Few IT systems exist to analyse EHM data, and devise a removal plan for a fleet of engines based on array of parameters. The functionality of these systems to consider all parameters and optimise maintenance costs, and how they are interfaced with EHM and M&E systems is examined.

Structuring an M&E IT system for engine maintenance management

The management of engine maintenance has undergone many changes over the past 15-20 years. The traditional system whereby airlines managed and conducted the maintenance of their own engines, or sub-contracted shop visits to independent shops, now competes with other options, including the management of engine maintenance under fixed-rate per engine flight hour (EFH) contracts. These are generically referred to as power-by-the-hour (PBH) contracts, and are offered by engine original equipment manufacturers (OEMs) and independent engine shops. PBH contracts not only provide maintenance at a pre-agreed fixed rate per EFH, but can also include additional services, such as health monitoring and engine maintenance management.

IT engine management

In addition to the increased options for arranging and performing engine maintenance, there has been an evolution in the quantity and quality of information provided by engine health monitoring (EHM) systems to assist in managing engine maintenance. There have also been several developments in the software available to process EHM data, and manage the removal of engines in a fleet, and plan shop-visit workscopes with the aim of achieving a lower overall cost per EFH for an entire fleet of engines.

The availability of software systems to manage engine removals and shop-visit workscopes is limited, however, compared to the plethora of maintenance & engineering (M&E) systems available for airlines to manage, plan, monitor and record the inputs of airframe base checks.

There are several best-of-breed and enterprise resource planning (ERP) M&E systems. These systems include Swiss AMOS, Trax, DigiMAINT, OASES, IFRSKEYES, Ultramain and Ramco *(see MRO IT market vendors survey, Aircraft Commerce, February/March 2011, page 40).*

Most M&E systems have limited or no functionality to monitor the in-service performance and operational health of engines, plan the optimum time for their removal in relation to a likely workscope and perform a variety of other engineering functions, and overall achieve the lowest maintenance costs per EFH.

A second level of engine management functionality that is generally lacking in many M&E systems and specialist point solutions is monitoring engine shop-visit progress, and compiling shop floor data collection (SFDC) information for financial management purposes.

This lack of development of engine management functionality within M&E systems is perhaps explained by an increased percentage of engines being managed under PBH contracts, especially those provided by engine OEMs. Since the onus is on the OEM to achieve the lowest possible cost per EFH, airlines may not have felt a pressing need for their M&E systems to have such functionality.

About half the engine fleet is still maintained, however, in airline or independent shops. Since the cost of engine maintenance represents such a high percentage of total aircraft maintenance costs, the need for specialist engine maintenance IT functionality may be greater than is immediately apparent.

There are, however, some specialist point IT solutions for providing engine engineering and maintenance management functions. These can be interfaced with M&E systems.

One specialist point solution that can be interfaced with an M&E system is the EFPAC engine management system, provided through AerData.

Some M&E systems also offer some functionality for managing engines.

The first M&E system to provide engine engineering and financial management functionality is Ultramain. The latest version, Ultramain 9.0, will have an option of a Powerplant Management module, with functionality for both engineering and financial management, and managing the process of the engine shop visit.

The RAMCO ERP system also has some functionality for engine engineering management. It also has extensive capability for shop-visit management.

Engine maintenance options

There are five main ways an airline can manage engine maintenance. From an IT perspective, this starts with the trend monitoring or EHM system in all cases. The use of any additional systems depends on how an airline manages the M&E for each of its engine fleets.

A key influence on the choice of engine management is whether the engines, and the aircraft they power, are owned or on long-term leases, or are on short-term leases.

Many of the world's larger carriers still use the traditional system of in-house engine management and maintenance. From an IT perspective, airlines will start with EHM systems, or data from an EHM system, gained from engines while in operation. The EHM system will be one provided by an engine OEM, or an independent system, or one developed in-house by the airline.

In-house engineering management and maintenance means an airline may

Although many engines are now managed under all-inclusive packages offered by the OEMs, more than half the engine fleet is still maintained in airline and independent shops. The engineering management for many of these engines is still performed by airlines, and specialist IT systems are designed to optimise their management.

choose from: the traditional method; a specialist point solution such as EFPAC together with its M&E system; or the module of an M&E system such as Ultramain's new Powerplant Management.

Using an independent, or major airline, engine shop has traditionally meant the airline was charged on a time-and-material basis. Engine management was therefore the function of the airline, which would use an EHM system, and then choose between: performing engineering management manually; or using EFPAC or another specialist solution in conjunction with an M&E system. This choice has been widened with the introduction of Ultramain's Powerplant Management.

One option for an airline is to sub-contract the engineering management to a provider such as Total Engine Support (TES) in the UK. TES developed EFPAC, prior to selling the solution to AerData in 2009. TES still uses EFPAC as an IT solution for the engineering and financial management functions of its customers' engine fleets.

In more recent years, independent and major airline shops have expanded their choices to offer PBH-style contracts to airlines as an alternative to the OEMs. These provide similar services to the OEMs so that airlines can leave most of the management of their engines, including coordinated engine removal timings, to the maintenance providers. "Such contracts mean the customer has no control over what parts are used in a workscope, or its content," says Lionel Maisonneuve, technical support services manager at TES. "The onus is on the provider to provide maintenance cover at a cost lower than the agreed PBH rate for the length of the contract. The maintenance provider may then try to reduce the cost of shop-visit workscopes, which may not be good for the long-term maintenance status of the engine."

Independent shops also now offer not-to-exceed cost per shop visit contracts, and fixed-price contracts for individual shop visits. "Not-to-exceed contracts will stipulate a limit on the shop visit price, plus certain upper limits for the percentage of parts that can be scrapped and replaced in each module," explains Maissoneuve. "This might be 40% in the case of high pressure turbine (HPT) blades. If the scrap rate is 60%, then the additional 20% of blades that are replaced have to be paid for at cost. If the airline is in luck, however, and the HPT scrap rate is only 20%, then the shop visit will cost less than $2 million.

"With a fixed price contract of, for example, $2 million per shop visit, if the actual cost is higher than $2 million the airline customer still pays no more than $2 million," continues Maissoneuve. "The same is true, however, if the actual cost for the shop visit is lower and the engine has a relatively light workscope."

Whatever type of contract is agreed with the airline customer, the onus is on each independent and third-party airline maintenance provider to manage its customers' engines to achieve the lowest cost per EFH. The engine shop therefore has to decide which IT systems to employ to manage engines from an engineering and financial perspective. It also has to interface its IT systems with the EHM data that come from the airline customer.

Support programmes offered by the OEMs include maintenance on a PBH-style contract, engineering management, and several ancillary services. These can include spare engine provisioning, supply and management of engine line replaceable unit (LRU) and accessory components. The engineering services will include EHM data and trend monitoring, removal timing decision, managing ADs and SBs, and shop-visit workscope definition and pattern.

The OEM is under pressure to make a financial margin from the fixed rate per EFH offered. The OEM will therefore use IT systems of its choice to perform the management functions.

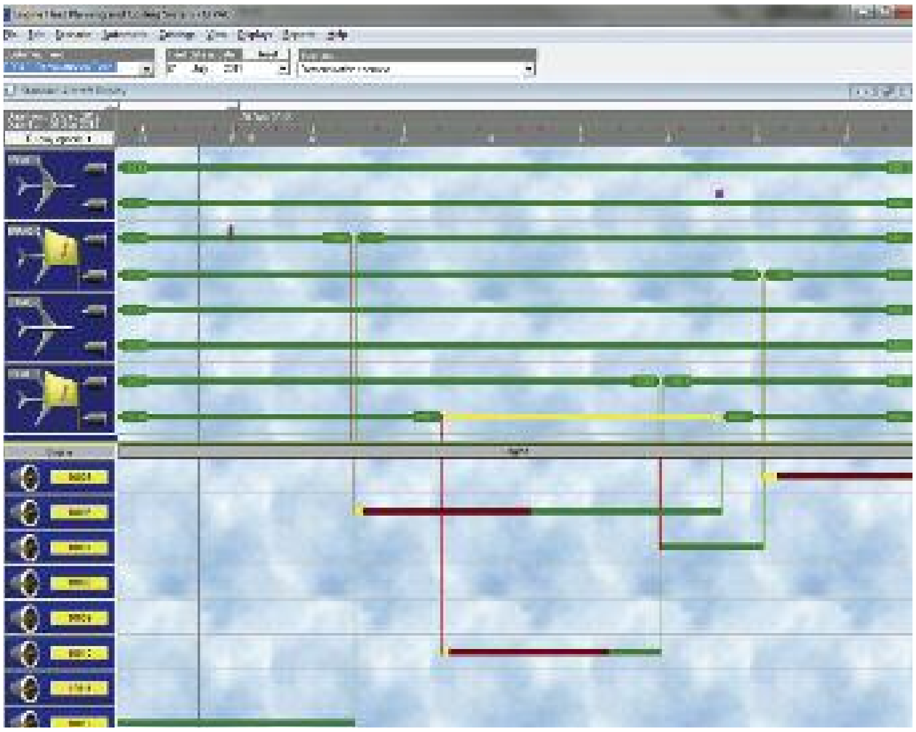
EHM

The data provided by engine health monitoring and its analysis are the first stage in the process of managing engines. A lower maintenance cost per EFH can generally be achieved for longer planned removal intervals between shop visits. Longer planned removal intervals can partly be achieved through the better monitoring of engine health and performance parameters. It can also prevent or reduce the incidence of unscheduled removals, for example.

EHM starts by collecting engine performance data from monitoring equipment on the engine. The raw data can be transmitted to a ground receiver either while the aircraft is in the air, or when it is on the ground and at the terminal gate after landing.

"A large number of an engine's parameters can be measured through EHM," says Mike Chemerynski, general manager of Pratt & Whitney Integrated Service Solutions. "The actual number of parameters depends on the on-board equipment on the engine and aircraft. The main ones are: the engine's exhaust gas temperature (EGT); fuel flow (FF); the speeds of the engine's two or three spools referred to as N1, N2 and N3; the vibration levels of the N1, N2 and N3 shafts; temperatures and pressures in each of the engine's modules; various aircraft flight conditions such as altitude and outside air temperature (OAT); various parameters from the oil system; and the engine's bleeds."

There are typically 30-40 main parameters monitored directly from sensors in the engine, many of which have to exist for the flightdeck avionics. "Another 60-100 parameters can be derived from these primary parameters by calculation," says Charles Dibsdale,



Reasons for engine removal are LLP life limit expiry, ADs, return lease conditions and engine performance and EGT limitations. EFPAC forecasts each engine's latest possible removal date, which are represented by flags.

PEHM chief engineer at Osys. "This includes factors such as engine thrust being generated and fuel efficiency.

"Other parameters relating to the engine's controls, such as bleed valve and guide vane positions, can be monitored," adds Dibsdale. "Parameters in the auxiliary systems can also be measured. These include the lubrication, fuel flow and full authority digital engine control (FADEC) units."

In most engine types these parameters are recorded at three or four main phases of each flight, including take-off and cruise. "The significance of these two phases is that take-off indicates the engine's performance at the highest thrust levels, while cruise is when the engine should be operating at a stable rate," says Maissoneuve. Other phases, such as approach or descent, can also be measured. The parameters are recorded automatically in modern aircraft types.

The important issue for engine management and maintenance is the transmission of EHM data to the ground, and its storage and analysis. "EHM data can be transmitted during flight to ground receiving stations using the aircraft crew and reporting system (ACARS)," says Dibsdale. "This provides line-of-sight transmission using VHF radio. ACARS messages are now also being sent to ground stations via satellite. Another method is to transmit the data from the aircraft when it is on the ground after landing. One method is gatelink, which uses a broadband connection."

Other examples of on-ground communication systems are transmissions of data over cellular and WiFi networks.

A common misperception is that all EHM data have to be transmitted to the ground in real time to prevent unscheduled removals. EHM data are received, processed, analysed and trended over the long term for a series of flights to detect a trend in main performance parameters, such as fuel consumption and EGT. This helps to decide the optimum time to remove an engine for shop-visit maintenance. Real-time transmission of EHM data is therefore not required.

Real-time transmissions of particular EHM parameters can be made for safety issues. "The aircraft's on-board aircraft health monitoring (AHM) and EHM systems generate reports when certain parameters exceed a pre-set safety level, and send them in real time if necessary," says Chemerynski.

Data transmitted by ACARS is a sub-set of ASCII codes. "Most ACARS messages are fixed format text files. ACARS does not have a full set of character codes, but only some of the ASCII codes, which have 256 characters," says Dibsdale. "The packet of EHM data transmitted to the ground is only about 3.5Kb, and so small in size. The Osys/Rolls-Royce system takes three of these snapshots per flight, and each packet costs $5-6 to send. Cost constraints therefore determine how many data snapshots can be captured and sent to the ground. Rolls-Royce introduced a system called ETRECS, which uses ASCII characters and letters to represent numbers."

The data transmitted from an aircraft in flight are captured in many different formats. "Most aircraft generate reports at the take-off, climb and cruise phases of each flight, but they can also be at other phases of a flight," says Chemerynski. "Data formats vary between airline and aircraft type. Our advanced diagnostics and engine management (ADEM) system accommodates all EHM data formats. Data have to be reformatted according to the various engine management and M&E systems and ground infrastructure used by each airline."

EHM systems

EHM systems, and the systems to process raw EHM data, were traditionally sold by the OEMs to airlines together with the engines as part of the purchase package. OEMs dominate the supply of EHM systems, although they do not have an absolute control over it. Some OEMs also provide EHM systems for competing engines in a few cases. "Pratt & Whitney provides EHM software for some competing engines as part of its engine management programme (EMP) services. This includes the CFM56," says Chemerynski.

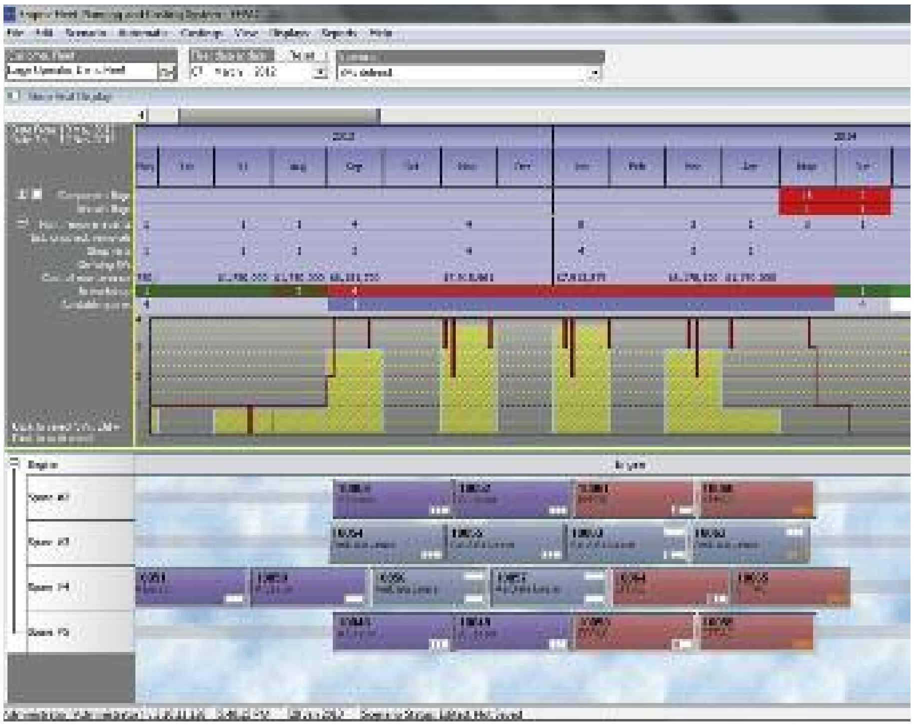
MTU Maintenance is an independent maintenance shop that has developed completely independent EHM software for the engine types it provides maintenance for across its network of shops: the CF6-50 and -80 series, the CFM56 family, the V2500, the GE90 Growth, the CF34 and the PW2000. "Some airlines have also developed EHM systems," says Uwe Zachau, senior manager performance and central engineering at MTU Maintenance. "This starts with the OEM-based model and has additional capability added.

"An EHM system is developed from the thermodynamic model of the engine type, but there is no limit to developing an EHM system for any engine type," continues Zachau. "For example, an airline or independent shop could develop a system for the PW1000G or LEAP-X."

Lufthansa uses several EHM systems for its engine fleet. "We use the GE diagnostics system for our CFM56 and GE engines; and the Osys system for our Trent 500, 700 and 900 engines, and our own custom-built PW2000 and PW4000 engines," says Thorsten Kuehl, team leader of ECM at Lufthansa Technik. "We built our own system together with a software company. An algorithm and formula were developed for each engine parameter to process the raw data."

EHM processing

The raw data provided by the engine are the intellectual property of the airline



Engine shop visit plan and budget is optimised for the lowest costs possible for the fleet, taking into consideration spare engine availability. It also takes into consideration EGT limitations as well, however, by not overbuilding engines, meeting return conditions and airworthiness requirements.

operator, but airlines using EHM systems provided by the OEMs, are often obliged to provide OEMs with the raw data for processing with analysis software. "Whether or not the data are given to the OEMs depends on the purchase contract, but the data can only be used to manage the airline's engines," says Zachau.

Nevertheless, OEMs like to have data from a range of operators to analyse the performance of an engine across a range of fleets and operations. Data from different operators with different route networks and operating conditions can be normalised by the OEMs to establish patterns of deterioration and rates of EGT margin erosion and other key performance parameters. "There are confidentiality agreements with each airline," says Dibsdale, "so each one's data are kept confidential and only used by Rolls-Royce, for example, for its own purposes. This analysis of fleetwide data is used to improve an engine type's reliability."

The alternative for some airlines is to analyse the data using the OEM's software and adding its own triggers and alerts. "This is the case where airlines are managing and maintaining their own engines," adds Chemerynski.

The M&E systems used by airlines to manage their fleet, the associated line and base maintenance, and configuration of each aircraft, have limited or no ability to manage and analyse raw EHM data.

Raw EHM data are first processed by the OEM's EHM software, but are also processed and trended by specialist solutions such as EFPAC.

PW's EHM system is ADEM. "Both PW and its airline customers use and analyse the EHM data. This is ultimately used to monitor the engine's health and operating performance with a view to increasing time on-wing and reducing the number of unscheduled removals and shop visits," says Chemerynski. "Our customers use ADEM to manage their own in-house maintenance, or when they contract with us for cost per EFH maintenance packages."

The EHM processing system has changed, however, with the increased acceptance by airlines of PBH-style contracts provided by the OEMs. EHM data are now sent directly from the aircraft to the OEM, while technically remaining the intellectual property of the airline, and is processed and stored by the OEM. The results of analysis are sent to the operator, who also receives alerts in real time for problems encountered during operation for the purposes of avoiding unscheduled removals. Bigger airlines can receive raw data, however, and analyse and process it themselves.

Airlines managing their engines and performing their own maintenance can buy EHM software, access it via a remote server from the OEM, or get the raw data analysed by an independent engine maintenance provider. EHM software is less likely to be bought by a smaller airline, or by one that has the aircraft and associated engines on short-term leases.

The cost of an EHM data collection and analysis service from an OEM is also influenced by the size of the fleet. An airline with a larger fleet can get an EHM service from an OEM for $2-3 per EFH.

Engine management

Several variables affect the ultimate maintenance cost per EFH. The time on-wing between planned and unplanned removals is probably the biggest influence on the ultimate cost per EFH.

Unplanned removals can result in very high shop-visit costs. A failed bearing, for example, can lead to a shop visit that is more expensive than a full overhaul. The reduction or near elimination of unplanned removals will therefore have a large impact on increasing average time on-wing between removals and reducing the overall maintenance cost per EFH for a fleet.

EHM can also be used to improve planned and scheduled related shop-visit maintenance by increasing removal intervals through improved predictions of the degradation of EGT margin and fuel efficiency. This will clearly improve overall costs per EFH.

Besides the on-condition performance of the engine, the engine flight cycle (EFC) limits of life limited parts (LLPs) will also force shop visits as the LLPs come close to expiry. Monitoring LLP lives is more important for engines operated on short cycle times, compared to those operating on long-haul missions.

A compromise may have to be made between the ultimate EFH removal interval for on-condition maintenance and LLP lives, especially for engines operating on short average cycle times.

Shop-visit costs increase with longer removal intervals, since the percentage of parts that has to be scrapped and replaced, or repaired, rises. This involves examining the relationship between removal interval and cost per EFH. "This requires extensive engineering knowledge of what affects shop-visit workscopes, the rate of parts replacement, and overall costs," says Maissoneuve. Cost per EFH will generally decline as planned removal interval increases because of the diluting effect of longer accumulated EFH. The cost per EFH will reach a trough with extended removal intervals, but the cost curve can rise for very long intervals. This is explained by the increase in the percentage of parts replaced, and shop-visit costs rising faster than incremental increases in removal interval because of sudden rises in the scrap and replacement rate of parts.

Airlines are rarely able to achieve such long removal periods that the resulting maintenance cost per EFH starts to rise. This is because removal intervals and timings become compromised by other issues, such as: LLP expiry;

TES UK specialises in managing engines, and uses EFPAC as its software tool. One customer includes UTAir, for which TES manages a fleet of more than 200 engines.

hardware deterioration that forces removals; reliability problems; the need to incorporate airworthiness directives (ADs) and service bulletins (SBs); and the constraints of shop capacity and number of spare engines. Airlines should aim to maximise planned removal intervals. There is also the issue of establishing a balanced, planned removal interval and shop-visit workscope pattern to achieve the overall lowest cost per EFH.

The fact that many engines in a fleet may be leased, further complicates matters. Engines needing to be returned to lessors at a particular date and in a specific maintenance condition can pose serious limitations on optimising engine management and resulting cost per EFH.

Managing all these issues for one or two individual engines, and achieving a balance between removal intervals, and shop-visit workscopes and costs may be possible using traditional manual techniques. It will be virtually impossible, however, for an entire fleet.

IT for engineering functions

Optimising all variables and the overall management of an engine fleet is made possible by specialist engine management software solutions. These are the EFPAC system, Ultramain's Powerplant Management module, and Ramco's engine management module.

EFPAC

EFPAC's main functionality is its ability to take into consideration the workscope, engine's maintenance status at the last shop visit, and the accumulated time on-wing, to predict the likely workscope and its cost at the next planned shop visit. Moreover, it can predict the variation between time on-wing and shop-visit workscope, and the resulting cost.

It makes these calculations by taking several factors into account, including operational performance issues such as EGT, vibration and fuel flow. EFPAC also requires extensive input from experienced engineers that understand how differences in removal interval affect issues such as part and component scrap rates, shop-visit workscope, and the resulting cost.

EFPAC further takes LLP lives into consideration, as well as time remaining until ADs have to be implemented, and their cost together with the cost of SBs.

EFPAC is therefore able to optimise the management of an engine fleet with respect to cost per EFH. The system requires a feed of essential data, such as: processed EHM data; accumulated EFH and EFC data; engine configuration data; and data on lives of installed LLPs. These data will be managed by M&E systems.

EFPAC not only considers single removals and workscopes, but several successive workscopes for each engine. So while a longer first removal interval may result in a lower cost per EFH up to that removal, the second interval may be shortened because LLPs limit the total time of the first and second intervals.

EFPAC therefore calculates several shop-visit removal scenarios for each engine, and the entire fleet, over three or four successive removals. It then provides transparency of multi-year and multi-removal plans.

"First, M&E systems have little or no ability to manage and analyse EHM data," says Louis Hazen, senior technical consultant at AerData. "EFPAC is the system that uses EHM data, in particular EGT and EGT margin data. EFPAC is not an operational or a day-to-day operational solution for closely watching engines. This is a task of the alert functions of EHM systems. EFPAC is a long-term planning tool.

"The EHM data can be fed into EFPAC from the OEM, or an airline's own EHM system, via the internet," continues Hazen. "EFPAC then analyses the data. It uses the main parameters after it has been processed."

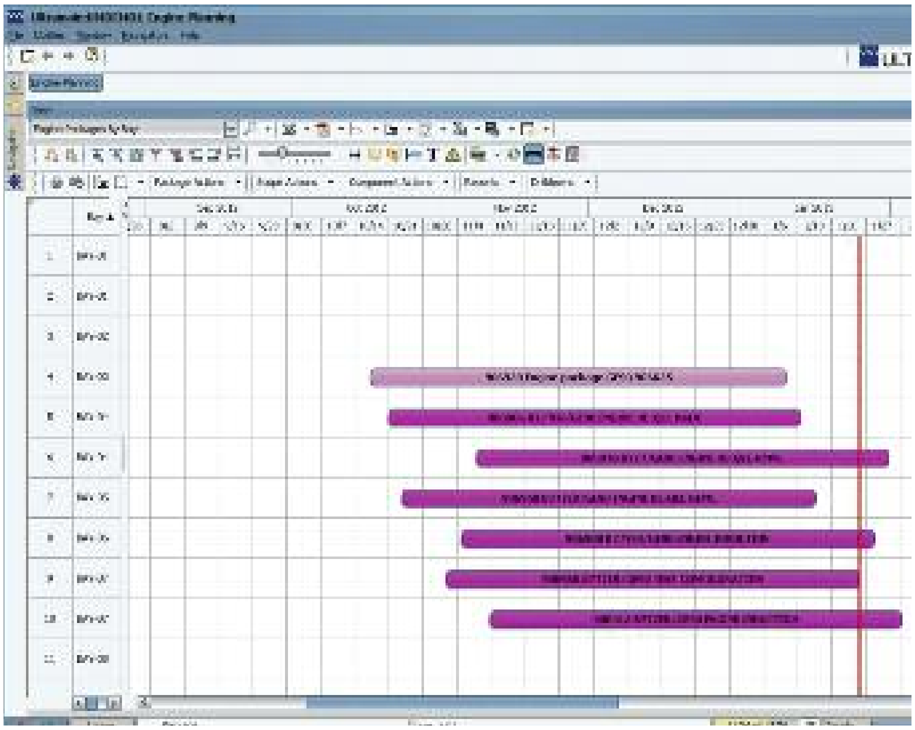
EFPAC can extrapolate EGT margin, fuel flow and vibration degradation data. "The user can set alert levels to warn when it is appropriate to remove the engine," says Maissoneuve. "Even though EFPAC can optimise the removal plan for an engine fleet, the user's engineers decide when to remove it."

LLPs are tracked by EFPAC when the configuration of an engine is entered into the system; including the serial number of each LLP, its exact time of installation and the accumulated EFC. Once in operation, the EFC from each day's operation are fed into EFPAC from the M&E system. EFPAC then recalculates the remaining EFC for each part, and the LLPs with the shortest lives are represented by vertical timeline bars as alerts on the gantt chart.

Overall, once each engine removal plan has been generated by EFPAC, the system will summarise the planned date for each removal, accumulated EFH and EFC, the workscope to be performed, and the estimated cost. The system provides transparency for each removal plan, allowing the user to drill down to all detailed information.

TES specialises in offering third-party engine engineering management services for airlines that wish to subcontract this function. "We manually load EHM data into EFPAC, although it can also be loaded automatically," says Maissoneuve. "This is together with EFH and EFC data, as well as EHM data relating to oil consumption, vibration and fuel flow."

TES uses EFPAC to manage engine fleets for Air Astana, National Air Cargo, Ryan International, Martinair, UTAir and Sriwijaya Air of Indonesia. "These customers want us to manage their engine fleets, decide when to remove, plan shop-visit workscopes, track ADs and SBs, and minimise the long-term maintenance cost



Ramco uses a gantt chart for managing engines and their the timing of their removals. The colour of the bar represents different management activities.

of the engines," says Maissoneuve. "Some of our customers have time-and-material contracts. We therefore advise the airline, and negotiate with the engine shops with them on shop-visit workscope and costs. Other airlines have not-to-exceed or PBH contracts, and ask us to negotiate with shops on their behalf."

Powerplant Management

As described, Ultramain's Powerplant Management is a module of Ultramain's M&E system. Powerplant Management is an alternative to EFPAC.

The first main step with engine engineering management is the use of a configuration tree to monitor the component and part configuration of the engine. Each engine module is mapped, and the serial number of each part installed is listed. This configuration map includes the limited lives of parts where applicable. "This particular functionality of the system can also have a lot of labour and material cost associated with each part and module," says John Stone, director of product management at Ultramain. "That is, the man-hours required for assembly, disassembly, repair, and overhaul of each part and module can be programmed to estimate the labour for shop-visit workscopes."

Ultramain's philosophy is that the trending and extrapolation of EHM data is best left to the OEMs' EHM systems. "An IT interface is needed between the OEMs' EHM systems and Powerplant Management so that it can be informed of the limits an engine can remain on-wing until EGT margin has eroded to a particular level," says Stone. "Powerplant Management uses this to know the limit of extending a removal interval. The user knows this upper limit, and uses it as part of the engine management process. The system can also be programmed with expected planned removal intervals.

"The module uses a gantt chart to illustrate a timeline of removal for each engine in the fleet," continues Stone. "For example, engines currently scheduled in overhaul is represented by a yellow bar on the Gantt, indicating a planned removal interval. Based on this interval, the accumulated time since the last shop visit, and the workscope at the last shop visit, the shop visit cost is estimated.

"The removal intervals can then be modified with a 'what if' scenario. These new removal dates are represented by a green bar in the same Gantt," adds Stone. "The system re-calculates the cost of the shop visit associated with the revised removal date. The system can make cost comparisons of the two plans, and summarise the labour and cost of materials for the shop visits for the overall fleet. This is all possible because of the system's cost forecasting functionality."

Ramco

Ramco is the third main system with engineering management functionality. "Ramco does not analyse and trend EHM data. Our customers send EHM data to another system," explains Praveen Neelambaran, principal consultant aviation practice at Ramco. "Our engine management functionality starts with a timeline of planned removals for each engine on a gantt chart, as do all systems. The type of icon used represents the type of planned workscope.

"The system uses historical utilisation to project a basic planned removal date," continues Neelambaran. "Ramco has an advanced planning scheduling (APS) module to generate an optimised removal plan for the fleet. It starts with the basic removal plan, with the predicted removal date, then takes in data on operational and practical constraints, including the physical limitations of: removals being close together or clustered; shop capacity; supply and availability of parts; spare engine availability; and turnaround time. The user can optimise the plan on a just-in-time or an as-soon-as-possible basis.

"The removal plan can also be optimised on another basis," continues Neelambaran. "The options are: maximising the number of fulfilled turn times for engines in the fleet; minimising the number of late turn time penalty costs; minimising the number of violated turn times; simulated annealing on late days versus early days; simulated annealing on total cost for the fleet; and overall total cost. This last option does not just consider costs, but also lost revenue or opportunity cost from excessive downtime. This gives the overall lowest cost for the engine fleet. This optimisation and calculation is done by the APS module, which interfaces with the main M&E system so that all relevant factors and data can be considered."

Much of the functionality described is relevant to airlines that perform maintenance in-house or sub-contract to independent shops. Although PBH-style contracts offered by the OEMs are intended to remove all management functions for the airline, Hazen explains that IT solutions for engine management can still be used by airlines to generate savings. "Airlines still need to keep track of airworthiness data such as ADs, SBs and LLP lives. They also have to provide the OEMs with the expected and actual EFH and EFC utilisation data," says Hazen. "There are several reasons why there has to be coordination between airlines and the OEMs with PBH-style contracts. Utilisation data is used by the OEMs to plan engine removals, and the OEMs need to inform the airlines of what the planned date is. Airlines clearly need to coordinate engine changes with sufficient downtime in the flight schedule maintenance programme.

"Airlines use EFPAC to analyse the economics and financial impact of the OEMs' proposals," continues Hazen. "The main issue is that PBH contracts have a lot of exclusions, while inclusions vary widely between contracts. Examples of items that may or may not be included are fuel-saving SBs that are applied at the operator's discretion, certain LLPs, and consideration for the return conditions of leased engines. The financial impact of such issues falls outside the scope of the PBH rate. A second issue is that airlines have to re-negotiate new PBH contracts for the same engine when the first contract expires. Third, EFPAC is very helpful when an airline introduces used engines into a fleet, and has to decide whether to put them on PBH contracts or organise the maintenance itself."

While airlines need to have control over engine utilisation and technical data when using PBH contracts, the OEMs also use software to manage engines. RR uses several systems, and started with Maximo, an enterprise asset management (EAM) solution. "Maximo's prime function has evolved into managing and providing engine utilisation data, information relating to modifications, tracking and recording line maintenance, and defining maintenance and shop-visit workscopes," says Dibsdale. "We use Maximo with SAP, which is our primary system to manage maintenance and the engine's configuration. The functionalities of the two systems have evolved over the years, so they now overlap. We use SAP's maintenance management function to define major shop-visit workscopes, while Maximo records line maintenance.

"We use a third system called practical engine lifecycle management (PELM) to achieve the most economic management of engines," adds Dibsdale. "PELM looks at all the factors that cause removals and aggregates the data into a pareto graph. It analyses which engines have the highest risk of failure or an unscheduled removal or EGT margin deterioration. PELM also has an economic function, and can generate an engine removal plan to maximise engine availability to cause minimum disruption to the operating schedule and deliver the lowest cost per EFH."

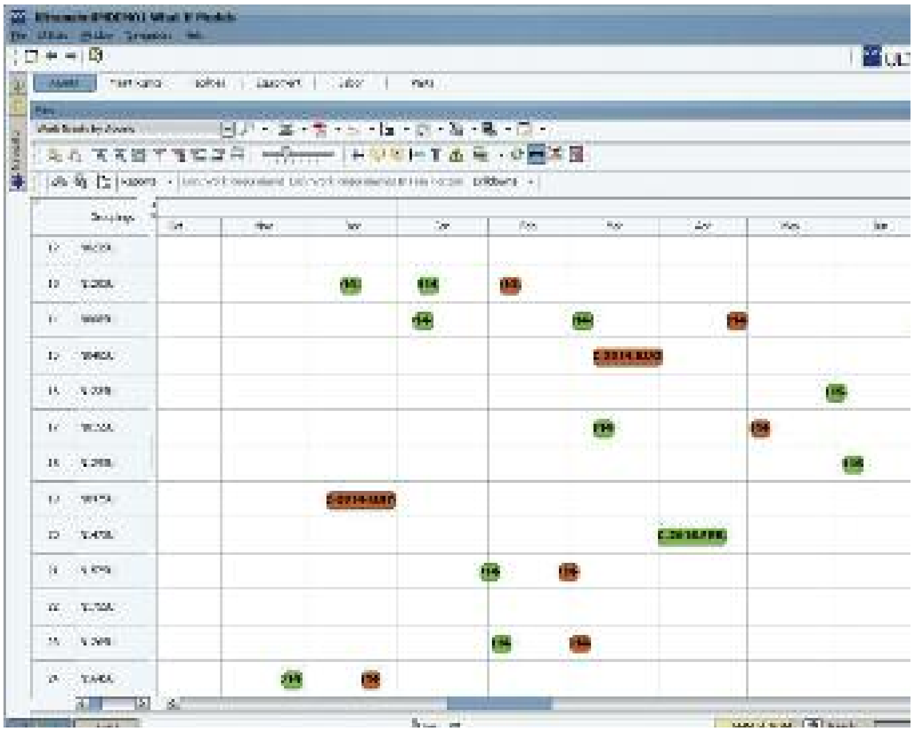
IT configuration

The basic configuration of an IT system for managing engines and carrying out their maintenance in-house therefore starts with either an OEM-supplied or an airline's own EHM system. The processed EHM data are then fed into EFPAC, if used by the airline. EFPAC also has to take data feeds from the airline's M&E system or specialist module such as Powerplant Management.

"The main streams of data that have to flow between the M&E system and EFPAC is the daily feed of aircraft utilisation data, and the engine's installation date, component configuration, and shop-visit history," says Hazen. "Shop-visit history has to include details for each module and that of each workscope performed. This will include data on which parts were repaired and or replaced. The shop-visit history data may come from a separate file, rather than the M&E system."

Prior to any maintenance being performed on the engines, no data have to be transferred from EFPAC to the M&E system. "EFPAC will use the data feeds from the EHM and M&E systems to calculate its optimised removal plan. The planned removal dates for each engine can be manually entered into the M&E system," says Hazen. "The actual date of removal will then be manually input into EFPAC and the M&E system.

"Post-maintenance EFPAC generates a detailed workpackage, using data from the shop-visit report from the engine shop," continues Hazen. "The shop-visit report has to be entered into the M&E system, because it tracks the engine's configuration and holds all technical and maintenance records. The data are then transferred to EFPAC so that it can continue the optimising process. There is inevitably some manual intervention, since an engine's configuration can change while it is off-wing."



Ultramain's Powerplant Management module has a 'what if' scenario capability to analyse the effects of changing removal dates and the scope of shop visits.

As described, Ultramain's Powerplant Management system does not take in EHM data, but instead will use an interface with the OEMs' EHM systems to tell Powerplant Management the maximum limit an engine can remain on-wing based on parameters such as EGT margin degradation. "Powerplant Management does, however, take in aircraft and engine utilisation data, the time since the last shop visit, and details of the workscope."

Shop visit management

A second main issue of engine management is monitoring each engine through the shop-visit process. As with M&E systems monitoring aircraft through base checks, it is necessary to monitor engines through the shop.

This can start with a timeline or warning on the engine removal plan gantt chart to indicate when airframe checks are coming due, to provide adequate downtime to remove and change an engine. This requires an interface with the M&E system, and coordination between the date and time an engine is available for installation following a shop visit, and aircraft that require an engine following the removal of an engine for a shop visit. The date of the engine removal can be manually brought forward in EFPAC and Ultramain's Powerplant Management. This may compromise the optimal engine removal plan, but will also reduce the need for spare engines. This change will subsequently require a revision to the calculated engine removal plan.

This functionality is interfaced with, and leads to, the shop-visit monitoring and management capability. Ultramain's Powerplant Management module categorises the shop-visit process into six phases. Ultramain Powerplant Management module categorises the shop visit process into phases. "Ultramain tracks the major phases/gates associated with engine overhaul: Induction; Teardown; Repair and Modification; Assembly: and Test," says Stone. "Each major phase can be divided into sub-phases. For example, it is logical to divide the Teardown phase into major assembly teardown and module teardown." These phases are represented diagrammatically, with information relating to the number of tasks, scheduled time, actual time spent, and whether the phase is on schedule or late.

"The system monitors the progress of the shop visit, with information being provided by individual mechanics in real time," continues Stone. "The system summarises the labour time spent, the number of days to date, the number of processes carried out, and the number of days remaining until completion. It also lists the number of parts the workscope will require, split between those that need repairing and those that will have to be bought. Overall the system keeps track of the number of parts required and consumed. Each of the shop-visit phase boxes can be drilled down to give further detail. Besides progress, labour and parts, the user can also look into the documents created by the mechanics as tasks are completed. These are items such as unserviceable and serviceable tags, and Form 1s."

Ultramain's Powerplant Management also has a shop status diagram. This provides a plan view of the shop floor, and real-time information of what is going on in each area of the shop floor. "The areas of the shop floor are places such as engine induction and disassembly, module disassembly, piece part repairs, cleaning baths, testing areas, and completed engines," says Stone. "The diagram also provides various visual indicators outlining work waiting, on schedule and behind schedule."

Either side of this plan are summary boxes. The one on the left lists the incoming engines, and the expected number of days for each engine's shop visit. The box on the right summarises the engines in work, and indicates the number of remaining days until completion of the shop visit. "This section is also dynamic, in that an engine in the left box can be picked up, and dragged into the receiving bay of the shop. This triggers the system to open a pop-up box where the user can create a workpackage," explains Stone. "The system can also be pre-populated with standard maintenance package templates, to which can be added tasks unique to that workscope."

Ramco has a shop work order module for monitoring maintenance events. This has a workscope planning section for engines and components. "The 'Plan Work Order' function creates a sequence of tasks for the shop visit, and finishes with testing and certification of the engine," says Neelambaran. "The user (mainly shops when generating quotes for the customer) then goes to the estimating section to compute the costs.

"If the system knows the engine, because the user is an airline or shop that has maintained the engine for an extended period, Ramco will have that engine's configuration and maintenance status," continues Neelambaran. "This means it can generate a list of all LLPs, ADs and SBs due on the engine. Each unit, module and assembly can be tracked through the shop. The system generates routing slips for each assembly and module as it passes through the shop visit process. There is also a section for mechanics to record their findings, make reports, request parts and materials, and record MH used for each task and step using a clock-in and clock-out system."

There is also a monitoring screen, with a colour-coded timeline plan for each engine work order, to monitor the progress of each shop visit. AC