There are more than 1,100 A320neo family aircraft in service equipped with CFM LEAP-1A engines. The engine's design is focussed on attaining high fuel efficiency. It has consequently experienced reliability problems in its early years of service. These are being addressed.

LEAP-1A in-service performance update

The CFM LEAP-1A engine is a high-bypass ratio conventional turbofan that gives the A320 new engine option (neo) family with a 15% reduction in fuel burn over its the current engine option (ceo) predecessors powering the first A320 family: the CFM56-5B and V2500-A5. The LEAP-1A had to achieve this, while also reaching similar maintenance costs to the -5B and V2500-A5.

The LEAP-1A has now been in active service for about seven years, with the first A320neos being delivered in mid-2017. Typical levels of engine utilisation are 2,800-3,000 engine flight hours (EFH) and 1,900-2,000 engine flight cycles (EFC) per year. Taking into account the drop in aircraft operations from 2020 up to late 2022, the oldest and most utilised LEAP-1A engines have had the opportunity to accumulate a total time of more than 15,000EFH and 10,000EFC.

A review of how the engine is performing in service with some lead operators is shown here. This includes actual fuel burn performance compared to the A320ceo, the LEAP-1A's exhaust gas temperature (EGT) margin and its rate of erosion, what removal intervals have been experienced and are expected, what factors are driving removals for shop visit (SV) maintenance, and what reliability and technical problems the engine has faced since it entered service.

LEAP-1A concept

The A320ceo's CFM56-5B engine was derived from the -5A1 series, the original engine that powered about 100 A320s built in the late 1980s. The -5B series required an extra low pressure compressor (LPC) stage to increase airflow through the core engine and generate adequate thrust for the engine to be rated at up to 33,000lbs of take-off thrust for the A321ceo. The core engine on the -5B was, however, larger than required. This was evidenced by the fact that, after various hardware improvements and upgrades, initial EGT margins of new engines installed on the A319ceo, the -5B5 rated at 22,000lbs thrust, were 145 degrees centigrade. The highest rated -5B3 rated at 33,000lbs thrust had initial EGT margins of 65-70 degrees centigrade.

The -5B series had an intake fan with a diameter of 68.3 inches. Coupled with the core engine and a high rate of airflow, this generates a bypass ratio ranging from 5.4:1 for the highest rated -5B3 and 6.0:1 for the lowest rated -5B8. The large size of core engine kept EGT relatively cool, and so EGT margin relatively high.

The -5B's core was also used by -7B series that powers the 737NG family. The -7B, however, was required to use a fan with a 61-inch diameter fan so as to avoid installation and ground contact problems when mounted under the 737NG's wing.

As a consequence, the -7B series has a bypass ratio ranging from 5.1:1 for the highest-rated -7B27 to 5.5:1 for the -7B18. As with the -5B series, the -7B's relatively large core provided it with a low EGT, and so made EGT margin high.

Moreover, the large core meant that EGT margin erosion rates were also relatively low for mature engines, so removal intervals were long in terms of EFH and EFC.

The main objective in the LEAP-1A's design is a 15% reduction in fuel burn compared to the CFM56-5B. This would provide airlines with the usual reduction in cash operating costs between successive aircraft generations.

CFM partly achieved this improvement in fuel burn performance through configuring the LEAP-1A with a 78-inch diameter intake fan, and a high bypass ratio of about 11.0:1; almost double that of the CFM56-5B series.

A second feature that contributes to the LEAP-1A's fuel efficiency is a high combustion temperature, and the use of a dual-stage high pressure turbine (HPT).

Bypass ratio

The LEAP-1A's targeted bypass ratio of 11.0:1 required the engine to be configured with an intake fan with a 9.7 inch wider diameter than the CFM56-5B. The LEAP-1A also uses a core engine with a smaller diameter than its predecessor, so that it would have a smaller volume of air passing through it relative to the bypassed air. These two factors would achieve the required bypass ratio.

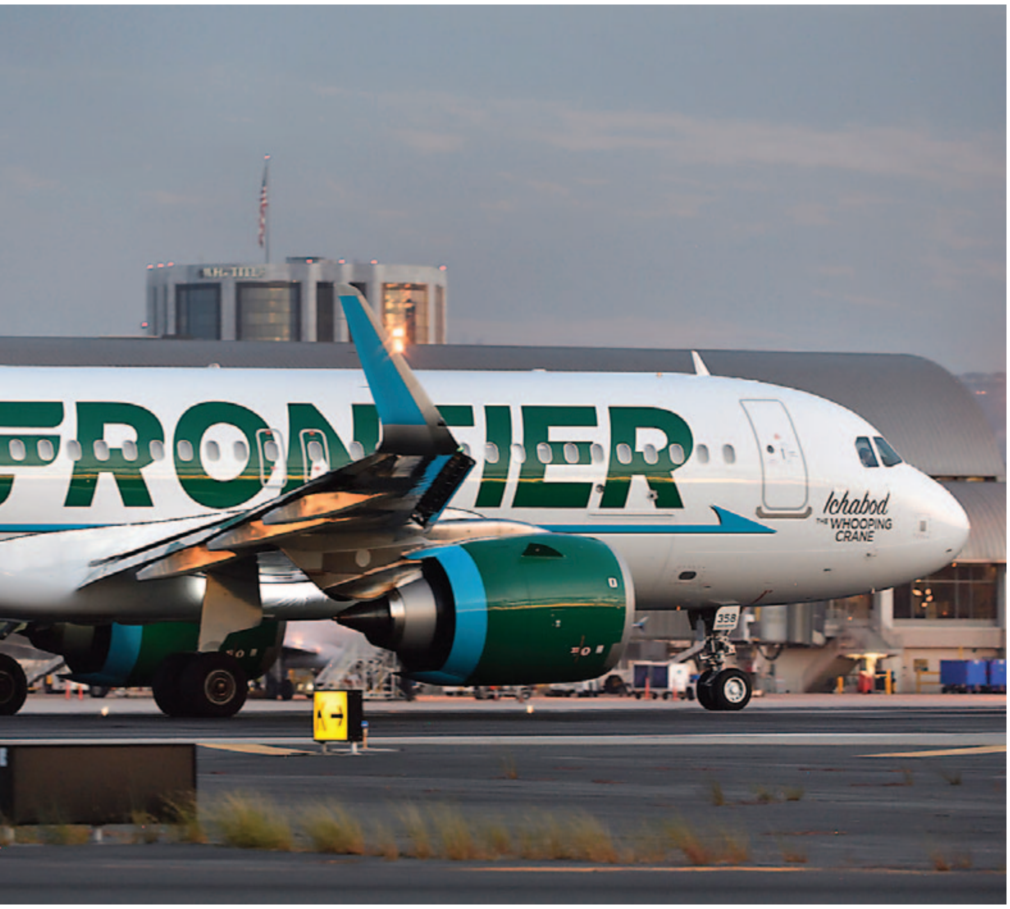
The -1A's core engine would therefore need to work harder than the -5B's core. The temperature of the air exiting the core would need to be higher to compensate for a reduced volume, and have sufficient power to turn a wider and heavier fan.

The wider fan diameter also means the -1A's core is restricted to a lower rate of revolutions per minute (RPM) than the -5B's. The -1A's LP module would require more stages in the low pressure turbine (LPT) to compensate for the lower RPM rate.

For the engine to achieve such a high bypass ratio, two main design features were required. The first was that the core engine was smaller in diameter than that of the CFM56-B. That is, a higher portion of the air was bypassed around the core engine and through the fan.

The second was that the engine had a high pressure ratio. That is, for the core to be as small as possible while being able to turn the fan, it has to generate more power from a relatively small volume of air. This is only possible if it achieves a pressure ratio higher than the -5B's. A high pressure ratio is achieved through improved aerodynamics of the stages in the HPC.

A large power requirement for the



The LEAP-1A's bypass ratio of 11.0:1 is helping the A320neo achieve fuel burn reductions of 15% or more compared the previous generation A320ceo equipped with the CFM56-5B series.

-1A's larger fan was partly offset by the use of widechord fan blades, thereby allowing 18 to be used; 18 fewer than the -5B's fan. The fan blades were manufactured using 3-D woven resin transfer moulding (RTM) carbon fibre composite material to save 500lbs of weight in the fan section.

Wide chord blades also eliminate the use of mid-span shrouds, reducing the fan's overall lower drag profile. The smaller number of blades and the material used save weight and reduce drag, thereby reducing the power required from the LPT.

These configuration features of the -1A's fan mean its additional power or energy requirement are not proportionate to its increase in size of the -5B's fan.

Core engine

As described, the -1A's core engine needs to be smaller than the -5B for the LEAP to achieve its high bypass ratio. The LEAP-1A's core generates a pressure ratio of 22:1, while the overall engine has a pressure ratio of 40:1. In contrast, the CFM56-5B has a core pressure ratio of 11:1, half that of the LEAP-1A's core, and an overall pressure ratio of 24.4-33.7:1 for the engine.

Another factor in the -1A's high fuel efficiency is the use of a two-stage HPT. Two stages extract more energy from the hot and compressed air, which is used to drive the high pressure compressor (HPC). These two stages are required for the HPC to achieve its high compression ratio.

The HPC's high pressure ratio therefore drives the LPT, which extracts the energy necessary to turn the intake fan. The LPT has seven stages compared to the -5B's four. The -1A requires additional stages because of its lower RPM rates.

The LEAP-1A has seven main variants rated at 24,010-32,160lbs of take-off thrust, and 23,510-31,690lbs of maximum continuous thrust.

While the LEAP-1A's configuration and architecture are intended to achieve the high bypass ratio and therefore 15% lower fuel burn than the -5B, the engine's design also has to take into account its maintenance costs. These will mainly be determined by the engine's EGT margin, margin erosion rates, and subsequent removal intervals; the number of airfoils, their rate of deterioration, and their list prices; the number, life and price of life-limited parts (LLPs); and the engine's overall reliability.

The LEAP-1A's high combustion temperature causes high deterioration rates of HPT hardware, especially the nozzle guide vanes (NGVs) and HPT blades. To offset this, CFM has configured the HPT with ceramic coatings for the HPT blades and the blade shrouds, which are the inner wall of the HPT facing the tips of the HPT blades. The use of ceramics maintains a tight clearance between the blade tips and the shrouds.

Another factor causing high internal temperatures is the HPC's high pressure ratio, and so high HPC exit temperature. This can increase the deterioration rate of HPC hardware.

Life limited parts

The CFM LEAP-1A's four main modules have a total of 23 LLPs: three in the fan/LPC, seven in the HPC, five in the HPT, and eight in the LPT.

CFM has target life limits specified in the number of EFC for LLPs on these four modules. The life limits of some parts vary with thrust rating. That is, the life limits of higher-rated variants are shorter than those of the lower-rated variants.

The initial life limits of each of the 23 parts were originally shorter than the target life. In some cases there are several part numbers (P/Ns) for each of the 23 parts. Each P/N can have its certified life limits periodically extended while installed in engines.

The life extension will allow the part to remain in the engine if the number of accumulated EFCs is fewer than the certified life limit. If the life extension has not yet been certified, the engine will have to be removed, and the relevant module disassembled for part replacement. This will then require a detailed inspection of all components, and could lead to findings and a larger workscope being required.

The three parts in the fan/LPC are the fan disk, the fan shaft and the LPC spool. All three parts have a target life of 30,000EFC for all seven thrust ratings.

Despite these target lives, the fan disc has a lower life limit. This has been 26,000EFC. The 2022 price for these three parts was about $0.85 million. On the basis of an annual increase of 6.9%, the 2023 list price for the three parts would be $0.91 million. There are, however, warnings that the rate of increase in 2023 will be higher.

The eight parts in the LPT are the five disks for the first five stages, the stage 6-7 spool, the LPT torque cone, and the LPT shaft. All eight parts have target lives of 30,000EFC, and current life limits shorter than these targets; in some cases as short as 5,200EFC. Many have lives of 11,000-18,000EFC. The lives of each part are generally uniform for all six thrust ratings.

The 2022 list price for these parts was $1.93 million. If the annual 6.9% increase is applied, the 2023 price will be about $2.07 million.

The seven LLPs in the HPC module are

five blisks for the first five stages, the stage 6-10 spool, the impeller tube support, and a rotating seal at the rear end of the module.

All seven LLPs have target lives of 20,000EFC for the four lower-rated variants: the -1A23, -1A24, and -1A26; rated at 24,010-27,120lbs. The same parts have target lives of 17,500EFC for the four higher-rated variants: the -1A30, -1A32, -1A33 and -1A35.

The seven parts have current life limits that are limited to 15,000EFC, and 10,200EFC in some cases. Their 2022 list price was about $1.52 million, and will increase to $1.62 million for 2023 if the 6.9% annual increase is applied.

The five parts in the HPT module are a forward and a rear rotating seal, the stage and stage 2 rotor disks, and a mid-module rotating seal.

As with the HPC, the target life limit for the lower rated variants is 20,000EFC, and the four higher-rated variants have target life limits of 17,500EFC.

The current life limits of these parts are 7,000-15,000EFC. The difference between the current and target life limits of the parts is largest in this module. Some parts need to have their life limits extended by as much as 13,000EFC.

The 2022 list price for these parts was about $1.28 million, and will rise to $1.37 million if increased by 6.9%.

Maintenance planning

The current life limits of LLPs in the HPT are limited to less than half the target lives. This will impact the removal intervals and related maintenance plan for the four main modules.

A maintenance plan proposed by CFM was for three SVs following planned removal intervals based on accumulated EFCs. The planned removal intervals are based on predicted deterioration of the engine hardware, particularly related to EGT margin erosion, and also on the LLPs reaching their target life limits.

Unless LLP life limits are extended in sufficient time, some parts with short certified lives will force early removals, and the requirement for an SV workscope. Most LEAP-1As in operation are accumulating about 2,000EFC per year. The oldest engines that entered service will have reached the first LLP life limits within four years of service entry.

CFM based the proposed removal and SV workscope on the first interval of an average of 16,000EFC, but up to 19,000EFC. This would have forced a removal and full disassembly and LLP replacement in the two HP modules. The two LP modules would not require any level of SV workscope.

A second interval of 9,000-13,000EFC would take the engine up to a total time of 27,000-29,000EFC, and so close to the LP module target lives of 30,000EFC. This would therefore force full workscopes on these two modules.

The HP modules would require performance restoration workscopes after a relatively short interval. This would restore some EGT margin.

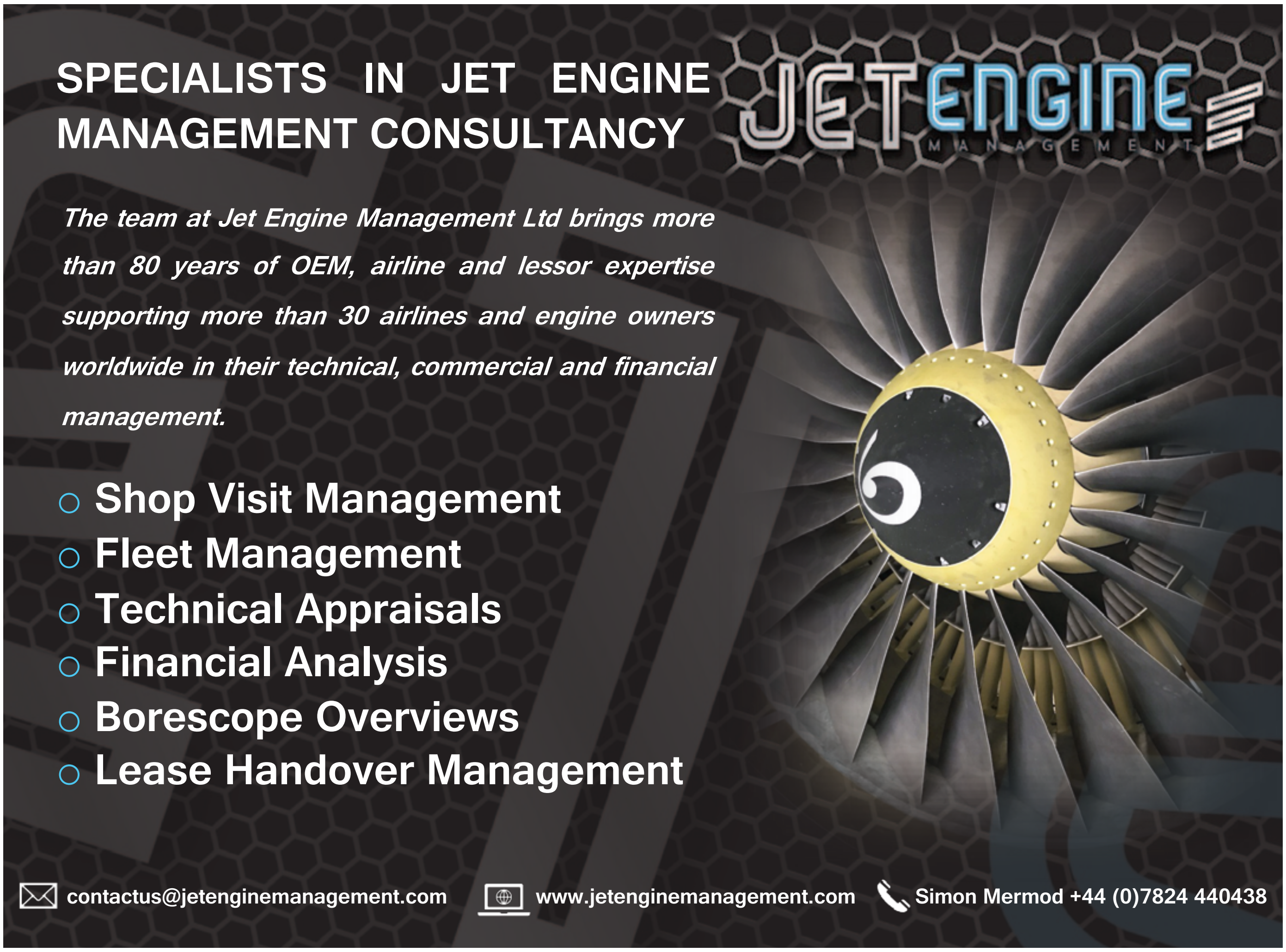
The third removal interval would therefore be limited to the LLP life limit in the HP modules of 20,000EFC minus the EFC interval achieved in the second interval, so this would be similar to the second interval. The resulting workscope would be full disassembly for LLP replacement plus performance restoration.

By this stage the engine would have accumulated 36,000EFC, equal to about 18 years of operation.

This raises several issues of whether the engine is capable of these planned removal intervals if the LLP lives are extended to the planned limits.

EGT margins & erosion

The key to removal intervals for most engines in service is the EGT margin, and the rate of EGT margin erosion. “CFM’s intention has been for the LEAP-1A to have the same EGT margins and a similar rate of EGT margin loss as the CFM56-5B,” says Francesco Baccarani, vice president engines at SGI Aviation. “If this



CFM has utilised several technologies to optimise the LEAP-1A for a very high bypass ratio and fuel efficiency. The use of wide-chord fan blades, that are manufactured with RTM, provide a low drag, light intake fan that contributes to the engine's low fuel burn performance.

is achieved, the LLP lives will allow the LEAP-1A to remain on-wing for intervals similar to the -5B, and so also follow the same type of removal, SV pattern, and LLP replacement schedule. The ultimate aim would be for the LEAP-1A to achieve similar maintenance costs per EFH or EFC as the CFM56-5B."

The CFM56-5B has of course been able to achieve long removal intervals, but this has been as a mature engine. The initial EGT margins of the later-built engines were about 66 degrees centigrade for the highest-rated -5B3 at 32,000lbs, and as high as 145 degrees for the lowest-rated -5B9 at 23,300lbs.

The -5B's EGT margin erosion rates were about 17 degrees for the first 2,000EFC on-wing, and then stabilised at 3.0 degrees per 1,000EFC. The lower- and medium-rated -5B variants can therefore remain on-wing for at least 20,000EFC, and so reach life limits for the LLPs in the HP modules *(see CFM56-5B maintenance management & SV inputs, Aircraft Commerce, issue 128 February/March page 34)*.

The highest-rated engines could remain on-wing for up to 10,000EFC, before requiring an SV involving a performance restoration to restore enough EGT margin. That is, sufficient for the engine to remain on-wing up to the core or HP module LLP limits of 20,000EFC.

These high EGT margins and stable EGT margin erosion rates were only achieved, however, after the incorporation of two major upgrade programmes. The first of these was the /P programme, released in 1996. This included the replacement of 2D airfoils with 3D blades and vanes in the HPC and HPT. The result was an increase in EGT margin of about 10 degrees centigrade.

The second was the Tech Insertion programme, launched in 2004. It included a further change to many of the engine's airfoils that improved aerodynamic efficiency. This further improved EGT margin, and so increased removal intervals.

In the initial period of operation, the CFM56-5B variants were achieving first removal intervals of 10,000EFH, or about 6,500EFC. These have clearly been steadily increased as the engine's performance and reliability have improved.

It is expected that the LEAP-1A will require several years of operation and possible performance and reliability upgrades before their removal intervals come close to the CFM56-5B.

The initial EGT margins of early-build LEAP-1A engines are 43-53 degrees centigrade for the -1A33 variant rated at 32,160lbs take-off thrust, 54-64 degrees for the -1A32 rated at 32,160lbs take-off thrust, 73-83 degrees centigrade for the -1A26 rated at 27,120lbs take-off thrust, and 85-95 degrees centigrade for the -1A24 rated at 23,500lbs take-off thrust.

If the rate of EGT margin erosion achieved by the LEAP-1A variants in service is similar to that of the CFM56-5B then the highest rated -1A33 should achieve an interval of 12,000-14,000EFC. This of course depends on all LLP lives reaching their certification targets of at least 14,000EFC.

The lowest-rated -1A24 and medium-rated -1A26 should both be capable of achieving an interval of at least 20,000EFC.

If this is achieved by the -1A variants then they should all be able to follow the same pattern of removals and SV workscope patterns as the CFM56-5B.

LEAP-1A in service

After the first few years in service, the LEAP-1A was experiencing initial EGT margin losses of 15 degrees centigrade for the first 1,000EFC on-wing. This was a combination of about 10 degrees in the first 500EFC, and then another five in the second 500EFC. Some initial rates of EGT margin loss were, however, as high as 18 degrees in the first 1,000EFC.

EGT margin loss rates then settled at about five degrees centigrade per 1,000EFC thereafter. On this basis, the -1A33 would be capable of an interval of 6,000-7,000EFC. This would be longer at 9,000-11,000EFC for the -1A32.

The medium-rated -1A26 should have been capable of a first run of 12,000-15,000EFC, and the -1A24 15,000-17,000EFC.

The LEAP-1A and the -1B experienced a technical problem relatively early on in their first years of operational service. The ceramic coating on the HPT blade and the ceramic material of the HPT blade shroud, which maintained a tight clearance between the HPT blade tip and shroud and therefore maintained the engine's EGT margin and a low rate of EGT margin loss, started to deteriorate and break away.

This loss of the ceramic material was relatively early, occurring in engines after being in service for just 300-2,800EFC.

"This loss of ceramic material after a relatively short operating life resulted in a sudden and large loss in EGT margin of about 30 degrees centigrade or more," says Baccarani. "Given mature rates of EGT margin loss, this is equal to a complete loss of margin in a removal interval of about 6,000EFC. This problem forced an SV for engines after just two to three years of operation."

One factor in the ceramic material in the HPT shroud was that it was relatively thick. The technical fix for this was a thinner ceramic coating, which resulted in a lower rate of degradation and an extended time on-wing.

"CFM dealt with the problem by releasing an improved shroud with a thinner layer of ceramic, issued as new P/Ns and via series of five service bulletins (SBs) and a service letter," continues Baccarani. "Each SB involved the issue of a new part number (P/N) for the HPT shroud. The latest P/Ns are installed in production engines. The third, fourth and fifth SBs involved a thin coating."

Each SB released provided a gradual improvement. These have been applied to the fleet in stages, and so only less than 1% of the current fleet has the latest P/N installed. More than 88% of the fleet have thin layer HPT shrouds, while only 1% of the fleet have the original P/N.

The latest P/N can be retrofitted in existing engines. It will require a few more years of operational service to see if this has worked."

While the ceramic coating and shroud were a main issue affecting the LEAP-1A and -1B family, there have been several other technical issues affecting its in-service performance. "One of the first issues has been the deterioration of HPT blades in the harsh environments in which the LEAP-1A operates," explains Baccarani. "These are hot or polluted regions such as the Middle East, India and China. The HPT stage 1 blades have experienced problems with cracks after about 4,000EFC of operational service. This problem has led to the requirement, via an AD issued by EASA, to have borescope inspections at regular intervals of the stage HPT blades and stator nozzles. This is AD 2022-0009R1, and has to be performed every few hundred EFH, this is more frequent than every airframe A check. This inspection, even if there are no problems found with the HPT blades, increases the aircraft's maintenance burden.

"In addition, the requirement to have the borescope inspection always raises the possibility of findings, such as cracks and deterioration of the blades," continues Baccarani. "This will force early removals at short removal intervals, leading to an increased rate of swapping engines, which will raise an airline's spare engine inventory requirements."

The LEAP-1A has also experienced problems with a series of other smaller issues. These include small components, such as the pneumatic starter motor. "There have also been problems with coking on the fuel nozzles, but these can be replaced relatively easily on-wing," says Baccarani. "The -1A has also recently experienced vibration of the HP spool, which is an indication of the early stages of a problem."

In the meantime, CFM is designing a new P/N for the stage 1 HPT blade. The performance improvement programme (PIP) for the CFM56-5B used a lot of new airfoils. "The HPT blade's cooling holes get blocked with sand and pollutant particles, which leads to poorer cooling inside the blade," says Baccarani. "These higher temperatures lead to cracking and burning, and so deterioration of the blade. This leads to EGT margin loss, and will force removals for blade replacement and performance restoration."

In-service experience of the LEAP-1A indicates that the earliest operators have experienced at least the 15% fuel burn improvement targeted by CFM. In some cases airlines that have extensive experience with the CFM56-5B on the A320 ceo say that the LEAP-powered A320neo family members are experiencing fuel burn differences closer to 20%.

Early experience of the LEAP-1A has been an initial EGT margin of 67 degrees centigrade for the -1A26 before modification to the engine's electronic engine control (EEC) software that was issued via a service bulletin (SB) by CFM.

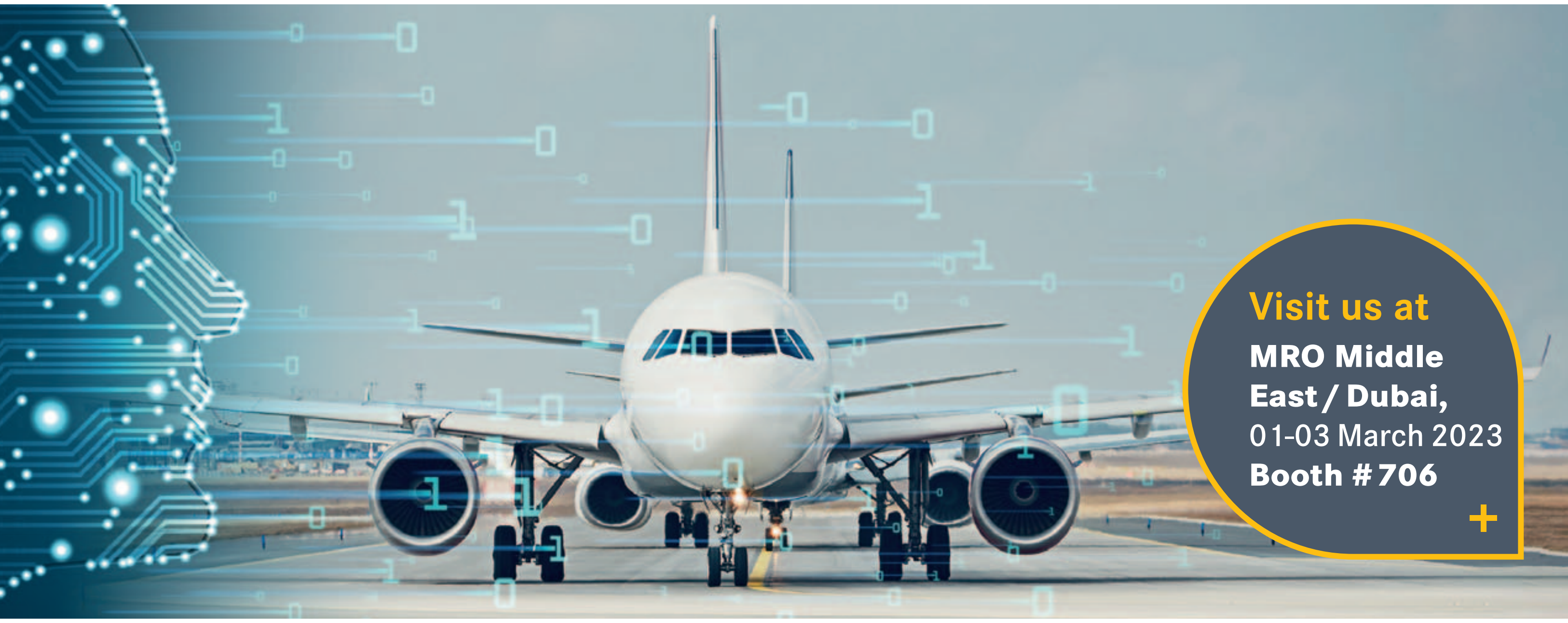
The rate of EGT margin in these early engines was at the level where removal intervals of only 6,000EFC were possible.

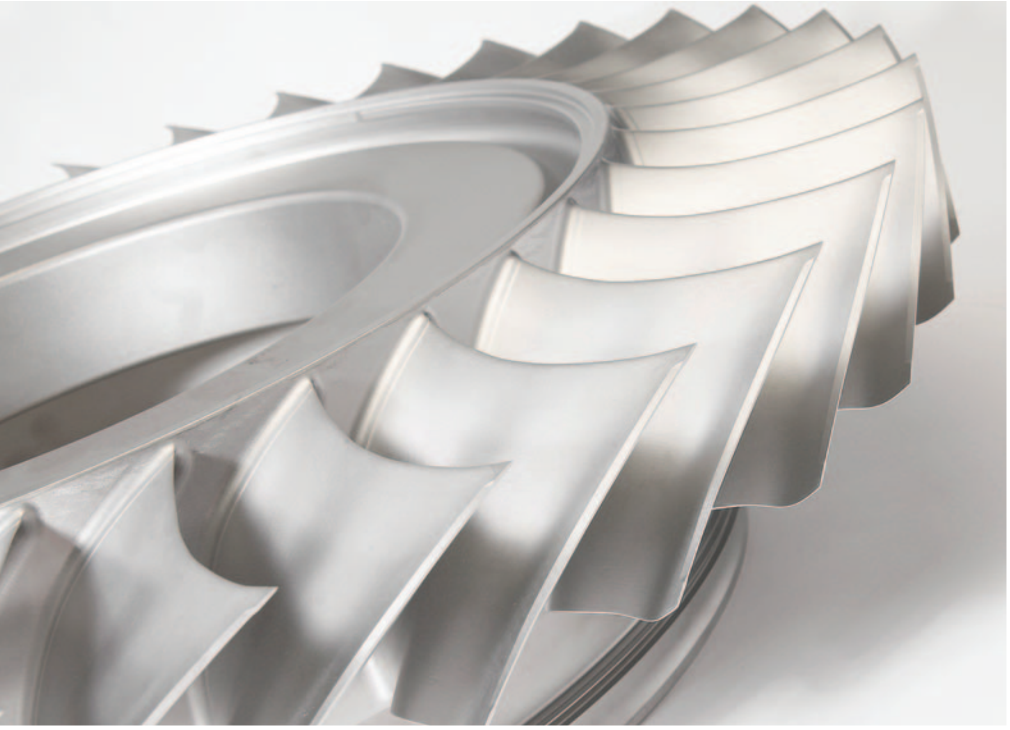
This increased the EGT margin to 93 degrees centigrade after the modification. At the rate of EGT margin erosion described, full EGT margin erosion could come after intervals as long as 17,000EFC.

The -1A32 variant had an initial EGT margin of 643 degrees, and so similar to the -1A26 despite the higher thrust rating.

Reliability improvement

All the main technical issues have to be dealt with if the LEAP-1A is to achieve sufficiently long removal intervals for its maintenance costs to be competitive. There are technical issues with most new engines in the first few years after service entry. Issues related to airfoil degradation and





The use of blisks in the first five stages of the HPC contribute to saving weight in the engine's overall configuration. The inherent risk of using blisks is that if damage beyond a particular limit is detected on HPC blades, then the entire unit has to be replaced instead of individual HPC blades.

EGT margin loss are the two main groups that affect removal interval. "The main objective is to get the LEAP-1A's removal interval up to a decent level," says Eugene O'Sullivan, senior vice president powerplant, at SMBC Aviation Capital. "It can take several iterations to fix one specific issue or a series of technical problems to get an engine to this position. CFM is targeting removal intervals of 25,000EFH or 16,000EFC when the engine's main reliability and technical problems have been ironed out.

"The situation is satisfactory if the full erosion of EGT margin coincides with LLP expiry," continues O'Sullivan. "It is unlikely, however, that the LEAP-1A will last up to 20,000EFC on-wing. This would be ideal where LLPs are replaced after using almost all of their life at the first removal and SV; achieving the lowest possible cost per EFC. It is more likely in the long run that the medium-rated LEAP-1A variants will require two removals within the 20,000EFC LLP life limits, and so have higher maintenance costs per EFC than the CFM56-5B. The lower-rated LEAP-1A variants will probably achieve first removal intervals of 16,000EFC or more, and so have a high level first workscope that coincides with using the majority of the LLPs' lives."

TAP Air Portugal reports that the removal intervals in EFH and EFC are improving much faster compared to its experience with the CFM56-5B. It comments that there are, however, always some uncertainties related to an engine's new configuration, materials, temperatures and other issues that all pose risks. It adds that it is confident that it will be able to operate the fleet with high reliability over the long term.

O'Sullivan adds that the LEAP-1A's expected inability to match the removal intervals and maintenance costs of the CFM56-5B are mainly due to its high combustion temperature, which is required to get the desired fuel efficiency. Its design has been optimised for the lowest possible fuel burn, not for maintenance costs.

"The CFM56-5B and -7B series first shared the same core engine, which helps reduce some costs. More importantly, the core is large compared to the fan in the case of both engines," says Baccarani. "That is, a large volume of air passes through the core engine, and this keeps EGTs relatively low and so EGT margins high. This has kept the -5B's and -7B's maintenance costs relatively low. It is not clear what the LEAP-1A's long -term maintenance costs will be, and it takes 10-15 years for a new engine to reach its mature levels of reliability."

Maintenance issues

Most LEAP-1A engines will have been signed into fleet-hour agreements (FHA) that are managed by CFM. These will provide airlines with predictable maintenance costs per EFH or EFC. While this type of contract provides airlines with predictable maintenance costs, there are several issues that will affect the actual maintenance costs of labour and all parts and materials of the engines.

Some of these are related to the engine's design and configuration. One of these is that the first five stages of the HPC are blisks, unlike other engines that have each stage of the HPC made from separate components of a disk and individual blades. In this form, individual blades can be inspected during an SV. Those that are below particular inspection limits have to be scrapped, while those whose condition is higher than a specific condition can be repaired. In the case of blisks, any physical damage to just one of the blades means the entire blisk that comprises the disk and all blades, has to be replaced. This will be expensive.

Moreover, the damage to HPC blades can be inspected using a borescope inspection. It is then possible to perform smaller repairs to blades via a top case minor SV. This avoids the need to disassemble an engine and put it through an SV. The use of a blisk for each of the first five stages of the HPC means that if a borescope inspection finds any blade damage below a specific limit, an SV becomes necessary.

The actual maintenance costs and reliability risks have to be borne by the original equipment manufacturer (OEM), which operates a network of engine shops and specialist parts repair facilities. Underlying reliability issues clearly mean a higher risk of unplanned removals and shorter planned removal intervals. This all translates to higher costs per EFH and per EFC. Consequently, FHA rates will have to be adjusted accordingly. The OEM does not want to discount FHA rates as much as it has with the CFM56-5B and -7B. In the case of the LEAP-1A, cheaper FHA deals are generally only available for larger operators. Higher rates need to be charged to smaller airlines, and there is generally a larger difference in rates between larger and smaller operators.

The FHA rates being offered are more in line with the maintenance costs incurred, so the same level of discounting is not generally offered with the LEAP-1A. The OEM is now being more conservative with modelling its costs and determining the FHA rates being offered.

Nevertheless, it must be appreciated that the LEAP-1A is in the immature phase of its life with respect to operational reliability and maintenance costs. The LEAP has been optimised for the lowest possible rate of fuel burn, while also having a sufficiently high EGT margin. The engine is more finely balanced in these two respects than the CFM56-5B/-7B. The consequences are that any reliability fix in the form of an airworthiness directive (AD) or SB must be carefully considered. AC