The original equipment manufacturers have many lines of communication with airline maintenance & engineering departments. These have traditionally been managed with paper systems and require large number of engineers. IT systems now exist to manage these processes.

Integrating maintenance & engineering IT systems with the OEMs

Original equipment manufacturers (OEMs) have several lines of communication with airlines' maintenance and engineering (M&E) departments, and third party maintenance providers. These include: passing component reliability data; supplying engineering data and information; supplying lists of part and dash numbers; issuing various technical manuals; recommending rotable and spares requirements; and several other factors in the acquisition of spare material and claiming of warranties. In the case of some OEMs, in particular engine manufacturers, communication with the airlines extends to health and condition monitoring of aircraft, engines and systems.

Airlines have traditionally used manual and paper systems for dealing with these issues. These are all large tasks that require large teams of engineers to manage. The availability of IT systems in M&E means the management of these processes can be automated, providing the airline operator with greater control and speed of process.

Aircraft configuration

The configuration of each aircraft continuously changes during operation. Rotable and repairable parts are removed due to failure or poor operation and replaced with serviceable items taken from an inventory store.

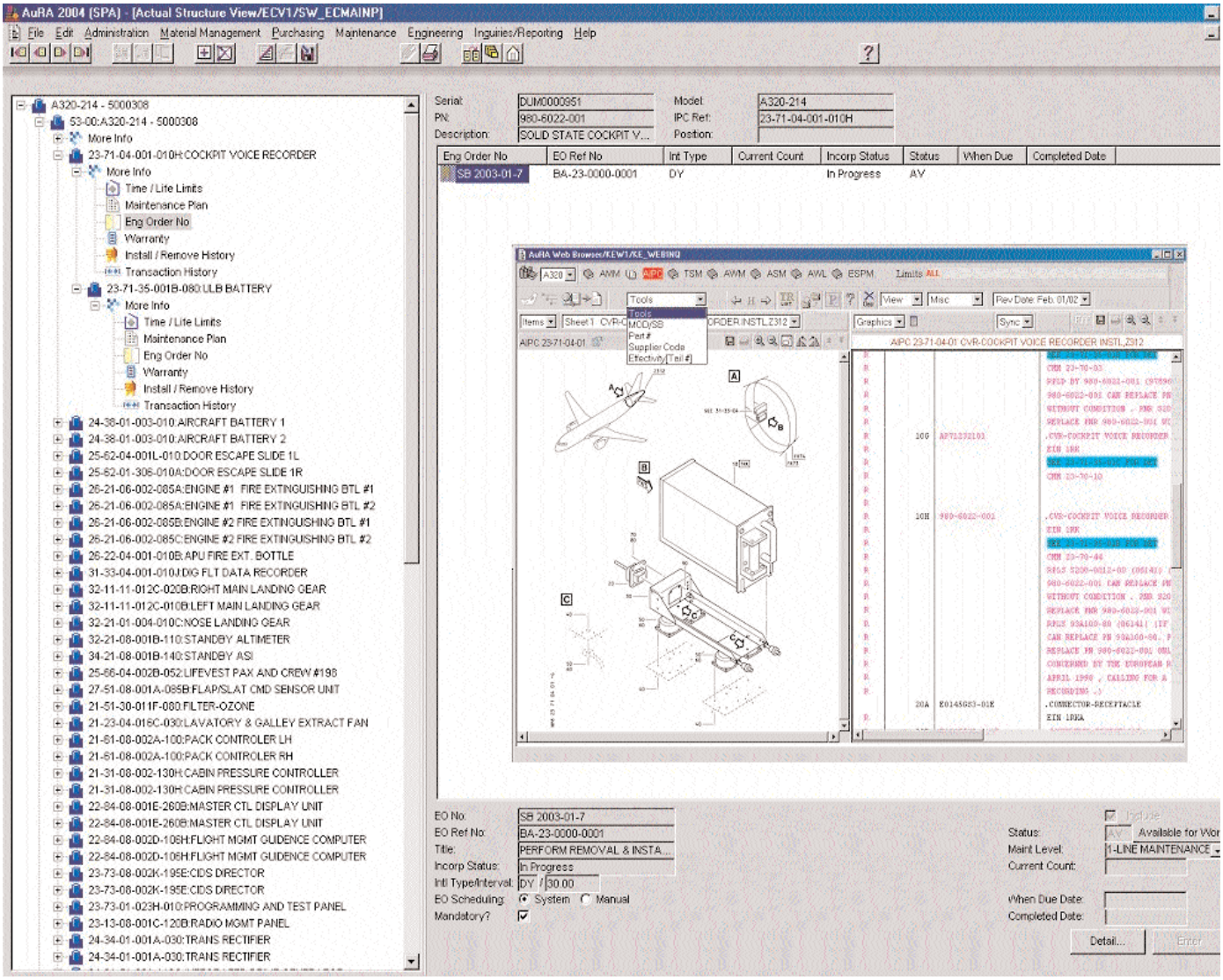
Preventing excess consumption of rotable and repairable parts requires the reliability of each part number and dash (variant) number to be monitored through reliability analysis. This analysis is passed to OEMs so that part and dash numbers with poor reliability can be identified and improved with modifications. Improved and modified parts can then be installed on the aircraft, which requires careful analysis for compatibility with other part numbers. That is, later dash numbers of a particular part number may only be compatible with certain dash numbers of other parts already installed on the aircraft for the two to work together.

This process has traditionally been managed with paper systems, which involved keeping of vast records and required large numbers of engineers. Maintenance IT systems first need to have the anatomy of the aircraft and its entire list of part, dash and serial numbers loaded to manage this process automatically. This management of the aircraft's configuration is the basis for allowing efficient component reliability analysis.

"Configuration management has always been one of the most complex tasks for airlines, MRO shops and indeed OEMs to cope with," explains Geoff Hughes, sales director at Spirent Systems (now MIRO Technologies). "Our AuRA system is a fully integrated solution across engineering, maintenance planning, technical records and materials procurement and has been designed specifically to deal with this immensely complex issue. AuRA holds the relationship between part numbers, aircraft models and sub-models, reference data such as ATA or Airbus FIN number, maintenance tasks and procurement data to ensure if the OEM makes any change, AuRA ensures that change ripples right throughout the organisation instantly."

"At the purchase or delivery of an aircraft, its component configuration is loaded into M&E IT systems," explains Paul Dibble, director of solutions management at Avexus. "These data when loaded not only list all part numbers, but list them according to the aircraft's structure and anatomy with respect to air transport association (ATA) chapter and physical location on the aircraft. This is accompanied by the maintenance intervals for each part, or notification that the part has an on-condition maintenance process if appropriate. The maintenance intervals of each part can then be grouped into maintenance checks.

"Once each part is listed, its maintenance record and history and removal and replacement history can be kept. Our impresa system can thus list an aircraft's entire configuration and component inventory at any one time. It can also summarise the aircraft's maintenance status and what maintenance is due as summarised in checks," continues Dibble. "The date the maintenance items and checks are due is continuously brought forward, revised and updated as the aircraft is utilised in operation. These utilisation data are entered either manually or received automatically from flight operations." (see Integrating MRO IT with airline



management, Aircraft Commerce, June/July 2004, page 35).

All major M&E IT systems have the aircraft configuration, part and component data, and maintenance information loaded as the basis for reliability analysis. MRO Software's Raptor system stores the configuration of an operator's fleet, listing all possible parts that can be used in each position on the aircraft and the maintenance plan for each part number. "Raptor's system keeps a maintenance plan of what maintenance is due and what maintenance has been performed for each part, as well as a history of all the individual part serial numbers that have been used in each position. With aircraft utilisation data input, it can thus also record when each part was removed or installed and if it is an on-condition or scheduled maintenance item," says Frank Henry at MRO Software. "Raptor has a system of direct counts from flight operations, which is a record of the accumulated flight hours (FH), flight cycles (FC) and engine starts the aircraft and each component has had. By tracking each part with respect to removals and installations, it is possible to compile a record of indirect counts. That is, a record of utilisation counts for each of the aircraft it has been installed on. In addition, Raptor has the facility to change the as-of date for an aircraft's configuration so that it and all data relating to maintenance condition and maintenance status can be shown at that date, or at any other time. The system can also go forward in time to see what maintenance events are due. It can then indicate what parts will be removed for maintenance and how this will alter the aircraft's configuration."

Reliability data with respect to the removal of parts are generated from the maintenance history of each part. "This removal, installation and removal interval information initially comes from maintenance operations control and pilot reports," explains Chris Reed, managing director of TRAX Software. "Some airlines put these data in manually, but the use of tablet computers on the flightdeck and at maintenance operations control speeds up the process."

Operators compile reliability data, and M&E IT systems obviously make this easier for operators to do. "Reliability of parts can be tracked very simply and quickly," explains Hughes. "Our AuRA system has the ability to call up a part number. It has a remove/install screen which lists a part by its serial number and other information such as illustrated parts catalogue (IPC) number and reason for removal. The system can analyse removal data with respect to part number, dash number, tail number, position in the aircraft, symptoms for removal, part and dash number upgrades, which mechanics removed, tested and repaired the part and what their findings were. AuRA's data collection means each individual part can be analysed with respect to the dates it was removed, or by their removal intervals. Overall, the total number of removals for each part and dash number over a period can be analysed. Sorting by serial number and tail number can allow the parts causing poor reliability to be analysed. These data are then sent to the OEMs for analysis. Automating the collection, collation and

Spirent's Systems AuRA aircraft configuration management system can not only show the structure of the aircraft by a structure tree with ATA Chapters, but also call up the illustrated parts catalogue and Service Bulletin information that relate to a specific part number.

Avexus's Impresa stores an aircraft's structure down to the level of each component. The maintenance status of each component is tracked and can be viewed, as can the maintenance task cards.

analysis of these data from several viewpoints provides good quality data which the OEMs can use for analysis. If reliability of a particular part or dash number is poor then the OEMs issue advisories, service bulletins (SBs) or airworthiness directives (ADs) to improve reliability."

Engineering data

There are several forms of engineering data and information. One of these is engineering orders: ADs and SBs issued by the OEMs and parts manufacturers to airlines. These upgrade and modify parts and systems, and are often used to improve reliability and performance, but may also be used to improve safety.

ADs and SBs are issued throughout an aircraft's period of manufacture and several decades of operation that follow. ADs and SBs alter the aircraft's configuration by replacing parts. Later-build aircraft have these SBs and ADs incorporated on the production line, and so are not affected by particular ADs and SBs. "Manufacturers supply a file of ADs and SBs incorporated in an aircraft when it is delivered so that engineering departments know which aircraft are affected. Engineering orders were issued in paper format, but are now issued in HTML format together with a picture of the repair and modification required and any other relevant diagrams," explains Reed. "The engineering order gets sent to the engineering control module of our TRAX system, and the engineer user analyses whether the AD or SB is mandatory or whether it should be done on an economic basis. Steps are then taken to create work packages to do the work. TRAX creates task cards for mechanics to do the modifications. An electronic task card can be made from the OEM's manual that is already loaded into the M&E IT system."

Directives are analysed in reference to what aircraft they affect by using the aircraft configuration and part tracking capability of the M&E IT system. "The AD will specify what part serial numbers are affected, and the IT system can trace the part and serial number database in the fleet, in inventory stock or in maintenance to see which ones are affected," says Hughes. "AuRA will follow all serial numbers affected in the fleet until they have been modified. It also follows any new parts purchased that are affected by ADs or SBs. When task cards are created to deal with an engineering order, AuRA also takes information from OEMs about what parts and tooling are required to complete the modification. The system also estimates how many MH are required to complete the work and which materials and skills are needed. Diagrams from the OEM's technical manual can also be attached to the task cards in AuRA, either on paper or indeed as Frontier Airlines is considering, on a wireless tablet computer or PDA online. AuRA is saving Frontier considerable downtime for mechanics and engineers and improving productivity significantly on the shopfloor."

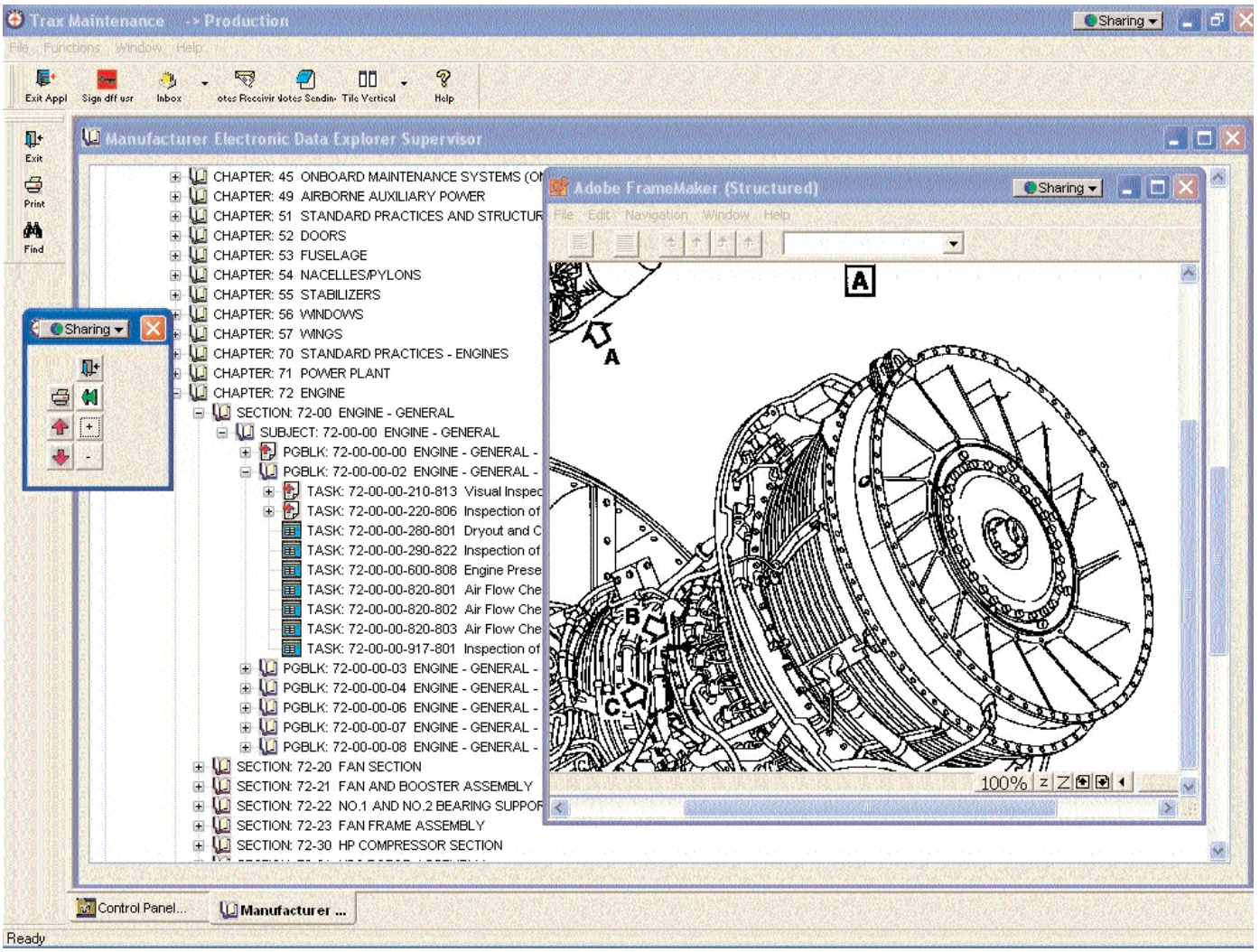
Dibble explains that data concerning building task cards for SBs and ADs can either be received electronically or entered manually. "A task card for an AD or SB will have FH and FC intervals and limits, as well as estimates for MH, materials and required tools. ADs often have repeat inspection intervals, and the utilisation counter in Impresa compares these repeat intervals to the due maintenance events so that planners can schedule them accordingly."

Besides identifying which parts and aircraft are affected and generating task cards to complete the engineering order, IT systems also have to consider the time and aircraft utilisation limits within which the modifications have to be completed. These limits are compared with the maintenance schedule and due maintenance events for each aircraft affected. ADs and SBs are thus scheduled with upcoming hangar checks if limits permit, and unscheduled visits have to be organised. The aircraft's maintenance schedule thus has to be incorporated into the M&E IT system.

In addition to engineering orders, another type of data supplied by OEMS to operators and maintenance facilities are aircraft maintenance schedules. A maintenance schedule is essentially the grouping of task cards into checks. These task cards are scheduled items of maintenance grouped with additional unscheduled items. The maintenance intervals for parts come together with the component and part configuration data that are supplied by the OEM. Reed points out that while task cards are now supplied by the OEMs in electronic format, ad-hoc task cards and AD task cards are generated by an airline's own engineering department. Task cards written by an airline's engineering department have to be approved by the regulatory authorities.

"Maintenance events for each component and part lead to the creation of job cards for a maintenance check," explains Henry at MRO Software. "Our Maximo system uses a template to plan, schedule and execute each job card. This will include estimating the materials required as well as accessing relevant documents, and Maximo has a connection to the illustrated parts catalogue (IPC) and other manuals to allow all parts to be provided in sufficient time and to save the mechanic time in completing the task."

Although the maintenance interval for each part is loaded together with their



TRAX Software's system keeps the configuration of each aircraft and can store this under an ATA Chapter structure. Components and parts can then be interfaced with the appropriate pages of the aircraft maintenance manual and illustrated parts catalogue.

serial numbers into M&E IT systems, OEMs make changes to the maintenance intervals of different parts. "These allow the timing of work packages to be altered," says Dibble. "Our system then goes on to examine what parts can be used for each job card, checks these with inventory levels and either reserves them for the check or orders them from suppliers. Maximo can also take into consideration the reliability of relevant components and decide whether they should be removed during the check."

Records have to be kept of maintenance items performed. M&E IT systems with aircraft configuration and the master parts list have the ability to track and keep a maintenance history, and automatically generate technical records. "The maintenance history for each serialised part is in effect the technical record required by the authorities," explains Stein Bruch, director of business development at VISaer. "The maintenance history of each part can be monitored with respect to time since overhaul, time since new and time since last service. Other information such as relevant engineering orders, accumulated FH and FC for the part, and maintenance removal history are all kept. As well as maintenance history information, the component's status can also be followed. This includes information such as where and when installed. Ultimately, technical records can be analysed by aircraft tail number, part and serial numbers and specific date."

During operation, aircraft components and structures will require repairs as well as component changes. "Repair schemes come from OEMs in the form of task cards together with maintenance manual references. Engineers have to manually estimate the MH, materials and tooling required to perform the repairs, however," explains Bruch.

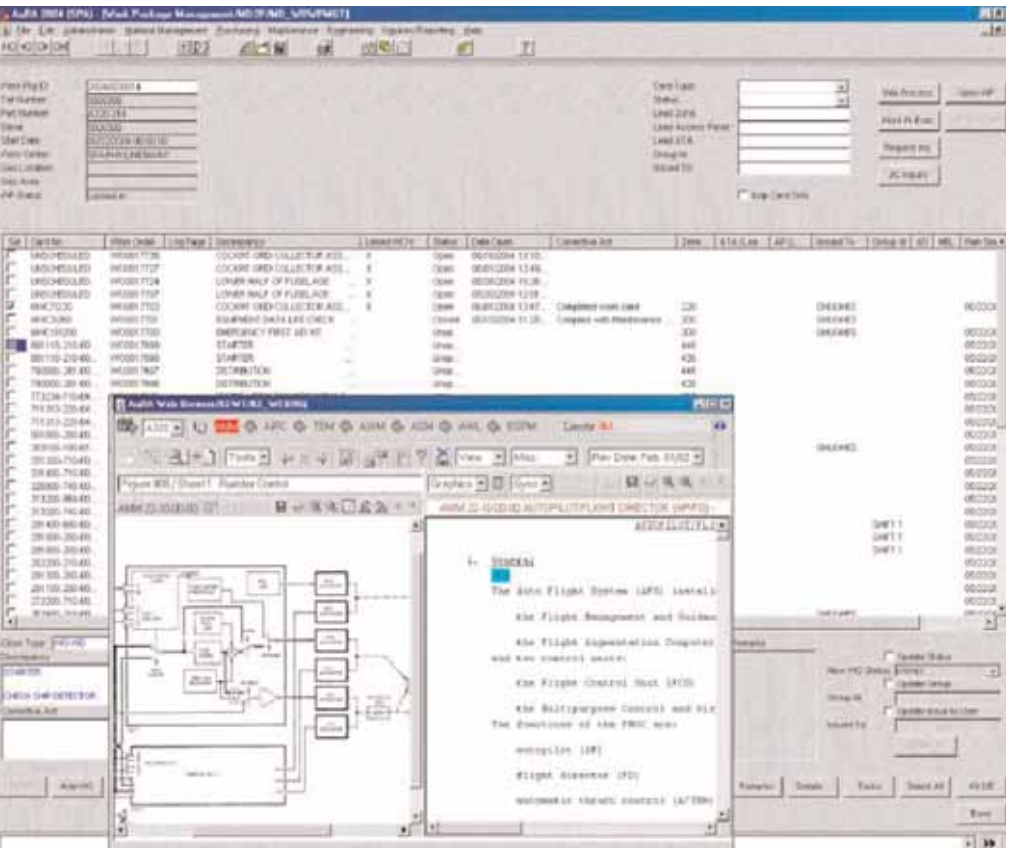
Repair schemes can either be standard for common problems, or have to be created when new ones are required. "These can then be used as templates for future requirements and are stored in the M&E IT system," says Dibble.

Ordering parts

Parts are continuously required by line mechanics and maintenance operations control for line maintenance, base maintenance for airframe checks, engine and component repair shops, and inventory warehouses. Parts and components can be acquired and purchased from OEMs or other suppliers. Purchasers can now make electronic purchase orders and communicate these directly to the OEMs' and suppliers' systems.

"The start of the purchasing process begins with the IPC reference number. This shows the part, dash and serial numbers allowed for each particular component and structure," explains Hughes. "The IPC also shows the aircraft tail numbers on which each part can be used, as well as indicating which parts can be interchanged with each other if the desired part number is not available."

Airline purchasers need to communicate with the OEMs and various other suppliers to check various aspects of availability and pricing information. "Purchasers will raise a purchase order, which can be done electronically with Maximo," says Henry. "This purchase order can be approved electronically and the purchaser can then use Maximo to



Spirent's AuRA provides mechanics with the ability to view a list of maintenance tasks, select a particular one and then access relevant pages from maintenance manuals and illustrated parts catalogues. All of this information can be accessed on a tablet computer, which has a wireless hyperlink to access the manuals.

identify the different suppliers of the part. Maximo also has links to the IPC so that the correct parts can be identified."

M&E IT systems communicate with the OEMs' and suppliers' systems via Spec 2000. "The airline's system logs into the suppliers. VISaer checks the various capabilities of suppliers, including repair capabilities, level of availability, availability lead times, and purchase discounts available and warranties that are offered," says Bruch. "VISaer also allows the purchaser to ask for alternative parts if the required one is not available, as well as enquiring about superseded and obsolete part numbers. Prices of various suppliers can also be checked."

Technical manuals

There are many types of technical manuals used in maintenance and engineering, including: the IPC for listing and illustrating parts; aircraft maintenance manual (AMM) in assisting with maintenance tasks; fault isolation manual (FIM) for isolating faults during line maintenance; troubleshooting manual; and wiring diagram manual. These have traditionally been supplied by OEMs in paper format or in some cases on microfiches. Engineering departments constantly receive revisions and updates to these manuals and this process requires a large infrastructure. Manuals are then consulted during operations, line maintenance, hangar checks and in component repairs.

These manuals can now be accessed in electronic format and used in the various M&E IT systems. "As an example, pages of these manuals can be accessed by mechanics via tablet computers while performing work, with a hyperlink to access the manuals," says Hughes. "This saves mechanics the time they would spend searching through manuals. Task cards can also be called up on tablet computers, together with pictures of the AMM or other manuals. Our AuRA system goes out on the server to the OEM's data and gets the latest manual. This leaves it up to the OEM to provide the latest picture of a manual's page, and means the engineering department no longer has to maintain and keep its manuals up to date. We are working closely with technologies like Jouve, and with OEMs like Airbus and Embraer on this integration."

Manuals can be accessed from OEMs in several ways. "They can be accessed via the server or uploaded into the airline's M&E IT system," explains Dibble. "Revisions to manuals are made automatically by updating the link to the OEM."

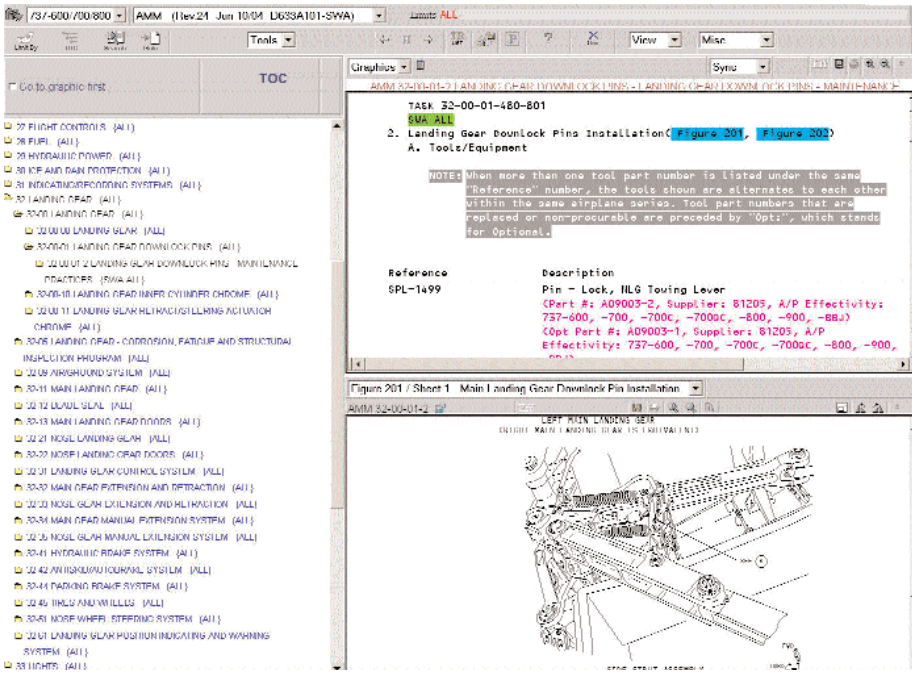
Bruch explains that manuals can also be accessed via the internet. Airlines have to pay for this on-line service, but realise savings because they no longer have to pay engineers to update and manage manuals.

Jouve provides another method of accessing technical manuals. Jouve's AirGTI manual takes OEMs' manuals and improves them. The manuals that can be viewed on AirGTI include: the aircraft maintenance manual (AMM), aircraft illustrated parts catalogue (AIPC), fault rectification and fault isolation manual (FRMFIM), electronic illustrated parts catalogue (EIPC), Aircraft service manual (ASM) and aircraft wiring manual (AWM).

"One example is by generating several thousand hyperlinks between wiring diagrams and wiring lists," explains Geoffrey Godet, president of Jouve. "A mechanic looking at the AMM will search for a part of sub-assembly in the AMM and can open it at the page level. It can also get groups of repair manual pages and acquire the graphics associated with the AMM text. AirGTI also has a 'limit by' function, which lists the aircraft to which the particular page of the AMM relates, ensuring the correct manual is used.

"The IPC can be searched by ATA chapter, by proximity to an aircraft part or structure, or by a word search. Once the part is found AirGTI gets a picture of the part, but the mechanic also needs to know the part number," continues Godet. "The IPC shows an item number, and this item number is used to find the part number. The ATA chapter system uses a hierarchy to locate the part number."

Another example of Jouve's system is the use of FIM or troubleshooting manuals. "Airbus and Boeing have different codes. Mechanics enter codes and error messages from the aircraft, and AirGTI brings up one or more ATA root codes. Once the correct root code is located then the correct document in the fault isolation manual or troubleshooting manual can be used," explains Godet.



Jouve's AirGTI creates hyperlinks between OEMs' manuals that include the illustrated parts catalogue, aircraft maintenance manual and fault isolation manual.

"This then gives reference to the AMM, which in turn looks up the schematic manual. These show how the electrical parts are mapped together, and also provides a reference to the wiring diagram manual. AirGTI then provides a magnifier to allow the mechanic to get down to electrical parts."

Jouve sources data from OEMs physically on a CD-ROM and then converts these into SGML format. "We have 15 days from being supplied the CD-ROMs to make the manuals usable on AirGTI," says Godet. "AirGTI is now web-based, which means updates to manuals can be provided instantly."

System users pay for the use of manuals supplied via AirGTI by buying software licenses, usually done on an individual aircraft basis. The user stipulates to the OEMs that it requires SGML source data for their technical manuals, and the SGML data are delivered to Jouve for processing into AirGTI electronic manuals. The customer then pays for the database productions at Jouve. Alternatively, AirGTI DocPublisher, the software which generates AirGTI manuals, can be licensed to the airline which produces its own electronic manuals in-house.

Several M&E IT systems, including AirGTI, also provide links between items such as ADs published by the Federal Aviation Administration (FAA) and other technical manuals. Boeing itself provides its Portable Maintenance Aid (PMA) product, while Airbus offers ADOC.

Once the manual that a mechanic is looking for is found it can be printed out, attached to a task card, or saved on the system. Manual pages accessed by AirGTI, for example, can be incorporated into task cards as they are written by planning engineers. Jouve also has AirGTI Task Manager which manages and writes task cards, and generates work packages based on aircraft tail number and check type. Revisions made to manuals that are applied to the AMM are also automatically incorporated into the task card.

Parts and inventory

The issue of the inventory of parts starts with the initial provisioning list supplied by the OEMs. "Each OEM provides a recommended spares provisioning list (RSPL), which is usually excess to requirements, when an airline places an aircraft order," says Reed. "The RSPL provides a list of all the different part numbers required and then a recommended quantity for each one. Some airlines load the RSPL into their M&E IT system, and this can be analysed and then ordered. The order then goes into the purchasing module of TRAX, and then parts can be purchased economically. OEMs now take electronic orders from M&E IT systems via web pages."

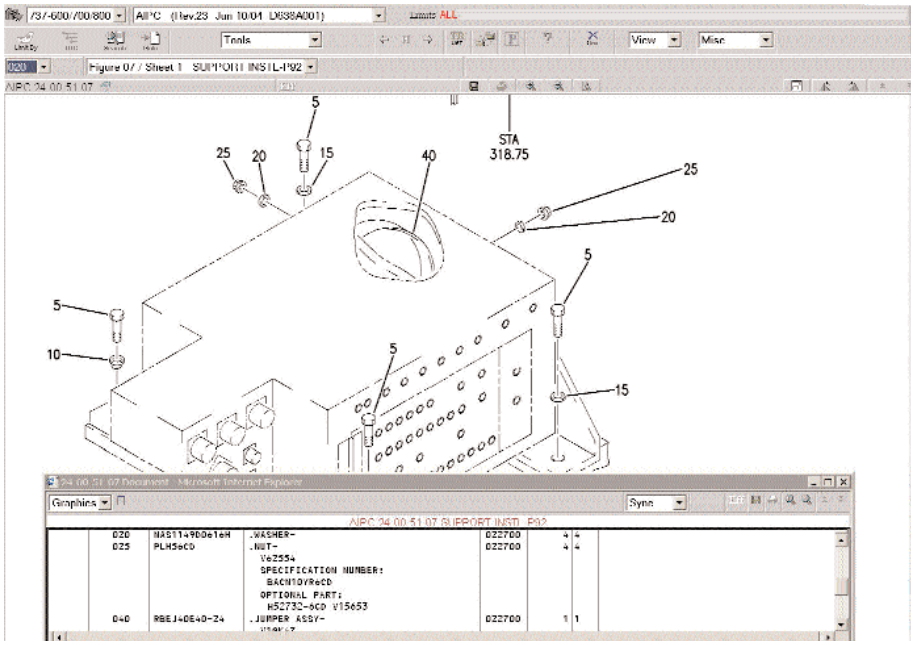
M&E IT systems have the ability to communicate with suppliers' catalogues on line. "Maximo searches through on-line catalogues and can also put together an aggregate catalogue from several vendors. This allows information on pricing, discounts, availability and warranties of suppliers to be compared," says Henry. "Catalogues can be searched by part number, name or part classification. This allows the buyer to narrow down their search. The ordering process is now paperless; so that notification orders, shipping orders, invoices and payment notifications are all sent electronically to and from Maximo."

Purchasing also has to be made with reference to current inventory levels. Most M&E IT systems inform buyers of current stock levels, and how many of a required part have already been allocated, as well as how many are on order and due for delivery.

The initial provisioning list is based on assumptions of fleet operating parameters, and reliability rates and removal intervals of all components. This list then has to be constantly refined by using the reliability data of the parts gained by the reliability analysis capability of various M&E IT systems. "AuRA will take into account removal intervals, as well as repair and transit times so that excessive inventory is not held. This process gets refined with operational experience of the fleet. It will also take into account the utilisation of the aircraft, with data coming from the airline operations module of the system," says Hughes. "The constant reassessment of the inventory also has to consider the upgrading of part dash numbers and fleet upgrades."

Besides provisioning estimates and their refinement, airlines then also have to consider claiming warranties from OEMs. Under traditional paper systems it was almost impossible for a typical airline inventory management team to check for remaining warranties on every part removed during line maintenance. Warranty information on each part is loaded when each serial number is loaded into the system. "This involves the integration of component purchasing and tracking. As each part is acquired, VISaer allows its warranty information, relating to the time in which a warranty can be claimed, to be loaded," explains Bruch. "Warranties are therefore followed automatically with accumulated FH and FC utilisation, since the warranty time remaining for any part can be looked up."

When parts are removed their



Jouve's AirGTI has the facility to search for a part with a word search. Once a picture of the part is retrieved, the IPC shows an item number. This item number is used to find the part number.

remaining warranty time can be examined, and checked against warranty contract parameters. Warranty claims can thus be analysed and made automatically.

Health monitoring

Health monitoring is a process carried out by engine manufacturers to assist with the planning and management of engine maintenance. Engine health monitoring has traditionally been carried out by airline engineering departments, and parameters recorded manually in flight were passed by flight crews to engineering departments for analysis. This traditional system recorded few parameters and involved manual interpretation, and so was limited in its ability to accurately predict the deterioration in engine performance and need for removal for a shop visit or maintenance.

All major engine OEMs have developed sophisticated engine health monitoring products to go with their engine maintenance and support services. Rolls-Royce (RR) provides total care and non-total care engine support packages, and DS&S provides engine health monitoring services to go with these. Core Alert is DS&S's engine health monitoring service. RR keeps a database of all engines it manages. The data kept include information on engine utilisation, flight hour (FH): flight cycle ratios, style and environment of operation, life and remaining lives of life limited parts and exhaust gas temperature (EGT) margin. These data are used to allow decisions to be made with respect to engine management and the timing of maintenance events. RR has a 24/7 customer support desk, which is used to capture performance data and provides engineering expertise to interpret it. Aircraft in flight send engine performance and parameter data via ACARS for short- and long-term engine health monitoring. RR's 24/7 desk provides the short-term health monitoring service.

RR provides customers with technical support by putting engines that are displaying technical problems 'on watch'. It also makes suggestions for short-term maintenance and technical fixes, as well as making suggestions to alter engine removal plans. Also to be added is a service where customer airlines will be given suggestions for line maintenance to be performed to deal with in service problems.

Health monitoring data are then passed to DS&S, which uses the data from a large number of parameters to analyse engine performance and make long-term decisions with respect to maintenance management.

Core Alert takes engine health data and plots trends of several performance parameters. These data, which are captured automatically, now follow a large number of parameters compared to the traditional manual systems. The large number of parameters now followed allow problems that are developing to be pinpointed down to a module level. This can even allow smaller shop visits to be performed, or repairs and maintenance that prevents full shop visits.

Performance data are summarised for operators, and predictions such as EGT margin reaching zero are also made. This timing is also compared to LLP lives, and so decisions about optimum timing of removal for shop visits or overhauls can be made.

Airline customers thus sub-contract engine health monitoring to DS&S, but because the system is web-based airlines can still monitor their own engines. This allows DS&S to liaise with customers and consult them about the management of their engines. Engine health monitoring data used by DS&S can either come directly from the customer airline or RR's 24/7 operations room.

In addition to plotting trend data, Core Alert also provides alerts to customers by text messages, e-mails and other formats.

The combined services of RR's 24/7 operations room and DS&S's Core Alert provide airlines with an operations management management service for engines.

Data are monitored and collected 24 hours per day, seven days per week, including data captured during take-off, climb, cruise, descent and landing phases of flight. Sub-contracting this function to RR and DS&S allows airlines to avoid investing in in-house capability while still maintaining compliance with all regulatory requirements. Technical problems can also be anticipated, preventing in-service delays and expensive unscheduled maintenance visits. Scheduled removals and engine maintenance can also be optimised. This allows lower cost per FH to be achieved, as well as preventing clusters of removals that result in peak demand for spare engines.

In greater detail, Core Alert can detect, among other technical issues, in-service problems relating to high pressure turbine system deterioration, compressor damage, fuel and nozzle coking, faulty bleed valves, sensor errors, foreign object damage and bearing distress.

Core Alert also has an intelligent diagnostic system that can pinpoint likely causes of alert notices sent to customers. Trend charts are generated automatically and kept up to date, and data can be analysed and displayed in a number of ways. Fleet summaries can also be provided, so that fleet status information of deterioration and EGT margin status can be provided. AC