The engine MRO market has become increasingly controlled by the engine manufacturers. The introduction of new generation engines to the marketplace raises the question of what the capabilities for third-party repair and overhaul will look like for airlines and independent shops.

Acquiring maintenance capability for new generation engines

Engine manufacturers strive to improve and maximise the operating efficiencies of new generation engines. Prominent examples of new generation engines are: the Rolls-Royce (RR) Trent XWB; General Electric (GE) GEnx; CFM International LEAP family; and the Pratt & Whitney PW1000G series.

The primary focus on the new generation engine designs has been to: increase fuel burn efficiency; reduce the number of life limited parts (LLPs); reduce the number of stages and therefore airfoil components; and ultimately reduce maintenance costs.

Engine performance

Turbomachinery modules in a two-shaft or two-spool engine are the fan, low pressure compressor (LPC), high pressure compressor (HPC), combustion chamber, high pressure turbine (HPT), and low pressure turbine (LPT). A three-shaft engine, like the RR, also has an intermediate pressure compressor (IPC) and an intermediate pressure turbine (IPT).

Compressor blades and stators or vanes and combustion chambers are all monitored on an 'on-condition' basis. The on-wing interval at which an engine has to be removed for a performance restoration is largely influenced by the wear and tear these airfoils and combustion chambers experience during operation.

Predictions can be made for expected or planned removal intervals in terms of engine flight hours (EFH) or engine flight cycles (EFC), based on estimated erosion rate of exhaust gas temperature (EGT) margin, and predicted rate of deterioration of engine hardware.

Original equipment manufacturers (OEMs) establish an EGT limit for each engine type, taking into consideration materials and coatings used in the airfoils. Deterioration of airfoils results in a rise in EGT. Once the EGT limit is almost reached and most of the EGT margin is exhausted, a performance restoration visit is required.

Shop visit process

A performance restoration is often needed at the first planned shop visit that will be after a significant removal interval, but long before expiry of an engine's life limited parts (LLPs). Full engine disassembly is usually not needed.

Performance restorations work towards re-establishing EGT margin and building the engine to a standard that maximises possible subsequent time on-wing.

A performance restoration will involve the refurbishment of airfoils and hardware the high pressure (HP) modules, including the combustion chambers. Each module is disassembled into sub-assemblies and piece parts. The airfoils are individually cleaned, and then either repaired or replaced in accordance

For the maintenance of new generation engine types, manufacturers are forming networks. This provides a select number of shops with licences to perform maintenance for a specific engine type, thus controlling the number of shops that have capability for the engine.

General Electric has developed a concept of a quick turn shop visit for the GE90 and the GEnx. This allows only modules with problems to be worked on, and so avoids the need for a full engine disassembly and shop visit. This is useful in avoiding expensive maintenance visits when dealing with the engine's initial reliability and in-service problems.

with limitations set out in the engine maintenance manual (EMM).

Airfoils in HP modules and the combustion chamber are the most expensive parts in the engine. Repair of parts is therefore preferred to replacement, so a hi-tech repair capability is needed at some location.

A second planned removal interval is often 15-20% shorter than the first. A second major shop visit workscope would be complete disassembly of all HP and low pressure (LP) modules, and possibly include the fan. It would involve the repair of a larger number of airfoils.

A third main reason for a shop visit will or would be to replace LLPs that are close to fully utilising their life limits.

The workscope planning guide (WPG), published by the OEM, provides limits that determine whether a module has to be disassembled, and if parts can be repaired rather than replaced. The WPG is, therefore, used to determine what shop visit workscope is required. It also includes recommended service bulletins (SBs).

In addition, OEMs have defined a minimum level workscope. Such a workscope would only include external inspections, minor repairs, and a small number of external repairs to turbomachinery, such as a top case repair to HPC blades in some engine types. This is made possible by removal of the HPC case. Disassembly of the engine or modules, and a full shop visit, is not deemed necessary.

A new engine type often experiences a relatively high number of reliability issues and defects in its first years of operation.

The first engines in service, therefore, suffer early removals and shop visits until these reliability problems are overcome through modifications and SBs. Later-build engines have improvements incorporated on the production line.

Acquiring MRO capability

What an engine maintenance provider has traditionally needed to provide full maintenance capability and support for an engine type has to be examined.

Besides the premises and labour force to perform engine maintenance, there are three main requirements: access to an OEM's intellectual property and licences; the ability to provide hi-tech and specialist component repairs for the engine type; and obtaining the relevant approvals and certifications.

Acquiring the necessary capabilities includes gaining access to an OEM's 'approved data', which is recognised by the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) as an appropriate source from which to carry out approved designs for repairs.

This approved data is referred to as intellectual property. This includes information in the EMM, component maintenance manual (CMM) and illustrated parts catalogue (IPC) for an engine type, software used in the shop visit process, and the OEM's parts repair techniques. Engine shops have previously experienced few limitations in accessing this OEM data.

Hi-tech parts repairs

The IPC and EMM describe the standard of hi-tech repairs developed by the OEM. The engine shop could thus use OEM hi-tech repair techniques for all airfoils if it had all the relevant tooling and trained workforce, as well as the necessary approvals and certifications.

Hi-tech repairs can prevent the replacement of a large number of airfoils at each shop visit, thereby saving operators tens or hundreds of thousands of dollars. Examples of repair techniques used on engine modules and components can include blazing, welding, blasting, hot forming, and laser drilling of cooling holes in blades and vanes.

Hi-tech repairs exist for the components of all major engine types. Over the long-term, they have become available for each major engine type from an increasing number of suppliers.

In addition to OEM-certified repairs, there are designated engineering representative (DER) repairs, which are those developed by an engine shop or a specialist parts repair facility completely independent of the OEM. It would be desirable to have these DER repairs approved by the regulatory authority of the country in which the engine is manufactured. If the engine is manufactured outside the US, it is also a requirement to have the DER repairs approved by the FAA. EASA has a similar approval process.

OEM repairs can often be expensive for the shop to use each time, because royalties are paid to the OEM in exchange for proprietary material access and repair information, and are included in the price of the repair. DER repairs have to be actively marketed by the repair provider. The FAA has defended the airworthiness of DER repairs, and has further expanded its approval processes to cover hi-tech, critical parts of the engine, which include HPT blades.

"One of the advantages of DER repairs for the operator is greater repair

yield," John McKirdy, vice president of commercial aerospace global accounts at Chromalloy, explains. "Our DER repairs are fully approved by the FAA, and instead of scrapping and buying new components, operators can elect to repair, which provides an advantage to operating metrics and, in many cases, extends the useful life of the asset. Additionally it has been proven that there is no operational loss in EGT margin or Thrust-Specific Fuel Consumption (TSFC)."

DER repairs can sometimes mean that a part can be repaired more times compared to when an OEM repair is used. Using DER repairs can also result in lower maintenance and overall operating costs.

Chromalloy provides both OEM and DER hi-tech repairs on blades, vanes, shrouds, cases and other components used in many current engine types.

An engine shop, therefore, has several choices for component repairs. It can:

- Use the OEM's repair in its own shops. These are expensive, due to royalties charged by the OEMs and required licensing agreements.
- Invest money on developing its own DER repairs.
- Outsource the repair to the OEM. This, however, increases turnaround time (TAT) and also increases costs.
- Outsource the repair to a third-party specialist. This could use either OEM or its own DER hi-tech repairs. Use of a third-party specialist increases TAT, but means the engine shop avoids the cost of developing its own repairs. OEM repairs would still be more expensive.

MTU Maintenance is headquartered in Hannover, Germany and it supplies maintenance for various current GE, IAE, and Pratt & Whitney (PW) products. For MTU Maintenance and other providers, repair capabilities remain a priority. "The main issue related to DERs is not quality, but market acceptance," says Uwe Zachau, director of industrial engineering at MTU Maintenance. "While demand and acceptance from operators and even leasing companies is growing, there are increasing barriers. Acceptance of DER repairs is not widespread among valuers and financiers, who fear that the engine residual values are being affected by the use of non-OEM parts and repairs. This resistance is being fuelled by the OEMs.

"OEMs have introduced protective marketing concepts over the past few years, and these claim that engines maintained according to OEM standards achieve higher residual values," continues Zachau. "While this is not proven, it undermines competition from non-OEM providers, since it diminishes the demand for alternative repair solutions."

"For current generation engines, MTU Maintenance carries out OEM repair processes in accordance with engine manual standards, and also special repairs, using proprietary high-tech repair methods developed and collectively marketed as MTUPlus repairs," explains Zachau. "These are repairs designed by MTU Maintenance, and approved by both the OEM and aviation authorities. As an EASA Part 21 design organisation, we can certify major repairs for non-rotating parts under design organisation approval (DOA). Repairs for rotating parts are further certified by the EASA itself. Developing such repairs takes time and significant investment, and follows a strict regulation process under EASA rules. In 2010, the FAA released an advising circular that makes repair development under FAA rules as stringent as under the EASA process."

Miguel Martins, general manager of engine sales at TAP Maintenance & Engineering, explains that "the main requirement of the authorisations and certifications for providers to perform hi-tech repairs is similar to obtaining maintenance approval. Since it becomes a 'niche' of knowledge in the new repair and part design, however, it may be increasingly difficult to get OEM approval, or the associated OEM repair documentation."

Licences & approvals

The final issue an engine shop has to resolve is licences, approvals and certifications. An engine shop traditionally paid a one-off fee to the OEM to gain a licence to offer maintenance services for the engine type. This is a one-off payment that allows the engine shop to gain the access to the OEM's intellectual property and its support throughout the engine shop's development as a provider for its product. OEMs have supported this development by, for example, supplying technical support, and assisting in calibrating the engine shop's test cell. Essentially, engine maintenance providers could pay to gain full capability on current and older generation engines.

The shop would also pay an additional fee to the OEM to become a licenced OEM-authorised shop. This would provide the engine shop with a marketing advantage. It is legally possible, however, to be a non-authorised service provider for an engine.

Nowadays, it is also beneficial for an engine shop to have an approval to carry out hi-tech repairs from the regulatory authority of the country of engine manufacture. In addition, the engine shop needs approval from its local authority. It would also be advantageous for the engine shop to have approval from the regulatory authorities of each country in which it is marketing its services.

New engine capability

The level of certification an engine shop required or requires for new generation engines to provide maintenance is similar to current and older generation engines.

"Engine shops still need OEM licences to perform maintenance for new generation engines and their specific parts. They also need approvals from the respective airworthiness authorities," explains Zachau. "A growing share of maintenance contracts are being closed

A key element for an engine maintenance provider to have capability for a particular engine type is for it to be provided with a licence from the engine manufacturer. This gives the engine shop access to the manufacturer's intellectual property, which includes technical manuals. These are required for the shop to develop OEM-approved parts repairs.

directly at the point of sale, together with the engine acquisition.

"It therefore becomes harder for third-party MRO providers to gain access to engine work in such a way that they are viable as truly independent maintenance providers," continues Zachau. "We consequently expect some consolidation among engine shops."

It is the ability to acquire a licence from the OEM that has become problematic. As new generation engines enter commercial operation, engine shops are seeing changes that are preventing them from obtaining the information and licences to perform a full range of maintenance services on emerging engine types. OEMs are becoming reluctant to share proprietary material with maintenance providers.

Access to this manufacturer-designed and approved proprietary information, basically intellectual property, has become limited and more difficult for independent engine shops to acquire over the past decade. For example, the level of content and detail disclosed in the EMM has declined. Historically, the EMM or CMM may have outlined detailed instructions to ensure continued airworthiness of a part, including information relating to standard OEM repairs. These instructions may now be limited to a list of approved facilities the operator, or some engine shops, can send the part to for repair in the case of new generation engines.

"Given that we already have engine shop capability, the required incremental step is mainly related to the technological update for new materials and new repairs," explains Martins. "It is not yet clear whether OEMs will maintain the specific capability for themselves or award licences to third-party providers."

Moreover, the price to obtain licenses from the OEMs to perform maintenance has also increased significantly.

OEMs have established limits that prevent independent shops from becoming fully self-sufficient maintenance providers. OEMs have limited the number of shops to which they issue licences that allow them to perform maintenance on new generation engines.

The licencing agreements are now separated into:

- Issuing licences and approvals for an airline to provide maintenance on just its own engine fleet.
- Giving an airline shop a licence to maintain its own engines and those of third-party customers. These licences were issued in relatively large numbers for older and current generation engines.

Providing a particular type of licence to an airline is often agreed at the time the airline places an engine order. This hints at the leverage an airline is able to use in discussions with the OEM. The cost of licencing can now be up to $10 million to gain full approval from an OEM, in addition to investments in tooling, training and intellectual property. It may now cost up to $35,000 to acquire just the IPC and thereafter annually its related revision and update service from the OEM, for example. Revisions and updates to the manuals, now also have to be paid for, as well as engineering queries and technical support for non-standard topics arising during a shop visit.

A possible explanation for OEMs imposing greater limits on the number of engine shop licences they issue could be the reduced number of predicted shop visits in the overall engine MRO market.

New parts repairs

As engine and component designs evolve, it follows that new parts will require specialised repair techniques.

"There are several hundred repairs being developed for the LEAP engine, including for the carbon fibre composite fan and the blisks, and many of these will be in place by entry into service," explains Gareth Richards, LEAP programme director at CFM International. "The design of the HPT blades are also different. These airfoils have special thermal barrier coatings and advanced cooling technology to allow the engine to operate at higher air temperature for thermal efficiency without sacrificing engine durability. This technology requires special tooling and equipment for manufacturing, as well as repairs."

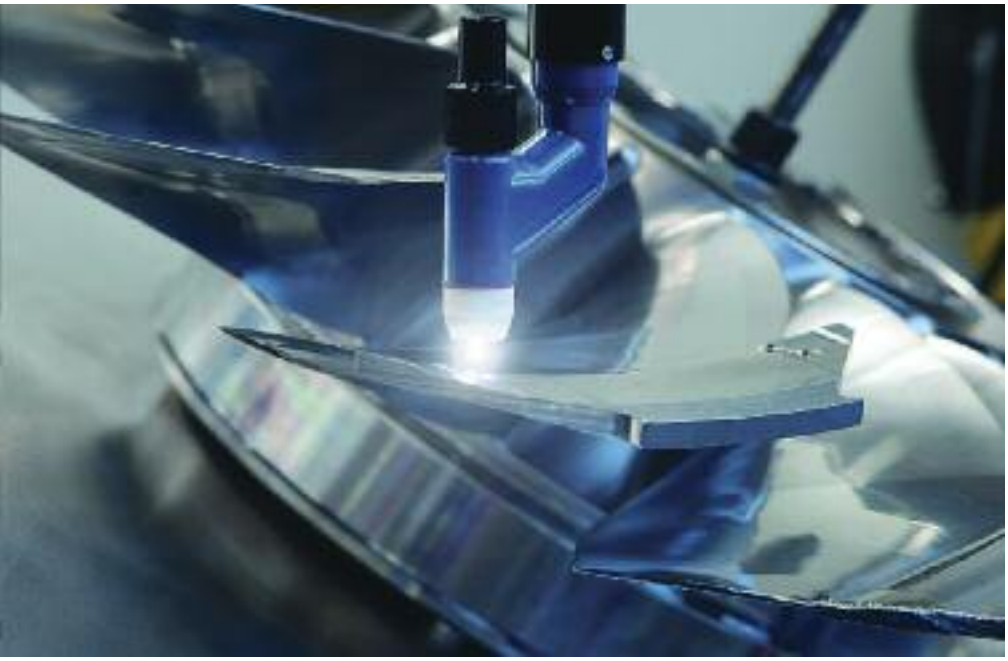
This means that maintenance providers will require access to new material information to develop repair techniques on the new generation engine parts, and this will have to be provided by the OEMs.

For new generation engines, MTU Maintenance will continue to work closely with the OEMs, with no current plans to progress into DER repairs.

In the long-term, airline and independent engine shops may wish or seek to develop DER repairs for new generation engines. Development of DER repairs is essentially a reverse engineering process, and will require local authority, FAA and EASA approval. DER repair development would also requires access to the OEM's licences, technical manuals and intellectual property. These are likely to be held by an airline operating the engine, but will have to be paid for.

There can be obstacles, however, to using DER repairs and gaining access to all the OEM's technical manuals. OEMs can elect which maintenance providers they provide intellectual property access and licences to.

OEMs have also made it difficult for shops and airlines to use DER repairs. This is by refusing to certify the integrity of original components and parts in the



It has become increasingly difficult for independent shops to use DER repairs for engine parts and components. While they remain legal, OEMs have reduced market acceptance of them to the point where it becomes unfeasible to use them in many situations.

engine, such as LLPs, if they are associated or related with a component or assembly that has received a DER repair. This therefore makes many airlines, lessors and engine traders cautious about using DER repairs.

The OEMs can therefore make it difficult or impossible for a shop to independently develop capability for an engine type.

Quick turn visit

GE has developed the concept of a 'quick turn' shop visit. This is a concept originally introduced on the GE90, and now used on the GEnx. KLM Engineering & Maintenance's engine shop at Amsterdam Schiphol has recently performed this quick shop visit technique for the first time on a GEnx-1B engine.

The GE90 and GEnx have been designed so that engine shop visits only need to be performed on a modular level. Rather than involving the complete disassembly of an engine, which is time-consuming, expensive and unnecessary in many cases, an engine shop is able to use a quick turn visit to work on just a specific module when a defect is raised by the engine health monitoring system (EHMS), or deal with a specific reliability issue that is encountered during the early years of operation.

The quick turn concept is changing the philosophy of the traditional engine shop visit, which would have been needed on an older engine type when initial reliability and technical problems were encountered in the first few years of operation. A traditional shop visit would have involved the complete disassembly of the engine. All modules may have had to be disassembled and parts inspected and repaired, depending on the problem or issue that triggered the removal.

"The quick turn visit is a new approach used to fix operational problems while the engine is in operation," explains Yolanda de Jong, GEnx project manager at KLM Engineering & Maintenance. "The engine's modular concept allows maintenance to be performed only on the modules that have been affected by a reliability or technical issue. The workscope is, therefore, not fixed, and is instead tailored for each event. It is more like a 'pit stop' concept, where you disassemble and reassemble in one area or module, rather than distribute all modules to each respective area of the engine shop."

So far the GEnx has had initial problems on the fan shaft, combustor outerliner and combuster mixers, which have been overcome. This has been through its quick turn shop visit concept.

While this modular concept is relatively new to engine maintenance, it requires little more than appropriate training, tooling and access to special OEM repairs in many cases.

OEM networks

As OEMs exercise an increasing level of control in the aftermarket of their engines, and limit further the access to material relating to their engines, the focus of independent maintenance providers is now on becoming part of an OEM 'network'. This entails working with and for the OEM throughout the development of a product, from design through to mainstream commercial use.

"An OEM network is a group of MROs that are used by an OEM to perform maintenance services on particular engine type," explains Martins. "Typically in these arrangements the MROs cannot market this capability by themselves, and the workload is assigned to them directly by the OEM. In some case, the OEM controls the market and therefore the engine shops do not market the services directly. All the marketing is performed under the OEM umbrella."

If an OEM is successful in developing an engine, the project has an obvious beneficial effect for the suppliers of parts, modules and assemblies. While it can take up to five years to develop an engine, it could be in service for 30 years or longer. Repair and overhaul capability is clearly required to maintain the engine while it is in operation. Given the potential benefits for these manufacturing organisations, it follows that by sharing some of the investment one could also qualify for the rewards of being a member of an OEM network. Risk-sharing, therefore, involves OEMs developing relationships with partners throughout the design and manufacture of an engine.

MTU Aero Engines is a risk- and revenue-sharing partner (RRSP) with PW for PW1000G development, among other programmes. In addition, MTU Maintenance is a specialist in OEM and DER repairs on HPT blades, vanes and other hi-tech repairs through all engine modules on older engine types. It may be assumed that MTU Maintenance's expertise would carry over to the emerging engine services for new generation engine types.

"We are an RRSP on several major new engine programmes, including PW for the PW1000G, IAE for the V2500 and GE for the GEnx," explains Zachau."As an engine sub-system manufacturer, we partner with OEMs to develop and manufacture complete aircraft engines.

"As such, we have access to overhaul licences and workloads that we plan to receive as an OEM network partner," continues Zachau. "We will continue to act as an independent MRO provider for most engines in our current portfolio and are offering a number of services in addition to traditional engine maintenance. These include engine leasing, on-wing and LRU support, engine condition monitoring, as well as asset and material management. As a partner of the OEM, however, we are not developing DER capabilities for new generation engines. It is still too early to define which OEM repairs we will be using. We will not be advertising our

services independently of the OEM, since OEM repairs will be distributed among partners in the network for the PW1000G. Part and component repairs will not be due until the first heavy shop visit, which is not due before 2020 for new generation engines such as the PW1000G and the LEAP," says Zachau.

MTU Maintenance will be part of the OEM network for the PW1000G, the GEnx and the GE90. "For the GEnx, MTU Aero Engines (the parent company) holds the system design responsibility for the turbine centre frame (TCF), and we will act as the OEM's TCF repair facility. The maintenance capability for the GEnx TCF is already in development, and we plan to be ready by spring 2016 at our Hannover facility," explains Zachau.

"We are also introducing PW1100G capabilities to support the A320neo entry into service. We plan to be ready for the first potential shop events by the first quarter of 2016," continues Zachau.

"Capabilities for additional engine types, such as the LEAP, are another possibility, especially for MTU Maintenance Zhuhai, which is a joint venture between MTU Maintenance and China Southern Air Holding. China Southern is the Asia Pacific's largest airline and a large operator of both A320s and 737s. It is, therefore, likely that somewhere in the future it will operate new generation aircraft and engines, such as the LEAP," adds Zachau.

As outlined by the concept of the OEM network, methods used by MRO facilities to acquire the capability often involve aligning or sharing interests with the engine manufacturer before or during engine manufacture and development.

GE Branded Services Agreement

Relationships between MRO providers and OEMs may take various forms. The GE branded services agreement (GBSA) is an example. The GBSA allows an engine shop to offer GE material and workscoping for shop visit work on a GE engine.

The GBSA is an example of the type of endorsement an engine shop requires from GE to be licensed to perform the in-depth, hi-tech parts repair and overhaul work on certain GE engines. The network of overhaul facilities for the GEnx engine is increasing as engine deliveries continue.

"OEMs only allow certain providers to do third-party maintenance, which means that only some shops will have access to GE's proprietary material for parts repairs," continues de Jong. "Every airline operating the GEnx can get a licence from GE to have a maintenance shop for just its own engines, if it feels it can justify the investment." Six shops in the GBSA will be able to perform overhaul and OEM parts repairs on the GEnx in their own facilities.

The network, or GBSA, is anchored by GE Aviation's engine shops in Caledonian in Scotland and at Petropolis in Brazil.

Other shops will provide additional facilities under the GBSA for the GEnx. These include a new joint venture with Evergreen Aviation Technologies (EGAT) in Taiwan, called GE Evergreen Engine Services. It recently completed its first quick turn visit of a GEnx engine, with full overhaul capability to follow in 2019.

Abu Dhabi Aircraft Technologies (ADAT) has received FAA and UAE General Civil Aviation Authority approval for quick turn operations. It will ultimately be an overhaul facility for both the GEnx-1B and -2B.

Air India is a member of the GBSA for GEnx-1Bs.

GE has also has an agreement with Air France Industries KLM Engineering and Maintenance (AFI KLM E&M).

Air France Industries and KLM Engineering & Maintenance (AFI KLM

E&M) have formed a joint venture where they share activity on the industrialisation and maintenance activity for the GEnx-1B. This will use Air France Industries' test cell facility at Charles de Gaulle Airport, and KLM Engineering and Maintenance's engine cell in Amsterdam Schiphol Airport. Working with GE, the joint venture is co-operating and progressing in parallel with the engine's production.

"We have a clear vision of our industrial strategy from the start," explains Jean Pierre Fleury, industrial development manager at Air France Industries. "The agreement outlines an industrialisation process for us to secure the maintenance scheme, specifying the provision of the test cell and engine shop facilities, the negotiation of the transfer of expertise and knowledge, including OEM material access, and the acquisition of tooling."

So in addition to being one of the six members of the GBSA for the GEnx-1B, AFI KLM E&M is also allowed to independently market its capabilities for the engine directly to third-party customers as a Part 145 facility. This will be a significant part of its maintenance activity and puts AFI KLM E&M in a unique position compared to other members of the GEnx GBSA.

"Tooling forms a large part of the investment," continues Fleury. "It was key to secure the cost of toolings from the start." Overall, it is estimated that the investment required is about EUR100 million to acquire full MRO capability on a new generation engine.

"There are few independent engine shops or airlines able to perform full MRO capabilities for third-party customers. This is due to the nature of hi-tech repairs and the high level of investment required. One needs established knowledge on repair processes, alongside the bargaining power of a large fleet as leverage to acquire extensive capabilities," says Fleury. "The current policy of AFI KLM E&M is to use mainly OEM repairs for new generation engines. We will also co-develop repairs with the OEMs, using our centres of excellence. This includes CRMA."

AFI KLM E&M's joint venture gives an insight into an outside provider's access to OEM intellectual property. Both have previous experience and a prior relationship with GE, having carried out full MRO services on GE90 engines.

AFI KLM E&M is keen to promote OEM-licensed repairs for the compressor and HPT blades underway for the GEnx.

Alongside the GEnx-1B, AFI KLM E&M's target is to develop industrial capabilities in-house to support the RR Trent XWB; a relationship similar to GE with Air France's future operation of the Airbus A350.

Initial addition to GE's GBSA for the GEnx (and GE90), PW has formed an initial similar type of network for the PW1000G. The first PW1000G shop visits will be performed by PW's own engine shop network, and RRSPs MTU and JAEC. PW's global engine shop network includes five overhaul centres and 15 part repair facilities.

As the volume of PW1000G shop visits increases, PW will expand the OEM network to include airline shops and independent engine shops.

Summary

As new generation engines develop and perform consistently in operation, with optimum time on-wing and shop visit patterns, time-and-material contracts (TM) may, however, become more attractive to operators. As the name suggests, TM agreements typically involve operators being charged on a visit-by-visit basis for the actual labour and materials used. This type of contract allows operators to customise workscopes, provides detailed cost transparencies, and encourages a market where DER hi-tech repairs are active. If the ability for independent shops to develop DER repairs becomes limited or even impossible, then TM contracts may follow suit, because the market for serviceable used parts will decline without a competitive market for repairs.

It seems the emphasis on providing maintenance and technical support is now on partnership strategies rather than fully independent maintenance rights on an engine. This is illustrated by the introduction of agreements, such as the GBSA for the GEnx, and another for the GE90. There is also increasing consolidation in the manufacturing of airfoils. Joint ventures are formed between OEMs and other parties as part of long-term global support capability. Some OEM network participants carry out maintenance for the OEM in an 'off-load' capability, and, therefore, cannot be deemed to be completely autonomous.

AFI KLM E&M's joint venture is licenced to market capabilities on the GEnx independently of GE. This is perhaps due to the fleet capabilities and volume of engines ordered. Other parties are not allowed direct contractual agreements with third-party customers.

Another factor to be taken into consideration is the eventual volume of work available in the aftermarket. If new generation engines reach the fleet sizes seen in CFM56 fleets, for example, a contained MRO market controlled by the OEM may not eventually be able to support all the subsequent number of shop visit events. Therefore, further truly independent third-party providers may emerge as the engines progress in commercial operation. For independent engine shops that are not aligned with OEMs in the production of a new generation engine and, therefore, not RRSPs, however, acquiring the tooling, manuals access and licensing repair capabilities to perform full maintenance will be so expensive that it can only be justified by a large volume of shop visits in the future. AC