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Ageing Aircraft Cost Management

How the ageing of an aircraft can see considerable changes in the way maintenance is planned and carried out

By David Dundas

The strategy or maintaining a new aircraft is a relatively straightforward challenge. However, over time, various different options begin to present themselves, and the older an aircraft gets, the more complex those options become. Questions arise regarding the merits of proactive as opposed to reactive maintenance, the use of used serviceable materials (USM) as opposed to brand-new OEM parts, whether repair or replacement of parts is a better option, and at what point should maintenance be aligned with any plans to phase out an aircraft. With the current supply chain problems seeing aircraft being cannibalised for parts far younger than was the norm, that introduces another variable factor into the mix.

So, when it comes to aircraft and engine maintenance cost management, what are seen as the best strategies to adopt and why? The following is a conglomeration of thoughts and ideas from eight experienced and reputable MRO-connected operators involved in the commercial airline sector of the aerospace industry.

The point where maintenance cost management becomes a strategic, rather than purely technical, concern for operators

Maintenance schedules for new and nearly new aircraft are easily planned. However, as aircraft age, so they develop a past history, and it is often that past history that can dictate ongoing maintenance schedules. The question is, at what point in an aircraft's life does the maintenance schedule begin to change and cost

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Dag Johnsen, Chief Operating Officer, Aero Norway management become a more strategic as opposed to technical concern?

Anca Mihalache, CEO of AERO CARE shares her thoughts: "In my opinion, we are already at that point. When the market is overinflated, operators naturally start looking more closely at costs. On the other hand, when engine availability is as low as it is today, there is very little that airlines can realistically do in terms of cost reduction. At present, we are in a situation where maintenance management is driven primarily by technical necessity rather than strategy, as operators need to keep aircraft flying and the additional costs cannot easily be avoided." For Dag Johnsen, Chief Operating Officer at Aero Norway, durability and predictability are key drivers: "The strategic cost management decision related to engine overhaul becomes most relevant with fleet exits and lease returns. During normal operation, i.e., not considering any fleet exits or lease returns, operators will typically build in durability and predictability to the fleet. However, as aircraft are planned to retire from service and/or returned to a leasing company, the question will be how much engine life needs to be considered to meet exit targets. Many lease agreements have return clauses such as remaining LLP life, residual performance etc. In some cases where the operator owns the airplanes, they are freer to utilise the residual "green time" engines to support their own operating fleet until retirement or selling these assets on the open market."

At PEM-Air, the company's Chief Executive Officer, Virgil D Pizer, sees a wide array of factors which can affect any maintenance strategy. As he explains: "Maintenance cost management stops being a purely technical issue and becomes a strategic one the moment engine behaviour starts influencing decisions outside the maintenance department. With ageing engines like the CFM56, V2500, CF6, PW4000, PW2000, CF34, or Trent 700/800, this shift usually happens when shop-visit costs become unpredictable and the financial exposure of a single event can swing several million dollars. At that point, planning isn't just about workscopes anymore — it's about protecting cash flow, managing risk, and stabilising the operation. For many smaller and midsized operators, this transition happens even earlier. With limited spare engines and tighter schedules, one unplanned removal can disrupt the entire network, force expensive short-term leases, or trigger cascading delays. When reliability starts shaping the flying programme, maintenance becomes a strategic concern by definition. The same is true when material scarcity and long lead times begin dictating the economics more than the technical findings themselves. Ageing platforms rely heavily on USM, PMA, DER repairs, and module exchanges, and when those markets tighten, operators have to think in terms of procurement strategy and long-term planning, not just shop-visit execution. Ultimately, maintenance cost management becomes strategic when engine economics start influencing fleet decisions — whether to extend life, convert, retire, or lease additional assets. At that point, the conversation moves from engineering to finance, operations, and executive leadership. From Pem-Air's perspective, we see this shift most clearly in smaller to mid-size operators. Their exposure to cost volatility is higher, their buffer capacity is smaller, and their ability to absorb long TATs or unexpected findings is limited. For them, maintenance cost management isn't just about keeping engines running — it's a core part of ensuring operational resilience and long-term fleet viability." On the other hand, Bruce Ansell, Technical Manager – Engine Division at APOC Aviation provides us with a very concise yet sound strategy from the onset: "Cost management starts prior to acquiring the engine, it should be part of the financial modelling prior to acceptance. The technical condition and future operational requirements will dictate the costs."

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Abhijeet Dey, the VP – Asset Management at Setna iO identifies maintenance problems with the same engines as those identified by Virgil D Pizer as he tells us that: "Operators are met with a unique blend of challenges and opportunities, particularly concerning ageing aircraft engines such as the CFM56-7B, CFM56-5B, V2500-A5, CF6-80C2, and CF6-80E1. These engines, once deemed the workhorses of commercial aviation, now signal an urgent need to re-evaluate maintenance strategies. Operators need to recognize that the costs of shop visits often exceed the residual values of ageing engines. This shift empowers them to navigate maintenance decisions more strategically, thereby ensuring operational efficiency while aligning maintenance practices with broader business goals. Since the CFM LEAP and PW GTF programmes are yet to achieve their individual targeted performance, retirement of older Boeing 737 NGs and A320 CEOs are getting pushed back by another 5-10 years. For operators maintaining the CFM56-7B and CFM56-5B, the industry's two most widely used engines, the stakes are higher than ever. Maintaining these engines requires meticulous planning, particularly regarding lease returns. The emphasis must be on maximising green-time usage

Abhijeet Dey, VP Asset Management, Setna iO

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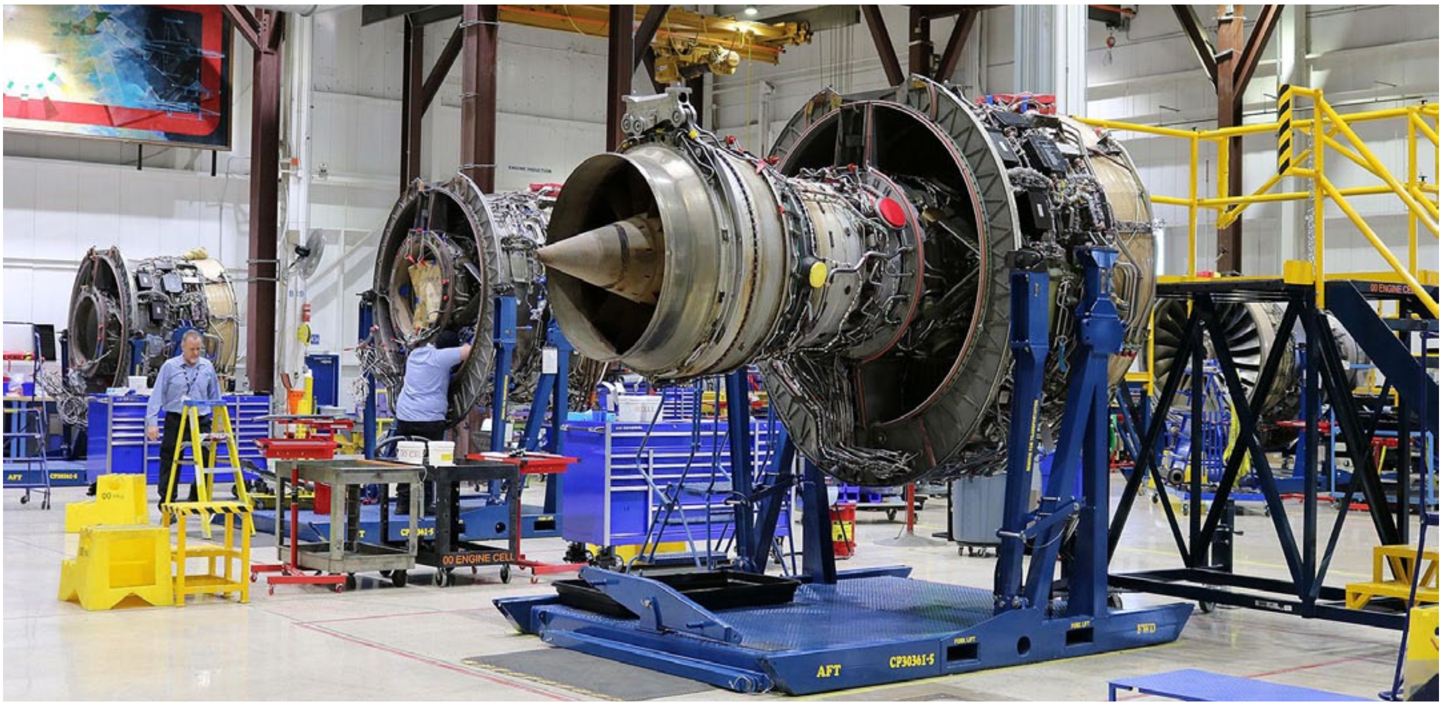
while simultaneously complying with the stringent requirements for back-to-birth documentation and necessary overhauls. This balancing act is critical for preventing costly, unexpected operational downtimes."

For David Williams, Director of Global RB211 Sales at StandardAero, forward planning is key. "We always encourage operators to consider maintenance cost management on a strategic basis, especially during times of extended shop visit turnaround times (and tight slot availability). By working with an MRO provider to plan their maintenance requirements well ahead operators will be able to avoid AOG issues, booking shop visit slots well in advance and securing the parts they need ahead of time," he explains, while for Cliff Topham, Senior Vice President, Werner Aero LLC, "Maintenance cost management is a major strategic driver when engines get towards the first SV."

The maintenance cost drivers which typically escalate most sharply as engines age (e.g., LLPs, unscheduled removals, shop visit frequency).

As engines move deeper into their lifecycle, a few cost drivers start to rise much faster than others, and they tend to do so in ways that operators feel immediately in both budget and operational stability. The most visible pressure usually comes from shop visit costs, because ageing engines accumulate more distress in the hot section, scrap rates increase, and the availability of affordable USM tightens. What used to be a predictable work scope becomes far more variable, and that variability alone drives costs sharply upward. Virgil D Pizer further explains: "At the same time, LLP exposure becomes a major factor. Even if an operator tries to defer full stack replacements, ageing fleets eventually hit staggered LLP expirations that create unavoidable cost spikes. For platforms like the CFM56, V2500, CF6, PW4000, PW2000, CF34, or Trent 700/800, the LLP market has also become more expensive and less liquid, which amplifies the financial impact. Another driver that escalates quickly is unscheduled removals. As EGT margin narrows and components accumulate cycles, engines become more sensitive to operating environment, borescope findings, and minor performance shifts. Each unplanned removal not only adds cost but also disrupts the flying program — especially for smaller operators with limited spare coverage. Finally, shop visit frequency itself increases. Engines that once reliably delivered long intervals between visits begin returning to the shop sooner, often with less warning. This compresses maintenance planning windows and forces operators to absorb more events over a shorter period, which compounds both cost and operational strain. From Pem Air's perspective, these escalating drivers hit smaller and midsized operators hardest. With fewer engines to spread risk across, limited access to green time assets, and tighter cash cycles, the combination of rising shop visit costs, LLP exposure, and unplanned removals can quickly shift from a technical challenge to a strategic one."

LLPs in particular are targeted by Abhijeet Dey, Dag Johnsen and Cliff Topham in terms of escalating costs. "The transition from predictable labour expenses to increasingly volatile material costs is starkly evident. Taking the CFM56 & V2500 engines as an example, operators are witnessing Life-Limited Parts (LLPs) prices increase by an alarming 5-7% annually due to elevated manufacturing demand and constrained availability. In such circumstances, replacing an entire LLP stack can account for an astonishing 40-50% of an engine's total mid-life value. When examining legacy engines, the need for increased scrutiny of shop visit frequently becomes apparent. As these engines age, their performance metrics, including EGT margins, tend to decline more markedly, resulting in shorter on-wing time. This decline not only increases the frequency of shop visits but also raises the overall costs needed to keep these aircraft operational. Coupled with impending fatigue thresholds, the risk of unscheduled engine removals escalates. Even minor component failures can trigger significant internal damage, ultimately leading to costly repairs and extended grounded periods," Dey advises. Beyond this, Johnsen tells us that: "The single largest expense during engine overhaul is the replacement of LLPs followed by the HPT blade set. A new CFM56 engine LLP core stack can cost up to US$5-6m per shop visit, and a new HPT blade set cost is more than US$2m. Unscheduled, or better described as unplanned removals, are always an element in engine operation, but most operators have some level of predictability based on historical data which account for these removals. The nature or failure mode of the unplanned removal will obviously have a large impact on the cost and can vary from a minor oil leak that can easily be resolved with minimum maintenance, to significant failure that can render the engine beyond economical repair. When Aero Norway works with a customer over a long period, we get to know their fleet, their goals and understand how we can really add value at a strategic level. With this knowledge, we can solve targeted problems and assist with unscheduled removals in a trusted, cost-effective way that is transparent with both pricing and process. The shop visit frequency is often predicted by the engine manufacturers



RB211-535 © *StandardAero*

based on the operating environment, and a first-run engine will typically have a longer service life compared to a first, second, third, etc., shop visit engine. Much of these predicted service lives are also dependent on the shop visit workscope level, and a full performance restoration workscope will yield longer service life compared to a limited workscope engine," while Cliff Topham suggests that: "LLPs cost becomes important as they can represent up to 50% of an SV when a combined PSR & LLP visit are combined."

Though Bruce Ansell succinctly advises that: "Mature engines have a reduced MTBOH (Mean Time Between Overhaul), at the same time the cost of replacement parts is rising each year, resulting in ever-increasing shop visit costs," interestingly, David Williams and Anca Mihalache both look beyond the previously identified problem of LLPs. Williams explains: "Parts supply is typically the main cost driver for aging engines such as the Rolls-Royce RB211-535, which we support from our San Antonio facility in Texas. While LLP is certainly a key concern here, it's not unheard of for a single non-LLP (e.g., structural) part to become a critical item, especially where demand for that items is extremely low, with the OEM (or the OEM's supply chain) often having ceased production of that component years ago. In such situations used serviceable material (USM) can become critical." "LLPs are an obvious driver due to the annual price escalation applied by the OEM. However, just as important are non-LLP parts, or parts with only a soft life limitation, such as HPC and HPT blades, nozzles, cases and similar components. Scheduled removals give lessors and operators the opportunity to plan shop visits and secure parts in advance. Unscheduled removals, depending on the nature of the repair required, can very quickly turn into a significant cost driver," says Mihalache.

How should operators rethink maintenance planning once engines move beyond their original economic design life?

It is abundantly clear that there is no 'one-size-fits-all' solution to this situation, a sentiment backed up by the wide-ranging list of strategies and options discussed by all the contributors. To begin with, Abhijeet Dey takes an interesting approach, in particular in relation to the end goal. He explains: "Engines like the CFM56 variants and CF6s eventually reach a sunset phase. Here, operators must pivot from a conventional 'Restore to New' mindset to a more strategic 'Build to Goal' approach. This new paradigm necessitates a focus on tailored workscopes that prioritise modular or hospital shop visits, designed to provide just enough cycles to efficiently meet an aircraft's retirement timeline. Instead of pursuing complete performance restorations, which can be prohibitively expensive, operators ought to prioritise longevity and operational efficiency. Incorporating effective green-time strategies is one method to extend the useful life of these engines across a fleet. For example, by judiciously swapping CFM56-7B or 5B engine modules within a fleet, lessors and operators can optimise the remaining life of both engines and their components across multiple aircraft. This approach ultimately minimises the need for new parts while promoting sustainability and resource efficiency." For Virgil D Pizer, he sees a shift in approach as necessary, in particular moving away from the more traditional OEM-style planning. "Once an engine moves beyond its original economic design life, operators really have to shift their mindset from 'maintaining the engine as designed' to 'managing the asset for the remainder of its useful value.' At this stage, the goal is no longer to chase like-new performance — it's to control cost volatility, extend reliability where it still makes sense, and avoid investing more than the asset can realistically return. For most fleets, this means moving away from rigid, OEM-style planning assumptions and toward a far more pragmatic, condition-based approach. Instead of defaulting to full restorations, operators start asking whether a performance restoration, a module level repair, or a DER/PMA-supported solution will deliver enough on-wing time to bridge to the next fleet milestone. The planning horizon becomes shorter and more tactical, with a stronger focus on aligning shop visits to remaining aircraft life, lease return conditions, or conversion timelines. It also means accepting that shop visit intervals will compress and that findings will become less predictable. Planning teams need to build more buffer into schedules, secure material earlier, and rely more heavily on USM and module exchanges to keep costs under control. For smaller and midsized operators, this is especially important because they often don't have the spare engine depth to absorb long TATs or unexpected removals. Another key shift is integrating maintenance planning more tightly with finance and fleet strategy. Once engines are past their economic design life, every major investment needs to be weighed against the aircraft's remaining value and the operator's long-term plans. In some cases, the right answer is to extend life with minimal investment; in others, it's to retire or part out the asset rather than fund another heavy shop visit," he informs us.

David Williams sees multiple options available, depending on the circumstances, suggesting that: "The key strategy for operators of ageing engines is to think smart when it comes to maintenance, and to utilise all of the solutions available to them. This includes not just new parts supply and MRO shop visits, but also USM, component repairs, green time engines, exchange pools, module swaps, PMA parts and DER repairs. Another solution sometimes open to operators is a so-called 'Frankenstein' build, i.e., utilising multiple donor engines to create a single airworthy powerplant. This approach may or may not be economical, depending on the condition of the donor engines and the cost of disassembly and rebuild." Bruce Ansell and Cliff Topham both provide brief but salient remarks on the matter. "The primary concern should be availability of spare parts, to the extent that hard to find parts should be sourced well in advance of the required date, allowing for any component repair or overhaul to be completed prior to the shop visit," says Ansell, while Topham adds that: "Many start to think of minimum scope visits to extend life at minimal incremental cost."

Of course, it would be difficult to avoid supply-chain issues when discussing any aspect of aircraft maintenance, and Anca Mihalache explains where it creates a problem. "This is relatively new territory for everyone. Historically, engines would typically go through two shop visits and then be retired which supported a healthy supply of used material for future shop visits. Today, I see two main issues. First, repair shops are increasingly focused on newer-generation engines, such as the LEAP, which means reduced capacity and fewer shop slots for legacy engines. Second, parts availability is very low. Engine parts repair shops are facing delays across the supply chain, including delays from OEMs for even basic hardware such as nuts and bolts," she tells us. Then, to conclude this section, Dag Johnsen takes a very interesting view of the situation in relation to piston-powered aircraft. He explains that: "The engine's economical design life is primarily driven by parts availability and finding MRO shops still maintaining these engine models. There are still piston-powered airplanes in commercial operation where a very few, but specialised MROs continue to overhaul these engines. Of the several thousand B727s, B737-200s and DC9s produced with the Pratt & Whitney JT8D engines, there are only a fraction of these airplanes still in service, and a very few MROs offer repair of these engines. Of the nearly 2,000 B737 "classic" airplanes produced with the CFM56-3 engines, there are a few hundred airplanes still in service. While the CFM56-3 engine production ceased in 1999, CFMI provides strong aftermarket support through new parts production and repair services, and several MROs still continue to provide repair services for these engines."

How operators should evaluate "repair versus replace" decisions as parts scarcity increases

As parts scarcity becomes a defining feature of aging engine programs, the "repair versus replace" question stops being a simple cost comparison and becomes a broader assessment of risk, timing, and remaining asset value. Operators have to look beyond the immediate shop visit quote and think about what each option means for on-wing time, reliability, and exposure to future material shortages. In practice, the first step is understanding whether a repair can realistically deliver the on-wing time needed to reach the next fleet milestone — whether that's a lease return, a conversion, or planned retirement. If a repair only buys a short interval and pushes the engine back into the shop sooner, the lower upfront cost may not actually save money. On the other hand, if a DER- or PMA-supported repair can reliably bridge the gap without compromising performance or compliance, it often becomes the more economical choice, especially when replacement parts are scarce or priced at a premium. PEM-Air's CEO, Virgil D Pizer, further advises us: "Operators also need to factor in the volatility of the USM market. For many aging platforms — such as the CFM56, V2500, CF6, PW4000, PW2000, CF34, or Trent 700/800 — replacement parts may be available one month and unobtainable the next. In that environment, a viable repair path can be more valuable than waiting for a part that may not arrive in time to support the schedule. This is particularly true for smaller and midsized operators, who typically don't have the spare engine depth to absorb long delays. Another key consideration is the long-term value of the asset. If the aircraft or engine is nearing the end of its economic life, investing heavily in new parts rarely makes sense. In those cases, operators often prioritise repairs that keep the engine compliant and reliable without overcapitalising an asset that won't return the investment." He concludes that from Pem Air's perspective, "the best decisions come from evaluating repair and

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Cliff Topham, Senior Vice President, Werner Aero LLC replacement options in the context of the operator's actual operating horizon, not the theoretical design intent of the engine. As scarcity increases, flexibility, creativity, and a willingness to tailor the workscope become essential. A repair that fits the business case is often more valuable than a perfect technical solution that doesn't fit the timeline or the budget."

Shane Hennessy, Director of Origination & Trading EMEA at EirTrade Aviation is particularly focused on the shortage of greentime engines and how this is affecting the decision-making process for many. As he points out: "Where airlines have a clear operational requirement for an engine, decision-making in the current market is increasingly tilting toward repair rather than replacement. The primary driver is the acute shortage of greentime engines, which is consistent across key narrow-body platforms such as the CFM56-5B/7B and V2500-A5, as well as wide-body types including the CF6-80E1 and Trent 700. Limited supply has materially constrained replacement options. While asset owners can command strong values for run-out engines from the market, the acquisition cost of greentime engines for the aforementioned engine types has reached peak levels. EirTrade has visibility of market values for CFM56-7B26E engines with approximately 5,000 FC remaining approaching US$10 million, fundamentally altering the replacement economics. Conversely, repair decisions are not without challenge. Operators must carefully factor in extended turnaround times, managing shop-visit scope creep, and rising material costs driven by OEM cost-loading and price escalation. As a result, repair versus replace decisions increasingly require a balanced assessment of parts availability, replacement options and long-term asset value." At AERO CARE, company CEO Anca Mihalache is also firmly in the repair as opposed to replace corner. "Presently, I believe decisions are predominantly made in favour of repair. Newer engines continue to experience technical challenges, while older engines are required to operate longer than originally anticipated. Combined with increased flight demand, this has pushed the market towards repairing engines rather than parting them out," she says. Aero Norway's COO Dag Johnsen is of a like mind to Mihalache as he advises that: "Most operators would prefer repairs during shop visits as opposed to replace with new parts due to cost considerations, as long as the repaired parts meet the service goals. When evaluating whether a repair is the appropriate course of action, it depends on the customer's requirements – mostly cost versus time. Once this has been determined, Aero Norway works closely with our component repair providers to ensure our solutions are as good as buying new, while also saving our customers money." He then adds that: "We also look for opportunities to help with the development of new solutions when we come across parts that are to be scrapped and non-repairable. This ensures that we keep developing new solutions that at the end of the day deliver an expert, cost-efficient service."


Shane Hennessy, Director of Origination & Trading EMEA, EirTrade Aviation

Bruce Ansell at APOC Aviation makes it clear that he feels that they type or 'repair versus replace' analysis is critical. "Repair analysis should involve time & cost, also the potential for BER or scrap rates which can effectively leave you without the required parts. APOC believes it is essential to take advice on repairs and current success rates from the repair shops," he tells us. On a slightly different tack, however, Abhijeet Dey at Setna iO is more focused on cost and availability as a guiding influence, pointing out that: "Operators are leaning toward innovative salvage repairs for older engines. The aviation industry has opened up more towards using parts with Designated Engineering Representative (DER) repairs, which allows them to extend the life of components that were often previously considered non-repairable. While most operators now have PBH contracts to counter parts scarcity during line operation, they do have to rely on repair shop Turn Around Time (TAT) when the engines are going through shop visits. Faced with approximately 3–6-month lead times for a part to be repaired, many operators opt for immediate DER repair solutions or even the acquisition of PMA parts. The financial burden of an aircraft being AOG (Aircraft on Ground) or engines off wing, often makes immediate repairs or the acquisition of Used Serviceable Material (USM) more favourable, even if these options come at a higher price."

David Williams makes it very clear that StandardAero has a long-held 'repair rather than replace' philosophy, wherever practical, based on the company's extensive in-house component repair and overhaul capabilities. "Component repairs are certainly an important option for operators facing parts shortages in the market, as they have the potential to deliver both TAT and cost benefits," he says, adding that: "Key criteria for operators to evaluate will be the TAT and cost differential of new parts versus repairs, as well as locating a reliable source of OEM-approved component repairs." And to conclude, once again, with a concise response from Cliff Topham at Werner Aero, he tells us that it "Depends on the planned life of the engine or aircraft and the return conditions if leased."

How important is the use of USM for the cost management of ageing engines

In general terms, USM offers operators greater cost control, generating savings of 30-50% compared to procuring new parts.

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RB211-535 on test at StandardAero © *StandardAero*

This flexibility plays a crucial role in guiding decisions about whether to retire an engine or extend its service life. Abhijeet Dey goes further by explaining that: "An Overhauled (OH) part is more cost effective than using a new part if the engine is already going through its 2nd or 3rd major shop visit. The on-wing time needs to be justified against the shop visit cost and using USM against new parts helps achieve the targeted economic performance. For example, a half-life OH CFM56 Core LLP set will cost 50% less than a new set of core LLPs. However, for a second-run or third-run engine, using new LLPs doesn't make any sense as the on-wing time will never exceed half-life during performance deterioration." David Williams is of a like mind to Dey with regard to the use of USM, providing traceability is intact. "USM can be a valid option for operators of aging engines, especially when facing long lead-times for new parts, and StandardAero relies heavily on its in-house Asset Management team to provide customers with USM options. USM may also offer operators the benefit of being able to select material to specifically meet their operational requirements, i.e., in terms of cycles remaining. Where USM is utilised, it is of course essential that operators have full 'back to birth' traceability for any LLP being utilised, in order to ensure the integrity of the components in question," he warns us. Of course, the financial benefit of USM depends on one obvious factor, as pointed out by Cliff Topham: "It is very important in controlling cost if you can find suitable material."

Shawn Hennessy sees that as carriers look to extend the life of existing aircraft, so the demand for USM has increased and its importance grown. He tells us that: "In the last 24-36 months, an increased number of airlines have pushed their fleet transition to newer-technology aircraft to the right and are operating their fleet for longer than 24 years, where previously airframes were sent for part out at this point. This is due to several factors, including the well known ones with the PW1100 engine, supply chain issues and entry into service issues from the OEMs. Coinciding with this increase, EirTrade Aviation has seen an increase in demand for USM. For operators, a significant proportion of the cost of engine shop visits & overhauls is made up of the value of the parts, thus reducing these costs with USM makes financial sense without compromising quality. USM can offer significant cost reductions when compared to purchasing parts directly from the OEM when accounting for increases in OEM CLP. Furthermore, Prolonged OEM lead times and supply chain constraints is driving strong demand for readily available USM. EirTrade Aviation is able to provide quick access to stocked engine & airframe USM, helping airlines mitigate downtime risk and avoid the operational and financial impact of extended OEM delivery timelines."

However, there is the challenge not simply of finding USM, but sourcing USM with matching cycles and this can be a whole different ball game. As Dag Johnsen explains: "Utilising USM as opposed to replace with new will yield significant cost savings but can sometimes be difficult to find. A new HPT blade set for a CFM56 engine will cost around US$2 million, and a repaired HPT blade set with lower, but matching cycles remaining for a specific target build will be significantly less expensive. The challenge is to locate a repaired HPT blade set that matches the service goal. The same principle will apply to LLPs where a typical CFM56-5B-/-7B full-performance restoration cycle goal is around 10,000 cycles dependent on the operational environment." Like many, Bruce Ansell and Anca Mihalache also build a strong case for the cost benefits of USM. "USM is essential for ensuring that mature assets are able to be returned to service, as the engine ages, several parts will go out of production which leaves USM or PMA as

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David Williams, Director of Global RB211 Sales, StandardAero the only alternatives. USM, from specialist providers like APOC, also allows engines to be rebuilt to fully utilise the remaining life of the engine - no-one should want to invest millions into new LLPs if the engine is going to require a full overhaul in a few years. Similarly, new blades etc., may not be necessary if the LLP life is low, USM can be acquired at a percentage of the new cost and be matched to the remaining LLP life," Ansell says, while Mihalache suggests that: "It is essential from two perspectives. First, USM helps keep maintenance costs under control. Second, in many cases the OEM is no longer producing certain parts, which makes USM not a cost choice but a necessity."

Beyond the above, Virgil D Pizer also delves into the area of the strategic dimension. As he explains: "USM becomes absolutely central to cost management once engines reach the later stages of their lifecycle. At that point, the economics of maintaining platforms like the CFM56, V2500, CF6, PW4000, PW2000, CF34, or Trent 700/800 shift heavily toward material availability, and new OEM parts often become either too expensive or too slow to source to make sense for an ageing asset. USM fills that gap by providing a more affordable, more flexible supply of components that still meet airworthiness and traceability requirements. For most operators, especially smaller and midsized fleets, USM is what keeps shop visits financially viable. Without it, the cost of a heavy visit can easily exceed the remaining value of the engine or aircraft. USM also helps stabilise budgets by reducing exposure to OEM price escalation and by offering more predictable lead times when the new parts supply chain is constrained. In many cases, the difference between a US$3 million shop visit and a US$5 million shop visit comes down to whether USM is available for the hot section, LLP stack, or key rotating parts. There's also a strategic dimension: USM allows operators to tailor their investment to their actual operating horizon. If an aircraft is only planned to fly for another three to five years, it rarely makes sense to install brand-new hardware with a full-life limit. A serviceable part with appropriate remaining life can deliver exactly the on-wing time needed at a fraction of the cost. From Pem Air's perspective, USM is not just a cost lever — it's a planning tool. It gives operators options, helps mitigate the unpredictability of ageing engine findings, and supports more flexible workscopes. For smaller operators in particular, access to reliable, well documented USM can be the difference between maintaining operational stability and facing disruptive, budget-breaking surprises."

Anca Mihalache, CEO AERO CARE

An overview of the overall availability of USM

Most MRO-based businesses feel that there is a shortage of USM and that this is predominantly as a result of the lack of aircraft being offered for teardown. This is likely because many carriers have extended the life of existing aircraft in their fleet as a direct consequence of delays in the delivery of certain preordered aircraft. This is backed up by David Williams, who states that: "The availability of USM varies from platform to platform. Overall, we have seen fewer retirements than expected in recent years – partly due to the service introduction issues affecting new-generation aircraft and powerplants – which has led to USM remaining relatively scarce, as operators retain older platforms in service for longer. This is especially true with regards to LLPs." However, Anca Mihalache, while recognising the shortage in one area, remains slightly more optimistic, depending on what one is specifically referring to. "For certain units, such as LLPs with a certain life-remaining blades and nozzles, availability is at the lowest level I have seen in my career. For other components, availability remains relatively stable. Of course, the specific engine type under consideration plays a major role in this assessment," she admits.

Bruce Ansell seems to be adopting a more cautious approach and, if anything, is not optimistic for the future, commenting that: "USM is in great demand and some parts are now getting scarce, APOC only sees this getting worse as more parts are scrapped during the repair process. The increasing demand for mature engines is leading to engines being repaired or rebuilt instead of being torn down, leading to a shortage of some USM components. Mid-life LLPs are now very difficult to find." Dag Johnsen, on the other hand, is slightly more optimistic as he looks to a time when aircraft delivery numbers improve. "The USM availability is very cyclical and tied to the world fleet's retirements, and MRO availability set up for engine teardowns. We have seen operators extending service of airplanes planned for exit due to new airplane delivery constraints, putting a strain on USM availability, but as new airplane deliveries are picking up the USM availability will improve," he suggests.

Virgil D Pizer sees flexibility as key when it comes to sourcing parts, as well as seeing a viable alternative to USM and OEM parts. He explains: "Overall USM availability is becoming more uneven across the major ageing engine platforms, and that inconsistency is one of the biggest challenges operators face today. Some material flows steadily from teardowns, while other components — especially hot-section hardware and LLPs — have become increasingly scarce or priced at a premium. That's why our focus at PEM-Air is less about relying on any single source of USM and more about building a broad, reliable supplier network that gives us multiple pathways to secure the right material at the right time. Because we're a smaller and more flexible MRO provider, we're not

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locked into rigid sourcing channels. We can move quickly between teardown partners, brokers, and specialised repair shops, and we can often secure material that larger organisations overlook or can't move on fast enough. That agility is essential when availability shifts month to month, especially for operators with limited spare engine coverage who can't afford long delays. At the same time, we're realistic about the fact that USM alone won't always solve the scarcity problem. In areas where the market is tight or pricing doesn't make economic sense, the PMA [Parts Manufacturer Approval] part becomes an important tool — not as a blanket solution, but as a targeted strategy. When a PMA part is well proven, cost effective, and aligned with the operator's remaining engine life, it can provide stability and predictability that the USM market sometimes can't. So, while USM availability is tightening in certain segments, our approach is to stay flexible, maintain a diverse supplier base, and use PMA where it genuinely supports the operator's business case. That combination allows us to keep shop visits moving, control costs, and give smaller and midsized operators the options they need to stay competitive."

Shane Hennessy is another to identify the knock-on effect of delays in the delivery of brand-new aircraft. The consequence, as he explains, means that: "Overall availability of USM is tightening, particularly for current-generation narrow-body and wide-body engines. Since 2020, the supply of greentime engines such as the CFM56-5B/7B, V2500-A5, and CF6-80E1 are at an all-time low. Rather than selling assets into the teardown market, airlines and lessors are increasingly choosing to rebuild engines or preforming modular swaps, thus extending on-wing life and the economic life of an engine. This has materially reduced the volume of engines available for part out. From an airframe perspective, delayed fleet renewal programmes are compounding the issue. Ongoing delivery delays from the OEMs and capacity constraints are pushing fleet transition plans to the right, resulting in lower-than-normal aircraft retirements. As a consequence, airframe part-out rates are at an all-time low, further constraining the feedstock that traditionally supports the USM ecosystem. Together, these dynamics are placing sustained downward pressure on USM availability. While demand continues to grow—driven by ageing fleets, rising OEM prices, and long lead times—supply remains structurally limited. In this environment, early access to assets, strategic inventory positioning, and strong teardown capabilities are becoming critical differentiators for both operators and material suppliers."

Of course there can be a metaphoric price to pay, as pointed out by Abhijeet Dey. "The USM market is playing catch-up with supply constraints. Recent audits have uncovered numerous production violations related to new parts that resulted in the calling back of many batches of used parts. Delayed retirements also plays a major role in the scarcity of USM. Such dynamics impede access to high-demand parts, thereby undermining operational flexibility during critical repair cycles and emphasising the urgent need for strategic planning. However, this high demand for USM also creates an unsavoury situation where companies try to take advantage of the demand hike of USM and creates an unsafe and unreliable eco system," he tells us.

How should operators define and manage the economic "end of life" for an engine?

The economic "end of life" for an engine isn't defined by a single metric — it's the point where the cost of keeping the engine flying no longer aligns with the value it returns to the operation. For ageing platforms, that moment usually arrives when shop visit costs become consistently higher than the remaining asset value, when LLP exposure can't be justified by the expected on-wing time, or when material scarcity makes future maintenance unpredictable or uneconomical. At that stage, operators have to look beyond technical feasibility and focus on whether continued investment still makes business sense. Virgil D Pizer then explains that: "Practically, this means evaluating each engine against its remaining aircraft life, lease obligations, mission profile, and the operator's broader fleet strategy. An engine nearing retirement might only need a minimal, compliance focused workscope to bridge to a planned phase out, while an engine supporting a long-term fleet may justify a deeper investment. The key is aligning maintenance decisions with the operator's actual operating horizon rather than the theoretical design life of the engine. For smaller and midsized operators, this evaluation is even more critical. With limited spare coverage and tighter capital cycles, a single misaligned shop visit can overcapitalise an asset or create avoidable operational risk. That's why defining end of life isn't just a financial exercise — it's a strategic one that requires a clear understanding of cost exposure, reliability trends, and future material availability."

Abhijeet Dey pays particular attention to the difference between economic and technical end of life (EOL). He explains: "Operators must distinguish between economic EOL, when the costs of the next shop visit exceed the potential revenue the engine could generate, and technical EOL, which is determined by the onset of critical component fatigue or irreparable corrosion. This understanding EOL is pivotal for making informed maintenance and replacement decisions. Understanding where an engine sits on this spectrum helps operators decide whether to repair, replace, or retire it. Using a simple Net Present Value (NPV) analysis ensures these decisions are both financially sound and aligned with long-term fleet goals." David Williams takes a slightly different

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approach to the question, admitting that the differing needs of one customer from another could mean the difference between whether an engine is classed as BER (beyond economic repair) or not. "The calculation of whether an engine is BER will depend on the cost estimation performed after Cycle 1 (i.e., based on estimated new parts, USM and repair costs), and the customer's own assessment of the engine's economics. One customer may consider a repair estimate to render the engine BER, while a second may consider the bill to be acceptable, depending on their respective needs. One obvious goal for operators in terms of managing EOL is to carefully manage the engine's maintenance schedule and LLPs: an operator will ideally 'run out' an engine prior to its retirement, deferring any major maintenance events through module swaps and/or the use of USM and component repairs," he advises.

Both Anca Mihalache and Bruce Ansell have individual parameters that guide their approach to the end of life of an engine. "At present, many operators choose to part-out engines themselves at end of life or to cannibalise multiple engines in order to build one serviceable unit, while retaining remaining parts as stock. Ultimately, the economic decision is driven by the need to keep aircraft flying and to avoid flight cancellation costs," says Mihalache, while Ansell suggests that: "Effective planning will ensure that some LLP and OH shop visits will occur at the same time. At this point it should be looked at as a 'repair or replace' decision, - why pay US$10+ million for an SV when a replacement engine with sufficient life can be acquired for less."

Bruce Ansell, Technical Manager – Engine Division, APOC Aviation

What role does part-out strategy and asset monetisation play in overall cost management?

To a major degree, the overall value of USM and the engine value of an aircraft scheduled for teardown are governed by the volume of parts and demand for the engine type. However, a sound part-out strategy is definitely an essential part of financial optimisation for ageing aircraft. "When engines approach economic end-of-life, part out transforms what would otherwise be a high-cost liability into a valuable source of USM, supporting both financial and operational objectives across the fleet. Part out enables operators and lessors to recover significant residual value from ageing engines by harvesting LLPs, modules, rotables, and high-demand accessories. These components, once overhauled and certified, become monetisable assets that offset prior shop visit costs and generate cash flow. For lessors and operators, harvested components help meet lease return conditions, support engine swaps, and simplify transitions between operators. This reduces downtime, increases asset utilization, and enhances lease portfolio performance. Asset monetisation through part out enhances financial resilience by converting depreciated engines into revenue-generating assets. As a part of fleet planning, it reduces total cost of ownership and provides material support for the broader engine portfolio. By unlocking residual value, part out plays a central role in optimising the economics of aging fleets and ensuring long-term cost competitiveness," Abhijeet Dey advises.

Both Bruce Ansell and David Williams highlight the market factors affecting a part-out strategy. "Part-out strategy and asset monetisation will depend both on the volume of USM remaining in an engine, and on the remaining market demand for the engine. The former will be influenced by the cycles remaining on high-demand parts such as LLPs, and by the engine's operating environment (which will influence the level of corrosion and erosion seen on parts). The latter will depend on the size of the remaining active fleet, utilisation, and the engine's supply chain. Are new parts still available, and how long are lead times? Are PMA parts available? What volume of USM is already available in the market?" suggests Williams. "An engine will have a residual value, this value depends on USM market requirements, as well as the engine condition at part out. As a financial asset the engine can be depreciated to the residual value over the period of operation," Ansell comments.

Additionally, Anca Mihalache has highlighted the changes in the market during the last three years as she tells us that: "In a normal market, the exit value of an engine supports medium- to long-term business projections. Over the past three years, and likely for several more to come, residual engine values have increased significantly and have remained at elevated levels. As a result, projections made five to eight years ago have proven to be understated compared with the actual outcomes. For newer engine types, which are expected to be more reliable and require less repair, the situation may evolve differently. However, for now, the market remains consistently strong." To conclude, Virgil D Pizer points out that there is still a lot of residual benefit that can be extracted from an engine that is no longer viable. "Part-out strategy becomes increasingly important as engines age because it allows operators to recover value from assets that no longer justify a full shop visit. Instead of continuing to invest in an engine whose maintenance costs exceed its remaining economic life, part out provides a way to turn that engine into usable material — either to support the operator's own fleet or to generate cash through resale. In a market where USM availability is tightening and certain components are becoming harder to source, a well-timed part out can be both a cost-avoidance tool and a revenue opportunity. For many operators, especially smaller and midsized fleets, part out is also a way to stabilise future maintenance costs. By harvesting serviceable material from

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their own retired engines, they can reduce dependence on volatile USM markets and secure components with known history and traceability. This can make a meaningful difference when planning for upcoming shop visits, particularly on platforms where hot-section hardware or LLPs are scarce or prohibitively expensive. Asset monetisation goes hand in hand with this. Engines that are no longer viable for continued operation may still hold significant value in modules, accessories, LLPs with remaining life, or even core components. Monetising those assets helps offset the cost of replacement engines, green-time leases, or future shop visits. It also allows operators to avoid overcapitalising ageing equipment and redirect funds toward more strategic fleet needs," he tells us.

How early should maintenance strategy be aligned with fleet renewal or phase-out plans?

Maintenance strategy needs to be aligned with fleet renewal or phase out plans much earlier than many operators realise. Once an engine family enters the aging phase — whether it is a PW4000, CF6, CFM56, V2500, PW2000, CF34, or Trent 700/800 — every major maintenance decision should be viewed through the lens of how long the aircraft is expected to remain in service. The goal is to avoid investing in shop visits or LLP stacks that outlive the aircraft, while still maintaining reliability and regulatory compliance for the remainder of its operational life. Virgil D Pizer goes on to explain further that: "In practical terms, alignment should begin several years before the first aircraft in the fleet is scheduled to retire or transition. That's when operators can still shape shop visit strategy, adjust workscope depth, plan for green time bridging, and secure the right mix of USM, PMA, or module exchanges to match the remaining horizon. Waiting until the final year or two often forces reactive decisions — heavier investments than necessary or, conversely, under investment that risks reliability issues. For smaller and midsized operators, early alignment is even more important. With limited spare engines and tighter capital cycles, a single misaligned shop visit can create avoidable cost spikes or leave an engine with more life than the aircraft it's attached to. Planning ahead ensures that maintenance spend is proportional to the value the aircraft will still deliver. And while defining the renewal or phase out timeline is ultimately an operator or lessor decision, PEM Air sees its role as a partner in that process. With our deep experience across multiple ageing engine platforms, we're more than happy to help customers evaluate remaining economic life, model different maintenance pathways, and tailor workscopes that fit their long term fleet plans. Our goal is always to ensure that maintenance strategy supports—not contradicts—the operator's broader business trajectory."

Abhijeet Dey is more focused on early planning as he feels that it "provides a clear view of engine and aircraft health, helping determine which assets to retain, overhaul, or retire. Aligning maintenance strategy with fleet renewal or phase-out plans 18–24 months in advance enables transitions with minimal disruption by assessing fleet condition, securing parts early, forecasting costs accurately, and maximising remaining asset value. Maintenance schedules can be optimised to extract maximum remaining value from engines. Early planning also ensures teams are fully prepared for new aircraft introductions, reducing operational risk and supporting a smoother transition." However, David Williams is more focused on the timing of the phase-out plan. "The engine fleet's maintenance strategy should be reviewed and adjusted as soon as a phase-out plan is agreed upon. This will enable the operator to ensure that remaining green time is effectively utilized, and that shop visits are customized to avoid unnecessary outlays," he advises. Beyond this, Bruce Ansell and Anca Mihalache are of a similar mind where timing is concerned. "APOC advises that the maintenance strategy should be considered prior to acquiring the engine, this can provide for budget estimates for maintenance events, and also the point where short-build engines can be produced (short build - using USM to provide less than full-life on exit from the shop, i.e. built for a certain number of flight hours or flight cycles)," suggests Ansell, while Milahache believes that: "While it is understood that circumstances can change, with the pandemic being a clear example, maintenance strategy should ideally be aligned at the point of engine acquisition. Early planning helps in managing long-term technical and financial exposure, even if later adjustments become necessary."