in the way of aftermarket support for the RR engines; for example, the BR-715 – an older generation powerplant for business jets alongside the 717 series – appears to have little option in the way of truly independent aftermarket care. Meanwhile, one of the largest MRO providers in the world, the Hong Kong Aircraft Engineering company (HAECO) narrowbody focus is predominantly as a service provider for the Pratt & Whitney JT8D engine family; a powerplant most commonly used on the DC9 and Boeing 727 series of aircraft.

There are many synergies to be recognised among the OEMs and the aligned repair providers. Not only are techniques either replicated or very similar across the brand and engine types, but the relationships with repair providers are almost identical to those outlined in specialist widebody engine parts repairs *(see Hi-tech engine parts repair providers, Aircraft Commerce, April/May 2015, page 46-56)*. While it is clear that independent repair providers have to adopt partnerships with the OEM to survive in the engine repair market, the extent of the divide remains to be seen, once the new generation engines are in operation and in need of repair and heavy maintenance. AC