Maintenance cannot be considered in isolation, and inter-reacts with other airline management functions. The principal ones are flight operations, human resources and finance. Airline management & maintenance IT systems have now evolved that provide airlines with a higher degree of control than they have ever had.

Integrating MRO IT with airline management

The complexity of the maintenance process and its implications for operating aircraft and airlines have been outlined *(see The applications for IT in maintenance & engineering, Aircraft Commerce, April/May 2004, page 26)*. This article was the first in a series analysing the use and application of IT systems in the many facets of aircraft maintenance, and described how these IT systems could be used to achieve savings.

Maintenance is not an issue that can be considered in isolation, and there are many airline management functions which interact with it.

The constant operation of aircraft affects the maintenance they require, while maintenance events and the timing and length of their performance affect where and when the aircraft is available for operation. This is one example of the need for maintenance to be considered in parallel with another airline management function.

Another example of an airline management function is human resources. Airlines consume large quantities of human resources. Many functions in an airline require unique and specialised qualifications that constantly expire and have to be re-validated or updated. Maintenance has the largest variety of licensed skills, each of which are utilised in the many different elements of aircraft maintenance and engineering.

Maintenance also requires large numbers of people. Monitoring qualifications, updating and renewing of licenses, maintaining the correct number of mechanics and engineers with the relevant licenses and skills, and planning available staff numbers with maintenance events all require a large management resource.

The third major airline management function finance. The large number of elements and complexity of maintenance means that manual accounting systems make it very difficult to monitor and control its cost, as well as allocate many of the different costs to different fleet types or individual aircraft or engines. The cost of maintenance furthermore affects the rest of the airline, since it has implications for fleet planning as well as overall profitability. It is therefore desirable to have the ability to accurately measure and allocate maintenance costs.

The three airline management functions of flight operations, human resources and finance all have to be considered in relation to maintenance and engineering. All three management functions are complex issues, whose integration using IT systems has to be analysed.

These three major airline management tasks have traditionally been managed manually by most airlines, as have maintenance and engineering. Comprehensive IT systems now exist that manage the entire maintenance and engineering process and specialised systems for major elements of maintenance now exist. These have to be interfaced with the manual management or IT systems that manage and control flight operations, human resources and finance.

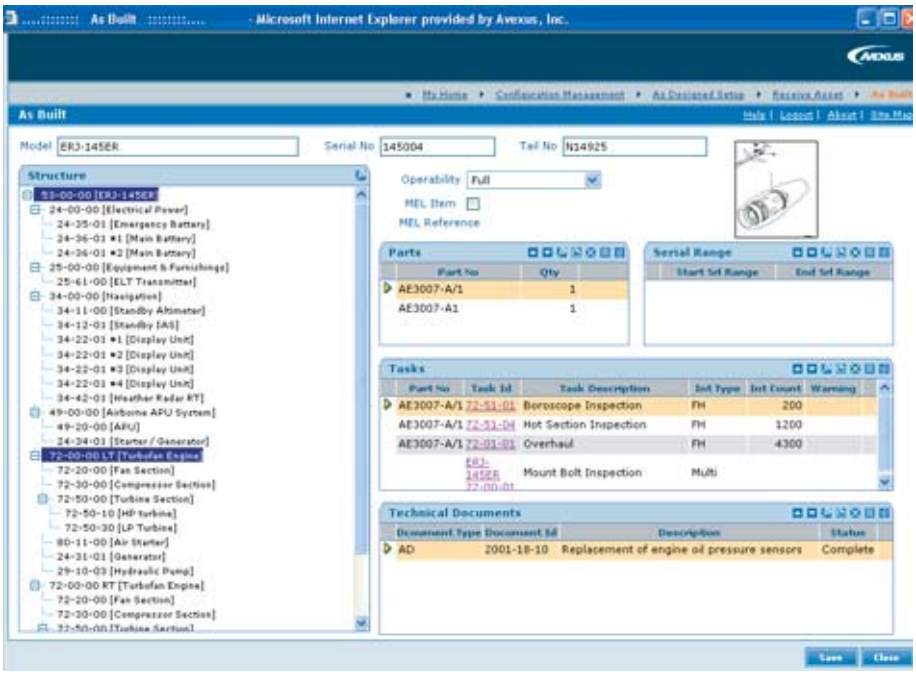
Operations & maintenance

Aircraft operation and maintenance have to be co-ordinated, most obviously with regard to the accumulated flight hours (FH) and the flight cycles (FC) an aircraft generates from each flight. These two parameters bring the aircraft closer to all scheduled and planned maintenance events. These include all types of check, from the smallest pre-flight line check to heavy maintenance visit. Accumulated FH and FC also bring forward items such as planned engine removals.

The difference between the forecast and actual accumulated number of aircraft FH and FC, and the timing of planned maintenance events will have to be constantly reassessed as aircraft operation continues. Most maintenance checks are dictated by intervals in FH or FC, and airlines will realise greater efficiencies if they achieve a higher rate of check interval utilisation. This is only possible if airlines maintain an accurate record of aircraft utilisation next to all maintenance events, and then co-ordinate this with the flight operations and maintenance planning departments in respect of downtime of the aircraft and availability of facilities, labour and materials.

Not only do airlines seek to achieve the highest rate of maintenance interval utilisation, but the progress and downtime of checks can alter from the original plan. Checks that finish early or late have a direct effect on the flight schedule. The flight schedule plan therefore also has to be updated as maintenance is performed. This will also alter subsequent aircraft utilisation and the timing of later maintenance checks.

Another maintenance issue arising from operations is random technical faults, which must be recorded by an airline's maintenance operations control department. An up-to-date record of outstanding defects on each aircraft monitors an aircraft's compliance with airworthiness requirements and ensures it has all items in the minimum equipment list (MEL) operable. This also ensures that the rectification of faults and defects can be planned in accordance with a scheduled maintenance event, or with unplanned additional events if necessary. The rectification of defects will cause little or no disruption to an aircraft's operation if the downtime necessary to rectify them



Avexus's Impresa has an asset configurator to maintain up to date records on aircraft configuration. This is automatically updated by data entered from flight operations and maintenance operations control.

does not exceed that of planned checks.

While rectification of most defects can be accomplished at later planned maintenance events, inevitably some defects arise that prevent further operation. These aircraft-on-ground (AOG) events have to be rectified immediately, and occur at random over an airline's network. Other defects occur which do not prevent the legal operation of an aircraft, but which airlines prefer to rectify in the shortest possible time. Examples are the failure of cabin items, such as electronic business class seats or in-flight entertainment systems. These events have to be managed by an airline's maintenance operations control department, which is responsible for co-ordinating the maintenance with the flight operations department so that alterations can be made to the operating schedule. Maintenance operations control also has to acquire the necessary labour, materials, parts, tooling and facilities to deal with these AOG situations.

The removal and replacement of components when rectifying defects alters an aircraft's configuration, which is also a direct consequence of constant aircraft operation. This is another issue that has to be monitored by maintenance and engineering through keeping large volumes of data and records.

Engine performance parameters are also monitored either manually or automatically during flight, after which a record is passed to engine management. These data can then be assessed for the purpose of planning engine removals. These also require sufficient downtime, and so have to be co-ordinated with other planned maintenance events and flight operations.

Aircraft performance and reliability also have to be monitored, and again data and information originating from operation have to be recorded and then passed to maintenance and engineering for storage and analysis.

So that aircraft technical dispatch reliability can be maintained at an acceptable level, maintenance and engineering departments also need to analyse reliability of different components and systems. This is so that the major culprits of technical failures and operational delays can be monitored, thereby allowing improvements to be made. Reliability data are also an essential part of extending check intervals, which in turn reduces aircraft downtimes and increases aircraft utilisation. Airlines therefore need to record and analyse large volumes of data in respect of reliability.

There are many links therefore between the operation of aircraft and maintenance. The traditional method of managing and co-ordinating flight operations with maintenance has been done manually. It requires large volumes of records and data to be kept, but also uses a significant amount of human resources. Co-ordinating flight operations and maintenance is so complex that manual management has inevitably resulted in inefficiencies. Airlines have had to accept that they have not been able to maintain the level of control they would like to achieve. "The many areas of maintenance which have traditionally had manual communication and co-ordination with flight operations can now be managed automatically with the appropriate IT systems. Airlines can have better control and co-ordination of their flight operations and maintenance," explains Paul Dibble, director of solutions management at Avexus. "A single flight record affects virtually all areas and elements of maintenance. The large number of flights airlines make each day therefore affects how difficult it is to efficiently co-ordinate operations and maintenance. The automation of co-ordinating flight operations and maintenance can achieve gains in efficiency."

Automated communication

The potential to realise gains in efficiency starts with the pilot reports (PIREPs) and technical log entries made at the end of each flight. Automating communications between flight operations and maintenance started with the use of central maintenance computers (CMCs) and aircraft communication and reporting system (ACARS).

ACARS made it possible to directly and automatically transmit information and data about technical faults occurring during flight to ground stations at an airline's maintenance operations control centre. These data could then be analysed and acted upon while the aircraft was still in flight. As a result a maintenance operations control department has more time to arrange the necessary labour, parts and facilities to fix technical problems, thereby reducing delays to subsequent operations.

The incorporation of CMCs in modern aircraft automatically recorded failure messages from built-in test equipment (BITE) on the aircraft. The CMC thus kept a record of these BITE messages for line mechanics and aircraft dispatchers to analyse at the end of each flight. This was faster than flight engineers and line mechanics going through the lengthy process of manually troubleshooting the aircraft and isolating faults whenever problems arose.

CMC messages are nevertheless provided in code, however, rather than specifying exact faults. They require engineers in maintenance operations control to analyse them with the use of the fault isolation manuals. Moreover, CMC messages, and their related failures, still have to be entered manually into traditional manual aircraft defects records where specific IT systems to manage them do not exist.

Further steps

While ACARS and CMCs made the process of identifying faults easier, co-ordination between flight operations and all other aspects of maintenance was still manual. PIREPS and technical logs are still written manually by pilots and then given to line mechanics for analysis and manual input into technical records. IT systems now exist to manage the different elements of maintenance and engineering. These include aircraft configuration management, maintenance operations control and maintenance planning. Other IT systems also exist for flight operations and scheduling, and there has to be an interface between the two.

"Some airlines now use electronic technical logs and electronic PIREPs and transmit data to maintenance systems using a tablet computer kept on the flightdeck," explains Chris Reed, managing director of Trax Software, "but there is strong resistance to this from flight dispatchers in many airlines. The tablet computers are also expensive. For example, United is considering these for its 500 aircraft, but at $10,000 each they represent an investment of at least $5 million. Our TRAX maintenance and engineering legacy system accepts flight operations data either electronically from tablet computers, or manual hand-written data from PIREPs and technical logs."

Most airlines still keep hand-written PIREPs and technical logs, but electronic systems are becoming popular with a larger number of airlines.

"The ultimate goal is to transmit all relevant flight operations data automatically to maintenance and engineering," says Dibble. "The first benefit is a saving in human resources that are required to write all these records. A single flight record affects all areas of maintenance and engineering. These include aircraft configuration, maintenance operations control and maintenance planning. Our Impresa system takes ACARS data and accumulates FH and FC data during flight. This cascades down through maintenance and engineering to update all maintenance events. Automatic, and therefore quicker, transmission means scheduling of maintenance events can be done more accurately. Automatic co-ordination of flight operations and maintenance data also allows the physical location of aircraft to be monitored so that maintenance can be planned more effectively.

"There is now a lot of demand for health monitoring data from all parts of the aircraft. That is, engine data and information from the CMC," continues Dibble. "With the aircraft configuration module in Impresa, the aircraft's component configuration can be matched with flight operations. A record of the removal of faulty or failed components and technical problems is used to generate a set of maintenance tasks. Health monitoring data and CMC codes from flight operations are then matched by Impresa with aircraft configuration data and the system automatically recommends a set of maintenance tasks. Airlines are starting to use this functionality to take health monitoring to a higher level.

"This ability saves line maintenance man-hours used in interpreting CMC data," continues Dibble. "It also improves aircraft technical reliability because of better interpretation of CMC data." The additional benefit of automatic CMC message interpretation is a reduction in the level of no-fault found on removed components. Maintenance systems can also be programmed to advise whether defects can be deferred or if they have to be rectified before releasing an aircraft for service.

Data Systems & Solutions (DS&S) has several products that co-ordinate flight operations data with maintenance. The first of these is Core Wing, which replaces hand-written pilot logs. "It provides data on aircraft utilisation and the schedule or route it has just performed. It also keeps data on fuel burn, maintenance reports and component failures," explains Nick Godwin, marketing director of civil aviation products at DS&S. "Core Wing uses a tablet computer which feeds data to both the airline's flight operations and maintenance and engineering IT systems. We also offer Core Fleet which stores technical data and analyses it. One of its

Although the central maintenance computer on a modern flightdeck provides messages relating to faults, they are still in code and have to be interpreted by line mechanics. Many MRO systems can now accept CMC messages transmitted from the flightdeck, automatically interpret them and devise a list of line maintenance tasks.

functions is to report on the aircraft's compliance with regulations in respect of how defects compare with the MEL. Core Fleet therefore provides a link between flight operations and maintenance. The data are also analysed to identify the main technical problems, and can be sent from the e-technical log book just five to 10 minutes after the end of the flight."

Traditionally, hand-written reports and data from the airlines' whole operation have to be collated and analysed. This takes a lot of resources and time, so airlines have to wait for a monthly report. It is now possible to have all defect, flight and aircraft performance data and other technical information provided and analysed in real time which gives a quick and accurate picture of the main technical problems.

"Core Fleet analyses and highlights the difficulties causing the largest problems with respect to technical dispatch reliability. This then saves management time used to find, analyse and deal with problems," continues Godwin. "This also leads to fewer technical delays and cancellations."

Many airlines still have manual flight records, PIREPs and technical logs, but these data can still be entered into IT systems used by maintenance and engineering departments. "Separate flight operations and maintenance IT systems can be run in parallel and then integrated. We do not offer flight operations software products, but do integrate them with our TRAX system," says Reed. "TRAX takes data from flight operations and is programmed to show what outstanding technical problems the aircraft has, whether the it is serviceable or unserviceable. It also keeps a list of outstanding defects on the aircraft. It is also programmed to send messages to departure control to hold flights if there are no-go technical problems. It also sends messages releasing the aircraft for service when technical problems have been cleared, or advises flight operations if another aircraft is required."

Like other systems, TRAX receives ACARS and CMC messages and data, which are used by maintenance operations control. It also tracks other flight operations data for maintenance planning. TRAX's maintenance planning module passes data back to the airline's flight scheduling system about the timing of maintenance checks. It also provides various management information, such as open MEL defects. This can be sorted and presented by ATA chapter, for example.

Human resources

Maintenance and engineering utilises large numbers of staff with a variety of skills and licenses. The number of different tasks in maintenance and their timing has to be planned in accordance with the flight schedule, which requires a high level of co-ordination and planning.

Once the timing of different scheduled maintenance events has been planned as far as possible, and the occurrence and timing of unplanned and unscheduled maintenance events has been anticipated, the number of staff required for each event can be estimated. This then has to be considered against the number of appropriately trained and licensed personnel. This co-ordination is made more complex by the fact that licenses regularly expire and require renewal. Another complication is that mechanics with different licenses are located in different places across an airline's network and locations for performing maintenance. Co-ordination is therefore only possible if an accurate database of mechanics and engineers, their licenses and locations is kept.

Lufthansa Systems is one IT provider that has developed a maintenance staff database for its human resources function. "The qualification management module of our system keeps three main columns of information for human resources," explains Evelin Willaschek, consultant of maintenance and engineering solutions at Lufthansa Systems. "The first is a qualification catalogue, which defines qualifications, and sub-divides them first by groups, then by actual qualifications and, then, at a more detailed level by proficiency.

"The second column holds the organisational structure of the company so that the number of employees in each department and group can be monitored," continues Willaschek. "The third column is a database of each employee's details. These human resources master data include information about employees' location and qualifications. Each skill level is identified by a number. Employee histories also have to be kept for regulatory authorities to show whether or not an employee was suitably qualified to perform a specific maintenance task in the past. These three columns are then linked."

The system can then be used to specify how many employees of each skill level and licence are available in each location for each maintenance task. The task is matched to the skill level to devise a plan for performing different tasks with the right people. The system can also project forward to see how many employees with each skill level there will be in the future. This is not only necessary for planning maintenance events, but also for planning growth or development of the airline or its maintenance and engineering capabilities. This will then indicate how many employees need to be trained or have their licenses renewed.

Avexus's Impresa has a human resources module. "This includes an employee database that not only maintains information on the number of staff with each skill level and licence, but

also has time and attendance modules and payroll information," says Dibble. "Time and attendance modules keep track of the number of hours each employee works every day. They also provide information on which shift each employee works, when their holidays are due and how much vacation time they have already had. This has to be factored into maintenance planning. Payroll information is also important, since the system can track the number of man-hours each employee uses when performing tasks and so measures the cost."

Another advantage of monitoring employees, their skill levels and man-hours used is that labour efficiency for each maintenance task can also be gauged.

A further issue of manpower is its co-ordination with the capacity required to perform maintenance tasks. "TRAX has a capacity planner and this function is designed to allow staff to be allocated to different tasks and jobs," says Reed. "It shows planners what labour is available, taking information from the employee database. Not only can the employee database compare maintenance tasks with the validity of licenses of assigned employees, it can also check if licenses are current and so prevent an employee signing off a maintenance task.

Geoff Hughes, sales director at Spirent Systems explains that employee systems have to be comprehensive. "Spirent's AuRA holds all relevant details on employees. These include age, salary, qualifications and licenses, employee number, department worked in, reviews, licence expiry and pension details. AuRA then focuses on human resource data relevant to maintenance and engineering and interfaces this with an airline's human resources system. The system is able to allocate tasks to each employee right down to the detail of different work cards to individual employees. The system also matches work cards and tasks with licenses, and can prevent unsuitable employees signing for a task. In turn, this concerns the recording and monitoring of man-hours used for each task."

Finance

The importance of finance with respect to maintenance and engineering is achieving the most accurate assessment of maintenance costs possible. This not only involves the accurate recording of all maintenance costs, but also splitting individual costs between those that can be attributed to specific tasks or aircraft and those that have to be categorised as overheads. Moreover, financial officers would ideally like to be able to allocate all variable maintenance costs to at least different fleet types, if not individual aircraft and engines, to get the most accurate information on maintenance costs.

"Impresa's finance module can communicate with an airline's existing financial system from another IT provider," says Dibble. "Impresa has been programmed to allocate costs to different maintenance tasks, and then translate this into cost per FH for each fleet. This is only possible because Impresa has the ability to record man-hours and the cost of materials, expendables and all other parts used in particular maintenance events. Also, the system interfaces with data concerning human resources. The additional benefit of this is that it is also able to generate an accurate time and materials invoice for the maintenance and engineering department's third party customers. Other benefits are that the airline can get an accurate picture of its own labour efficiency and maintenance costs."

While the accurate recording of labour and materials costs, and translating these into maintenance costs per FH is the ultimate objective of finance modules, maintenance and engineering

The ultimate goal of airline chief financial officers is to fully allocate all maintenance costs at an individual aircraft and engine level. MRO and airline management IT systems now exist that record man-hours and materials consumed in maintenance and can accurately allocate costs to provide a detailed picture of maintenance costs.

has to be concerned with all costs at a detailed level. One area Spirent's AuRA starts with is the reconciliation of invoices with maintenance records. "This starts with the matching of purchase orders or outsourced repair orders for sub-contracted maintenance events with the receipt of goods or work done and actual invoices received from suppliers," says Hughes. "AuRA flags any transactions that do not reconcile. Overall, the system models all the organisation's financial transactions. The system can then be adapted to give each order a ledger code so that costs can be allocated to individual jobs or aircraft. Financial records can also be channelled into different cost categories of labour, materials, inventory, tools and overheads. The system also needs to account for the cost of labour. This not only concerns the recording and allocating of man-hours spent by individuals on specific tasks, but also the allocation and cost of non-productive labour as the overhead of providing maintenance."

Another facet of finance in maintenance and engineering is wastage. An example is the wastage of parts used in the repair of components. "A finance system has to be able to account for removed, repaired and reinstalled parts and components. Some parts are forgotten and this adds to cost and downtime. AuRA can track all parts and their associated repair costs, as well as their repair cycle times, with the benefit of reducing the wastage associated with lost parts," says Hughes.

Finance modules in maintenance and engineering systems can also provide daily journals of costs and expenses that are collected from all over the maintenance and engineering department. "These journals have to be synchronised with an airline's financial system so that accurate information for the profit and loss account, balance sheet, value of inventory and assets, debtors and creditors, and depreciation calculations is available," says Reed. "This starts with the accurate input of financial costs. An example is the use of parts for a specific task. Parts may have been held in an airline's store for several months and already paid for, but then later used during an airframe check or engine shop visit. First, the original purchase cost has to be recorded in inventory or stock. The cost of the used part then has to be allocated to the maintenance task. TRAX makes this transaction automatically when the part is ordered from the store and used against a specific job card or maintenance task."

Benefits

As Dibble has explained, the use of IT systems that co-ordinate airline management functions with the maintenance and engineering process gives airlines more control.

An example of the potential gains in efficiency is the increase in check interval utilisation. Airlines typically use 85-95% of their check intervals, which represents a large loss over the course of a heavy maintenance cycle. An A320 has a heavy maintenance visit performed every eighth C check. If 85-95% of the C check interval is not used, the D check interval could be reduced by as much as two years. This could raise the cost per FH by 25%.

The use of IT systems can tighten up the interval utilisation losses for all checks, through better co-ordination of timing of maintenance visits, availability of facilities and other resources with flight operations and the operating schedule. Increased interval utilisation would also raise aircraft availability and so productivity.

Another major benefit of interfacing flight operations to maintenance via IT systems is the use of fewer human resources to input, collate and analyse data and information from PIREPs, technical logs and flight reports. The level of automation possible now means fewer human resources are needed to generate tasks for line checks.

A further benefit of co-ordinating flight operations with maintenance and engineering is the improved quality of reliability and health monitoring data. This can provide alerts to problems arising with components, systems and engines so that removals or corrective action can be planned and taken before aircraft operation is interrupted by unscheduled maintenance events.

The ultimate goal in the management of human resources in respect of maintenance is to match labour requirements with labour supply. A higher level of control over the timing of maintenance events and a more accurate estimate of labour required due to critical path analysis is now possible with IT systems used for maintenance and engineering. With a higher degree of control over the requirement for human resources, a better matching of this with labour employed is possible.

The ultimate level of control airlines desire is that of greater visibility in maintenance costs. While measuring man-hours and materials used in checks gives great insight into the costs for individual aircraft, the ability to accurately track the use of rotables around the circuit of installation, removal and repair means their cost and efficiency of use allows chief financial officers (CFOs) to identify surpluses in inventory and make disposals without putting fleet reliability or the operation of an aircraft at risk. A thorough IT system that fully co-ordinates an airline's finance department with all elements of maintenance and engineering will allow CFOs to monitor and allocate all costs, as well as reduce wasteful expense. AC