A decline in engine values on the aftermarket makes it economic for airlines to acquire time-continued parts and used serviceable material at a rate that generates savings up several hundred thousand dollars for each shop visit. The economics for older generation engines are studied.

The economics of using repaired & serviceable parts in engine maintenance

The use of time-continued parts and used serviceable material (USM) is a common cost-saving practice in the maintenance of mature and older generation engine types. Given the right material acquisition cost and the maintenance status and remaining life of the engine, this practice can generate substantial savings in engine maintenance costs. The economics of this are examined here.

Economic basis

The economic basis for using USM in engine material revolves around two main issues.

The first is that the cost of similar engine shop visit (SV) workscopes does not decline as an engine ages. Most of an engine SV cost is related to purchase or repair of materials, parts and components. The cost of parts, and in particular engine blades and vanes, does not decline over the 35-45 year period that an engine type is in operation.

The second main issue is that, as a fleet's size declines due to retirements and fleet disposals, the supply of used engines generally increases. At some stage, engine values will decline to the point where the total cost of disassembling the engine to all the main constituent parts, and repairing some of the material, allows a specialist engine trader to offer repaired parts and components on the market at an economic rate. Selling USM to airlines exceeds the cost of engine acquisition, teardown and part repair for the broker, while it is significantly cheaper for airline operators to buy USM than new parts from original equipment manufacturers (OEMs).

"A specialist engine trader will typically sell repaired USM to airlines at 70-75% of OEM catalogue list price (CLP)," says Simon Mermod, director at Jet Engine Management. "This will save several hundreds of thousands of dollars per SV, depending on the number of modules worked on and the extent of USM used."

There are four or five main categories of engine components: life-limited parts (LLPs) of the disks and shafts; turbomachinery blades and vanes and combustion unit; main cases; accessories and quick engine change (QEC) kit; and remaining small parts and components.

"The 80:20 rule applies in the use of USM and parts in engine maintenance," says Chris Grey, principal at Aer Auster. "About 20% of the components account for about 80% of the value of an engine USM and parts and materials that will be in demand from airlines to lower engine maintenance costs. This will be most of the blades and vanes from the modules in the core engine. These are the high pressure compressor (HPC), combustor, high pressure turbine (HPT), and low pressure turbine (LPT). The LLPs in these modules are also in high demand.

"It is rare, however, to sell and use all LLPs from a disassembled and torn down engine," continues Grey. "There is little demand for fan section components, including the blades, or for low pressure compressor (LPC) blades and vanes/stators, because their maintenance costs are relatively low, so they offer only a small scope for savings. Some airlines, however, will buy complete fan and LPC modules under the right circumstances.

There is also some commonality between engine types. For example, the HPC, combustor, HPT, and LPT in the CFM56-5B are common with the CFM56-7B. "There is also commonality between the CFM56-5C, powering the A340-200/-300, and the CFM56-5B and -7B. This includes a lot of LLP commonality between the three engine models," says David Rushe, director of sales and marketing for Europe at Magellan Aviation Group.

There is also commonality of parts between the three main PW4000 variants.

The trader or broker is, therefore, taking a gamble in buying the used engine, disassembling and inspecting the parts, repairing some parts, warehousing material until it is sold, and shipping parts and modules to the buyer. The engine's maintenance condition is also a gamble, since a high percentage scrap rate will mean a total lower re-sale value of parts that get repaired. The process generally becomes more worthwhile the lower the market value of used engines.

"It takes about one week to tear down an engine, and it requires use of a specialist facility," says Grey. "It can cost $50,000-70,000 to disassemble an engine. From this, an electronic inventory of all parts in the engine is produced. All the parts have to be inspected and tagged. All relevant paperwork also has to be archived, including that related to repairs.

There are also risks for airlines using USM, both in the case of engine parts, as well as buying complete modules.

Potential pitfalls

In addition to core engine turbomachinery parts and LLPs, there are other main considerations for an airline.

The first is that the on-wing life of the engine is not compromised or too short, compared to financial saving. There are several aspects to this. The first is that USM might be installed in an engine without it being repaired, which risks compromising the engine's predicted subsequent on-wing life.

The second is that repaired USM may be installed in the engine. While this material is more expensive, it will extend the engine's on-wing life, but it will still not be as long as that expected with new

The CFM56-3 and younger variants of the -5B/-7B are available in large enough numbers to make the use of USM in engine maintenance economic. The potential savings extend to several hundreds of thousands of dollars per shop visit.

material. USM will still cost less than new parts, and can achieve a similar on-wing intervals in the case of some lower thrust settings and cooler environments.

Ultimately the overall cost per engine flight hour (EFH) or engine flight cycle (EFC), or actual SV cost should be reduced compared to a workscope using new parts.

USM also circumvents the need to perform full maintenance, saving maintenance costs. An example is the case of swapping used modules with time-continued or 'green time' modules taken from a disassembled engine. This is be cheaper than repairing or replacing parts, and performing full maintenance on the original module. This can generate large savings, especially if it avoids replacement of LLPs at high cost, and where the required remaining life of the module is a fraction of the lives of the new LLPs being installed.

There are several situations where this technique will work, mostly where older engines are being operated, and may only be for a limited number of years before retirement or for a longer term, but at low rates of utilisation. This has to consider typical annual rates of utilisation. These can be as low as 800-1,000 flight cycles (FC) in the case of some short-haul freighter aircraft, 1,500-2,300FC per year for short-haul passenger aircraft, and 700-1,500FC per year for medium- and long-haul aircraft.

These rates must be considered against the LLP lives of parts in different modules of most engine types. Most high pressure (HP) module LLPs in most engine types are generally 15,000-20,000EFC, and 25,000-30,000EFC in low pressure (LP) modules.

Engines or modules that will only operate for another five to eight years before being scrapped do not need to have a new set of LLPs installed.

An airline's demand for USM and time-continued modules will ultimately depend on the engine's last SV, its on-wing interval since then, its resulting maintenance condition, and the required subsequent on-wing interval.

Engine purchase values

The purchase price of engines for disassembly and salvage, repair and sale of parts is key to its being economically viable for a specialist broker and trader. "The general rule is that purchase value of an engine on the aftermarket will be pro-rated according to remaining LLP lives," says Glenford Marston, chief executive officer at Aero Norway. "As a simple example, if the full lives of LLPs for an engine type are 20,000EFC, and the remaining lives of installed parts are half at 10,000EFC, then the engine will be valued on the basis of a percentage of half the cost of a full shipset of LLPs. So, if the list price of new LLPs is $4 million, and the engine has remaining LLP lives of 10,000EFC, then the 100% pro-rated market value will be $2 million."

If the pro-rate percentage or factor is 50%, which is more often the case with older engine types that are declining in number, then the market value in this case will actually be $1 million. This is equal to 25% of the CLP of a LLP shipset.

The overall issue is that no additional value is attributed to the possible value or condition of the remaining material in the engine.

Pro-rate percentages or factors are relatively high for younger and current engine types. "Examples are about 100% for types like the CFM56-5B and -7B, or the V2500-A5," says Mermod. "Types like the CFM56-3 typically have pro-rate percentages or factors of 50%. This is because the fleet has imploded, the number left in operation is constantly declining, and the large number of retirements means there is always a plentiful supply on the market."

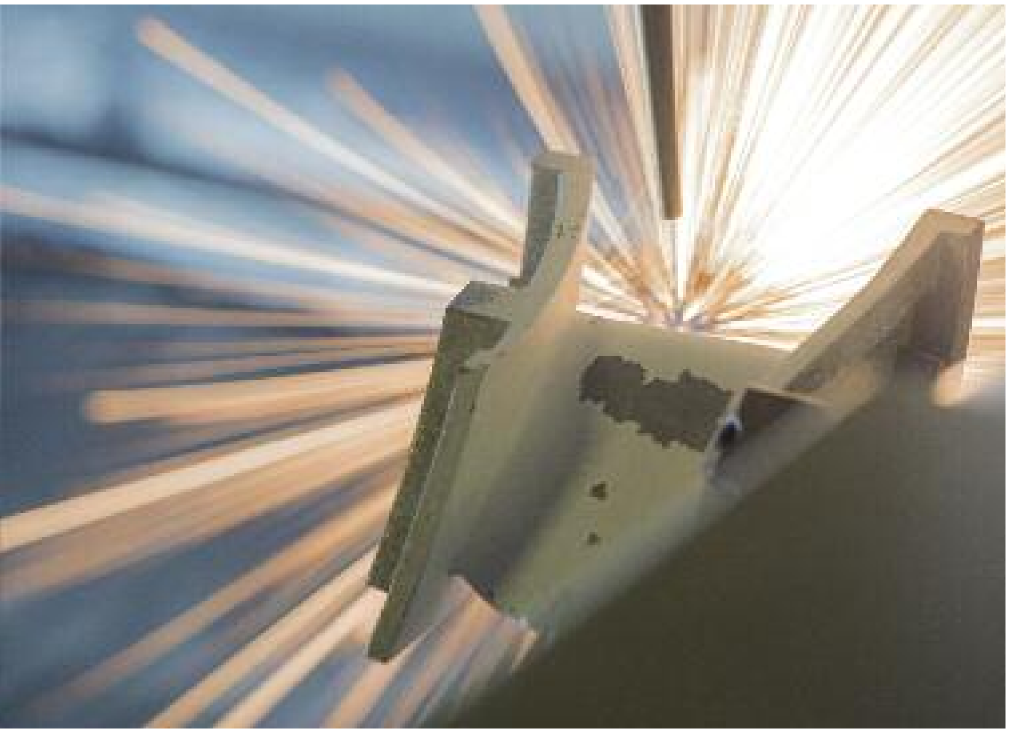
The pro-rate factor is not always the lowest for oldest engine types. An example is the PW2000, one of two engine options on the 757. The 757 is popular with freight operators, and the PW2000 is the popular choice with airlines because of the limited number of independent maintenance shops available for the RB211-535, as well as its relatively high SV costs. There are relatively few PW2000 operators, with Delta and United being the two largest users. Delta is likely to fully utilise the maintenance life of its engines. This limits the supply of engines with maintenance life remaining on the aftermarket, and means that the pro-rate factor of the PW2000 is relatively high. It has been known to be close to 100% in some cases. Demand for PW2000s and related material will be sustained by the 757's popularity as a freighter.

Engine acquisition

The most usual route to acquiring used engines is for specialist traders and brokers to acquire retired aircraft as entire units from airlines and lessors. In many cases the aircraft will be valued at the pro-rated value of each of its engines, plus an allowance for the value of airframe parts, taking into consideration the number of the type already retired and the general supply of airframe material on the aftermarket. This will be next to zero for types like the 737 Classic and 747-400. Their values will, therefore, be entirely based on engine pro-rated values in relation to remaining LLP lives.

The number of 747-400s, 737 Classics and a few other types being absorbed by freight carriers and secondary operators is now declining. An active freighter fleet, however, will maintain healthy demand for engines.

The case is different for types such as the 767, A320ceo and 737NG. There is a strong aftermarket interest in these aircraft, so their used market values will



Despite the cost of acquiring and repairing core module blades and vanes, USM can be sold to airlines at 50-70% of the OEM list price for new parts. This generates savings of several hundred thousand dollars at each shop visit, especially in the high pressure turbine.

be more than just pro-rated engines.

The engine types that are more likely to use USM during maintenance to reduce engine-related costs include older narrowbody engines. This will include the CFM56-3 in the case of 737-300s and -400s, many now operating as freighters. The PW2000 is another type.

The PW4000-94 and CF6-80C2, which power large numbers of 767-300ERs, about 300 747-400s, about 120 MD-11Fs, and a small fleet of A300-600s and A310s, are also likely to use USM in maintenance and so realise a savings.

The oldest CFM56-5Bs and -7Bs, and V2500-A5s powering the A320ceo and 737NG fleets, are now over 20 years old. There are, therefore, several hundred of each of these aircraft in the later mature and ageing phases of their maintenance lives. These can all realise engine maintenance cost savings with the use of USM. This would not necessarily make sense, however, if there was a good possibility of these aircraft being utilised for a period that was at least as long as the on-wing time of engines that had received a full workscope that included the use of new material.

In addition, the CFM56-5A is operated in relatively large numbers by a small remaining fleet of A320-100s and about 135 A319s. This engine may also be a candidate for using USM.

Engine market values

The LLP shipsets, the lives of parts in each main module, and the OEM's list prices provide a benchmark for the likely market value of pro-rated used engines.

Starting with the CFM56-3, the full shipset of LLPs had a list price of about $3.1 million in 2017. The LLPs for the -3 are now being sold by Aviall on a quote basis. This applies to all parts in the LPT and the fan shaft. All other LLPs have standard CLPs.

The 2017 CLP for a LLP shipset is the fan/LPC with lives of 30,000EFC and a CLP of $618,000; the HPC module with lives of 15,000-20,000 and a CLP of $850,000; a HPT with lives of 15,000-20,000 and a CLP of $676,000; and a LPT with lives of 19,000-25,000 and a CLP of $965,000.

The pro-rate factor for the CFM56-3 is generally 50%, and so an engine with 50% of LLP life remaining will have a market value of about $0.75 million.

The CFM56-5B and V2500-A5 power the A320ceo. The CFM56-5B LLP shipset has a list price of $3.9 million. These are split between the fan/LPC with lives of 30,000EFC and a CLP of $864,000; HPC with lives of 20,000EFC and a CLP of $950,000; HPT with lives of 20,000EFC and a CLP of 1.007 million; and LPT with lives of 25,000EFC and a CLP of $1.068 million.

The V2500-A5 has 25 main parts, all with lives of 20,000EFC. These have a CLP of $3.84 million.

The CFM56-7B has 19 parts in four main modules. The fan/LPC module has lives of 30,000EFC, the HPC and HPT modules have lives of 20,000EFC, and parts in the LPT module have lives of 25,000EFC. These have a CLP of $3.76 million.

The pro-rate factor of these three engines is likely to be 90-100%, with 90% being paid for older engines and those with 50-80% LLP life remaining. This would put the market value of a CFM56-7B at $1.7-2.7 million. A high pro-rate factor of 100% is likely for engines with 90% of LLP life remaining, putting a CFM56-7B at $3.4 million.

Market values of CFM56-5Bs and V2500-A5s would be similar, at $1.75-2.8 million for engines with 50-80% of LLP life remaining, and $3.5 million for an engine with 90% of life remaining.

Older types, such as the PW4000-94 and CF6-80C2, would have pro-rate factors of 50% for engines with remaining LLP life of 50-70%, putting market values at $1.8-2.7 million. Either of these engines with 80% LLP life remaining may achieve a higher pro-rate factor of about 60%, and so have market values of $3.4-3.7 million.

Scenarios

There are several scenarios where the use of USM in engine maintenance makes economic sense.

The most usual situation is the teardown of an older example of an old engine type, that is no longer being manufactured, to acquire material for use in maintenance of an older engine type.

This situation can apply to two scenarios. One is where the USM is installed in an engine owned by a lessor, and the other is where the engine is owned by the airline.

The third example is teardown of an engine that is owned by an airline for the purpose of providing material for its own engine maintenance shop. "This is rare, but is currently happening with some of the large US carriers," says Bill Polyi, president and chief operating officer at Magellan Aviation Group. "It has been happening recently because of a larger than predicted surge in SV activity for the CFM56-5B, CFM56-7B and V2500-A5 because of the continued growth in fleet numbers. There has been a surge in engine shop activity among these three main types, which has caused a delay in supply of new parts and materials. We expect this situation to last for another two years."

A fourth example is acquisition of a brand new or young engine that has just been manufactured and is acquired by a broker, trader or an airline with the specific purpose of being broken to sell all the main parts.

"The purchase and re-sale value of the salvaged parts would be different in this case, because the re-sale value of all salvaged parts would be greater than the engine's purchase value," says Grey.

There are certain situations where this can be economic for the purchaser and trader. Many engine types now provide a range of thrust ratings, up to 10 in the case of the CFM56-5B/3 series, varying from 21,600lbs to 33,280lbs. Turbomachinery parts are common to all thrust ratings. It is possible to buy new low-rated variants of engines that are in the last few years of production, disassemble them and sell parts for use in higher-rated variants.

Purchase price is based on the original thrust rating, so buying an engine at a low rating will result in a price that is up to 30% lower than for the highest-rated variant. "The high demand and value parts in these engines can be used in all thrust-rated variants," says Grey. "These include the HPT blades and the HPT nozzle guide vanes (NGVs). It is possible to sell all the parts from a disassembled engine for a total value that is close to the purchase price of a high-rated variant, and it can even be higher. Fast-moving material includes blades and vanes, the seals, combustor units, seals and LLPs. These alone can achieve 95-97% of the OEM list price on the aftermarket."

Maintenance cost savings

The best illustration of how use of USM can save engine maintenance costs is by using several examples of SV workscopes of several engine types.

Engine workscopes will vary in size, depending on engine modules worked on. Using USM in the different modules for main engine types is the first way to illustrate possible savings. In the case of turbomachinery blades and vanes, the main issue relates to what percentage of parts can be repaired, and what percentage have to be scrapped and replaced. The main saving for an airline will come from replacing scrapped parts with USM bought from a specialist provider, rather than buying new OEM parts at CLP. The HPT is the module whose parts have the highest CLPs and so can generate the largest saving.

A second way to achieve potential savings from USM is to use time-continued LLPs in the same modules.

A third is to use time-continued modules acquired from disassembled engines instead of performing maintenance on existing engines.

The engines examined here are the CFM56-3, CFM56-5B/-7B, PW4000-94 and the CF6-80C2.

CFM56-3

Out of almost 2,000 737-300/-400/-500s built, 734 of these are still in active service. This includes 469 passenger and 265 freighter and combi aircraft.

There are three main CFM56-3 variants: the -3B1, -3B2 and the -3C1. Of the 734 aircraft in active service, 535 or 73% are equipped with -3C1 engines. The -3C1 can be rated at 23,500lbs, 22,000lbs, 20,000lbs and 18,000lbs. The large number of retired aircraft includes several hundred 737-500s that were equipped with -3C1 engines. The -3B2 has a maximum thrust of 22,000lbs.

Engines rated at 23,500lbs are referred to as Class C engines, while engines rated at 22,000lbs and 20,000lbs are referred to as Class B engines. The -3C1 uses the highest standard material. In addition, some of the Class C and B engines were modified with CFMI's Tech Insertion programme, which used improved turbomachinery hardware that included 3D blades. The kit increased on-wing interval and reduced fuel burn.

The -3's mature removal interval will depend on the operating environment and the EFH:EFC ratio. Non-Tech Insertion engines rated at 20,000lbs thrust, however, can generally achieve mature intervals of about 8,000EFC.

Non-Tech Insertion engines rated at 22,000lbs thrust and 23,500lbs thrust will achieve shorter intervals of 6,000EFC and 5,000EFC.

Category C Tech Insertion engines are thought to generally achieve longer removal intervals of 9,500-12,000EFC.

A core engine SV workscope will either usually be a core restoration or

The CF6-80C2, and other older types like the PW4000-94, benefit from the large number of retired units available on the market. This allows operators of older 747-400s, 767-300ERs and MD-11s to utilise the aircraft for several years while minimising engine maintenance costs.

overhaul. Examining the three modules of the HPC, combustor and HPT will illustrate potential savings.

Aero Norway performs CFM56-3 maintenance and SVs, but also acquires -3 engines for teardown to salvage material for repair to be sold to airlines as USM. This includes material used for SVs performed at the company's facility. The USM from -3 engines generally attracts 45-50% of CLP, in contrast to 65-70% for younger generation engines. Tech Insertion 3D blades, however, fetch a high percentage value, but will achieve long removal intervals if that is required.

The CFM56-3 has a single-stage HPT with 72 blades. "The purchase price of each HPT blade is $12,500, so a complete shipset has a CLP of $900,000," says Marston. "A main issue is the percentage fill rate, which is the percentage of parts replaced with USM. The remainder will be repaired. If the fill rate is 50%, then about 36 of the blades will be repaired, and the other 36 blades will be USM purchased at a price of about 50% of the CLP for a new part.

The repaired 36 blades will cost about 25% of the price of a new part, so about $112,000.

The saving, however, comes with the USM versus the price of brand new parts from the OEM. This will be $450,000 for 36 new HPT blades. Each USM HPT blade is about $6,250 per blade, and so the cost of the USM is about $225,000. The saving is this about $225,000."

The other two main sets in the HPT module are the NGVs and the HPT shrouds. The NGV shipset has a CLP of about $1.535 million. On the basis of 50% being replaced with USM at a price of 50% of CLP, the saving is about $384,000.

The HPT shroud shipset has a CLP of about $268,000. One the same basis, the potential saving of 50% parts being replaced with USM is about $67,000.

Total saving in the HPT module from using USM is this about $675,000.

The CFM56-3 has a nine-stage HPC. The whole module will thus include nine rotor stages and nine stator stages, some of which will be variable stator vane (VSV). "The full shipset of blades in the HPC rotor stages has a CLP of $390,000-400,000," says Marston. "The CLP per blade of the first two stages is relatively high at $1,000-2,000. It is then a few hundred dollars per blade for the remaining seven stages. The cost of repair is $120-250 per blade."

An average repair cost of 25% of CLP will mean a cost of $70,000-75,000 for 70% of the blades.

USM purchased to replace the remaining 30% at a cost of $80,000 versus $120,000 for new replacement parts. This generates a savings of about $40,000. Similar savings can be made in the case of the nine stator stages, so a total savings of about $80,000 is possible for the whole of the HPC module.

There is then the possibility of using time-continued LLPs to gain further savings. This will make sense where the LLPs in a module are almost fully utilised, and the time required until engine retirement is substantially less than the life limit of new parts. "The market rate paid for LLPs for the CFM56-3 is generally 30-40% of the life value," says David Hobbs, director of engine material sales at Aerfin. "That is, if the LLPs for an LPT module are required, and those available have about half the full life remaining, then the rate paid for time-continued parts will be 30-40% of 50% of $965,000, which is $145,000-195,000. Large savings can, therefore, be made."

In may make economic sense for an airline to acquire time-continued modules. "It is possible to acquire a time-continued LPT module for a -3 engine for $400,000-500,000," says Hobbs. "This compares to $700,000-900,000 for a mix of repaired and USM blades and vanes, about $190,000 for time-continued LLPs, plus additional costs of other parts and sub-contract repairs, and the labour involved. A new shipset of LLPs for this module alone will cost $965,000.

"Another module that may be acquired as a time-continued unit will be the fan/LPC, which will have a market value in the region of $550,000 in the case of half-life LLPs," adds Hobbs.

CFM56-5B & -7B

The CFM56-5B and -7B have significant commonality, and most core engine modules are identical between the two variants. Exceptions are the fan and LPC. This commonality widens the scope for savings by using time-continued material and USM.

The original -5B series has eight variants. These were the -5B8 rated at 21,600lbs, up to the-5B3 rated at 32,000lbs thrust. These have the same hardware. There were two later main series. The first was the -5B/P; the /P suffix indicated a performance improvement package that reduced exhaust gas temperature.

The second was the -5B/3, which was a production standard that included the Tech Insertion hardware standard. Like the /P, the /3 programme improved engine performance and on-wing life.

Mature engines achieve removal intervals of about 10,000EFC, although they will be longer for engines rated at 27,000lbs and lower if they are not limited by remaining LLP lives.

The -7B series has six variants rated at between 19,500lbs thrust, for the -7B18, to 27,300lbs thrust for the -7B27.

Mature removal intervals will be compromised to an extent by LLP lives in the core, which are 20,000EFC. The highest-rated engines will have intervals of 9,000-10,000EFC, while low-rated engines can be 12,000-15,000EFC if they are not overly compromised by LLP lives.

There is a potential for savings of up to $700,000 when using USM in all core engine modules, and a saving of a further $445,000 for the LP modules.

The HPT provides the largest potential for savings. The -5B and -7B have a single-stage HPT, with 80 blades. CLP for the shipset is about $1.16 million. A typical fill rate for HPT blades will be 50%. Repair cost at 25% of CLP will mean that repairing half the blades will cost about $145,000. The cost of replacing the other 50% of blades with USM will be about $405,000, versus a cost of about $580,000 for replacing them with new OEM material. The potential saving is $175,000 in the case of HPT blades.

The HPT also has a single-stage NGV, which comprises 21 parts that each have a list price of $66,760. The shipset has a CLP of $1.4 million, the highest CLP for any stage of blades or vanes in the engine. In some cases, all parts can be repaired following a short removal interval, or for an engine operated at a low thrust rating. A relatively low repair cost for these items is about $350,000.

In the case of a fill rate of about 50%, half of the NGV can be replaced with USM at a cost of $490,000. This generates a saving of $210,000.

The final element of the HPT is the HPT shrouds. There are 42 in a shipset, which has a CLP of $245,000. A fill rate of about 50% means the repair cost for half the units will be about $30,000. The other half of the 42 parts can be replaced with USM at a cost of about $116,000, thereby saving about $7,000.

The total saving for the HPT module will, therefore, be about $420,000.

The combustion section of the CFM56-5B/-7B is a continuous combustion module, rather than individual combustion cans. The three main elements are inner liner, outer liner, and combustion casing. The casing is rarely repaired, and can be acquired for about $500,000, versus a price of about $755,000 for a new unit, a saving of about $255,000.

If the two liners cannot be repaired, and 30% are replaced with USM, then a small saving of about $40,000 can be made. It is, therefore, possible to save about $250,000 in the case of the combustion chamber module.

The HPC in the -5B/-76B is a nine-stage compressor, with the first three stator stages configured as VSVs. The overall shipset for all blades and vanes has a CLP of about $910,000. The average repair cost is about 25% of CLP.

A typical fill rate for the HPC is about 70%, so only about 30% of the parts are usually replaced with USM or new material. The repair cost for the 70% of parts is about $160,000. The cost of USM for the replaced parts is about $190,000, and a saving of $80,000 can be realised.

The total saving from the HPT, combustor and HPC modules in the core engine is up to $700,000.

There is also the possibility of an airline using time-continued LLPs. This makes sense when the 30,000EFC, 25,000EFC and 20,000EFC life limits of the three main groups of LLPs are considered.

"There is high demand for all types of -5B and -7B material," says Hobbs. "Airlines will have to pay a rate of about 100% of life factor, and even 120-130% for time-continued LLPs on these engines. Therefore, if a part has a life limit of 20,000EFC and a list price of $100,000, and its remaining life is 10,000EFC, then the market value will be at least $50,000 and up to $65,000."

Potential saving comes from buying fan/LPC or LPT parts when only half the LLP life is required. In the case of fan/LPC, buying a complete set of LLPs will save $350,000-450,000, and in the case of the LPT, a complete set of LPT parts at half life will save $400,000-600,000.

Lastly, time-continued modules will provide savings for airlines. One potential use is the purchase of fan/LPC or LPT modules with remaining LLP lives of 5,000-8,000EFC. "These can easily be sold by engine brokers and traders," says Hobbs. "The fan/LPC module on a -5B engine, for example, with 50% LLP life remaining can realise about $1.1 million on the aftermarket. This compares to about $860,000 for a full set of LLPs and up to $1.04 million for repair of about 70% of the blades and vanes at a repair cost of about $660,000, plus another $380,000 for the purchase of USM and other materials and parts, and all the associated labour of an extensive SV.

PW4000-94

There are four thrust ratings for the PW4000-94, between 52,000lbs and 62,000lbs. Most higher-rated engines power the 767-300ER and A300-600R fleets, while most PW4056 at 56,000lbs power 747-400s.

The 24 LLPs for engines rated at 52,000lbs and 56,000lbs have uniform lives of 20,000EFC. LLPs have uniform lives of 15,000EFC in the two higher-rated variants at 60,000lbs and 62,000lbs. A shipset of new LLPs has a CLP of $7.1 million.

Used engines can be acquired on the market at a pro-rate factor of about 50%. An engine with about half the EFC limits remaining will have a market value in the region of $1.8 million.

Most remaining aircraft and engines are operated on long-haul cycles that average 7.0-8.0FH. These are with the 747-700, 767-300ER and MD-11. Engine removal intervals are driven by EFH rather than EFC, and average 15,000-18,000EFC, or 1,900-2,400EFC.

There is potential for airlines operating the PW4000-94 to realise savings in engine maintenance. This can be more than $1.0 million in the case of blades and vanes of all four main modules, and several million dollars in the case of LLPs.

The PW4000-94 has a two-stage HPT, the first with 60 blades and the second with 82 blades. The first and second stage HPT blades have a shipset CLP of $1.02 million and $862,460.

On the basis of a fill rate of 50% in each stage at a shop visit, half the blades in the two stages can be repaired at a cost of about 25% of the CLP of new blades. The repair cost in these two stages is thus about $125,000 and $110,000.

The savings comes from using USM for the other half of the blades at a cost of about 70% of CLP. Thus, the savings in the first stage will be a cost of $510,000 for new blades, less the 70% cost of about $350,000 for USM, which is about $160,000. The savings in the second stage will be the CLP of about $430,000, less the cost of USM at about $300,000, equal to $130,000.

The two NGV stages of the HPT have 34 and 20 units. Total CLP of complete shipsets is $728,000 and $714,000.

A fill rate of about 50% might be expected by an airline. Repair costs are in region of 15-20% of CLP for each part. Savings will come from using purchased repaired parts as USM as an alternative to buying new parts. On the basis of USM acquired at about 70% of CLP, the saving in these two stages will be in the region of $215,000. Total savings in the HPT module from using USM in the two stages of blades and NGVs will thus be about $500,000. This is in the case of USM being used in all four stages during the same SV.

The LPT provides another example of potential savings. The module has four stages, with 128, 130, 126 and 128 blades. The blades have list prices of $1,700-3,300 each, and the entire shipset of blades have CLPs of $280,000, $219,000, $232,000 and $423,000, a total of $1.15 million.

The accompanying four rotor stages have 40, 44, 38 and 36 vanes. These have list prices of $7,500, $5,750, $7,350, and $8,290. The entire shipset of vanes have CLPs of $300,000, $253,000, $279,000, and $298,000; a total of $1.13 million.

Again, the fill rate may be about 50%, although this will vary and is less predictable for a mature engine. Average repair costs are $75-115 per blade and $250-727 per vane. The use of USM for the remaining 50% of blades and vanes in the LPT will provide the savings. A rate of about 70% for USM will generate savings of about $175,000 in the four stages of LPT blades, and $162,000 in the four stages of LPT, a total of about $337,000.

Clearly there is potential for further savings in the maintenance of other modules, such as the combustor and HPC.

Purchase of time-continued LLPs provides another opportunity to realise savings. A full shipset of LLPs on the PW4000-94 has a 2018 CLP of $7.1 million. This is split between $1.37 million for the fan/LPC, $2.6 million for the HPC module, $1.18 million for the HPT, and $1.94 million for the LPT.

In the case of using time-continued LLPs in SV maintenance, LLPs with about half EFC limits remaining can thus provide substantial savings for operators. The 15,000EFC and 20,000EFC life limits of LLPs in the engine and the typical rates of utilisation mean that most parts are fully utilised and due for replacement at an age of about 20 years or more.

Airlines are likely to pay a rate equal to about 70% of CLP, adjusted for remaining life. For parts with 50% of EFC remaining, this would be a purchase cost of $479,000 for the fan/LPC, $911,000 for the HPC, $414,000 for the HPT, and $678,000 for the LPT. This translates into savings compared to the OEM's CLP of $889,000 for the fan/LPC, $1.69 million for the HPC, $770,000 for the HPT, and $1.26 million for the LPT. This totals savings of $4.6 million for all engine modules. The savings in each module would be greater where remaining EFC life is less than the 50% used here. These savings will be particularly attractive to freight carriers operating the 747-400 or MD-11 for another five to eight years, or to passenger airlines that have delayed the retirement of 767-300ERs.

CF6-80C2

The CF6-80C2 is a similar case in point to the PW4000-94. Both engines power the same aircraft, similar numbers have been retired, engines remaining in service have similar operational and utilisation characteristics, and both can be acquired on the aftermarket at similar pro-rate factors of 50%.

The CF6-80C2 shipset of LLPs has a 2018 CLP of about $7.75 million. The parts in the fan/LPC, HPC and LPT modules have uniform lives of 20,000EFC, and parts in the HPT have lives of 15,000EFC. The implication is a market value of about $1.94 million for and engine with 50% of LLP life remaining.

The CF6-80C2 has mature removal intervals of about 2,400EFC when powering the 747-700, intervals of about 2,500EFC when powering the 767-300ER and 2,200EFC when powering the MD-11 at a higher thrust rating.

The CF6-80C2 has two-stage HPT, and like all other engines, savings are made between the difference of purchasing new material and buying USM at about 70% of CLP. Blades in the two HPT stages have CLPs of $16,500 and $9,500 per blade, and there are 80 and 74 blades in the two stages. This is a total shipset cost of about $2.02 million for all 154 blades. In the case of repairing 50%, and purchasing USM for the other 50% of the blades, a USM market rate of 70% will generate savings of about $300,000 for the HPT blades.

The two HPT NGV stages have a total CLP of $1.33 million. On the same basis of a 50% replacement rate, the possible savings when purchasing USM is up to about $200,000. Total potential saving for this module is thus about $0.5 million when all blades and NGVs are considered.

The LPT presents another opportunity for savings. The LPT has five stages. The CLP for a complete set of LPT blades is about $1.32 million, and the CLP for a complete set of LPT vanes is $1.99 million, for a total of $3.31 million. On the same basis of a 50% replacement rate for the entire shipset of blades and vanes in the module, the potential savings from USM is $497,000.

The purchase of time-continued LLPs provides another substantial opportunity for savings. As with the PW4000-94, the pro-rate factor in the aftermarket for purchasing CF6-80C2s with time-continued parts is in the region of 50%. The 2018 CLP for a complete shipset of LLPs is divided between $2.167 million for the fan/LPC, $2.15 million for the HPC, $1.43 million for the HPT, and about $2.0 million for the LPT.

An engine with half the LLP EFC limits remaining will, therefore, have a market value of about $1.94 million. This will be split between $542,000 for LLPs in the fan/LPC, $538,000 for parts in the HPC, 357,000 for parts in the HPT, and $499,000 for parts in the LPT.

In the case of using time-continued LLPs in SV maintenance, LLPs with about half their EFC limits remaining will provide about 10,000EFC for the fan/LPC, HPC and LPT modules, and 7,500EFC for the HPT modules. If purchased at a factor of about 70% of pro-rate life, potential savings compared to the purchase of new parts at CLP are about $1.4 million for the fan/LPC, $1.4 million for the HPC, $930,000 for the HPT, and $600,000 for the LPT. This is a total of up to $4.3 million on the basis of the entire engine's LLP stack being replaced with time-continued LLPs.

The possible savings with CF6-80C2 extend from several hundred thousand to up to $1 million at each shop visit. This is possible considering the age of most engines that are retired, and the likely number of years that 747-400s, 767-300ERs and MD-11s will be operated. AC