As part of the effort to reduce maintenance & engineering costs, airlines can use their maintenance IT systems to track rotable components and various parameters relating to their management and maintenance to determine optimum stock levels.

Using MRO IT systems to optimise rotable inventories and identify surplus stocks

The management of inventories of rotable and line replaceable unit (LRU) components is one of the most complex functions performed by an airline's maintenance & engineering department. The complexity is so great that most airlines have experienced significant inefficiencies when using the traditional manual system of managing rotables. Maintenance information technology (IT) systems are able to reduce or eliminate such inefficiencies, thereby realising savings in time and money for airlines.

Rotable management

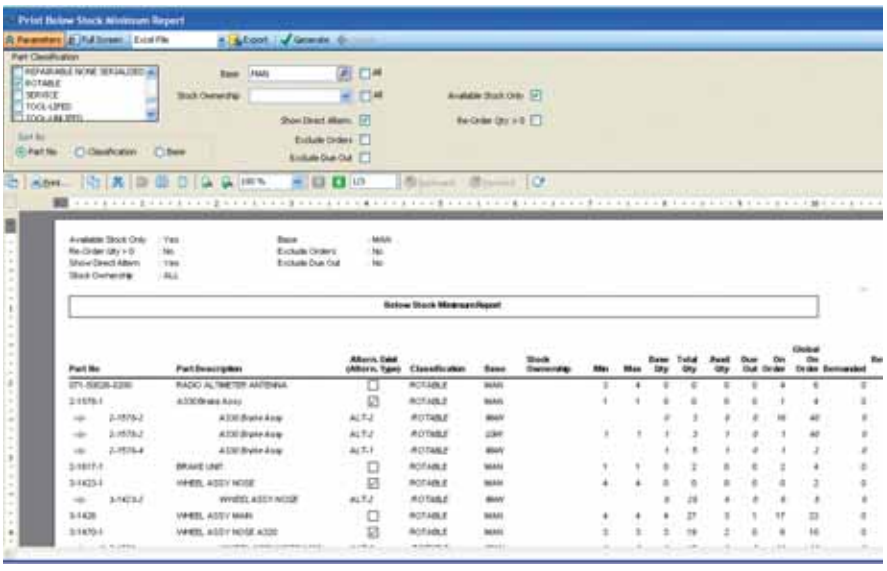
Most rotable and LRU components are maintained on an on-condition basis. These, and the minority of parts that are removed for maintenance at fixed or hard-time intervals, are sent for inspection and then repair, and sometimes even have to be shipped abroad, and pass customs inspections. Repaired items, or those that are found to be serviceable, are subsequently returned to inventory stores, to await installation and use on an aircraft as replacements for removed parts.

The random failure rate of parts that are maintained on-condition, and the fact that some parts (that is, part numbers) are classed as no-go, while others are classed as go items, means that it has always been difficult for airlines to estimate exactly how many units of each part number they need to have available in their inventory stores in order to keep their fleet operational. An aircraft can continue to operate despite the failure and removal of a go item, although this must nevertheless be replaced within a certain period. Spares for go items must therefore still be readily available. Failure of no-go items, however, means that the aircraft is grounded, so serviceable parts have to be immediately available in stores, or from another local supplier, to ensure that the airline can maintain a reliable operation.

One key parameter used to define the quantity of each part number is the availability of parts. This is expressed as the percentage of times a part is available in the stores. Most airlines prefer to operate with part availability rates of 95-99%.

Rotable management is further complicated by the fact that each aircraft type has 2,500-3,000 different parts installed, and about 1,500 actual part numbers installed. The parts installed on one aircraft type will differ completely from those installed on another, unless there is some commonality between the two types. An example is the A330 and A340, which share some part numbers. There will be commonality between almost all rotable parts on the variants of an aircraft type, such as the 737-700, -800 and -900.

The number of parts held in stores that are required to maintain the



Rusada's Enterprise system has a 'min' and 'max' function. This uses an algorithm to calculate the optimum stock levels. These are displayed in a table, along with the stock levels held and the reorder levels required to bring the stock requirements up to the minimum levels.

availability level at 95-99% varies according to fleet size. About $13-14 million of inventory is required to support a fleet of one or two narrowbodies, while $15-18 million is required to support 10 aircraft, and $20-23 million is required to support a fleet of 20. The economies of scale that result from commonality between two or three sub-types or variants, are clearly useful in minimising the amount of spares that need to be held per aircraft.

The number of spares needed for each part number is also influenced by several parameters, including: the mean time between removals (MTBR) or fixed removal interval; the time for testing; the time for repair; the time to clear any necessary customs; the time for transport; and the fleet size.

Taking a recirculating fan on a 737-700/-800 as an example, this part has an mean time between removal of about 3,700 flight hours (FH).

The inventory size required to keep a fleet operational is further complicated by the fact that there are several variants of each part number, which often arise over years of production and operation, leading to upgrades, modifications and improved variants. A part number ABC, for example, may have a -1 variant produced when the aircraft on which it is installed first enters service. Service bulletins (SBs) and other upgrades are subsequently released to modify the part so that -2, -3 and -4 and other variants of the part number are produced as time progresses.

As operation with the aircraft continues, the variants for the part number can reach as high as a -25 or -30. As the fleet ages, airlines will progressively update and modify their rotables, and have a policy of no longer operating older variants. For example, all older aircraft would only operate with the -9 or -10 or higher variants of the part number, making older variants with earlier dash numbers obsolete.

The issue becomes more complicated when the airline orders more aircraft of the same type in later years. These later line numbers are likely to have rotable part numbers with later variants and dash numbers, which creates a sub-fleet of the aircraft type.

Moreover, when a fleet is upgraded from one dash number to another, a fleet or sub-fleet may end up using two or more dash numbers or variants of a part number over the course of several months or even years.

Finally, when fleets or sub-fleets are phased out of operation altogether, the part and dash numbers supporting these fleets are no longer required.

These three issues concerning dash numbers and variants of a particular part number cause several problems with managing rotables manually. The first is that a maintenance & engineering department can never be sure how many examples of each dash number are installed on aircraft, are in various stages of repair or transport, or are available in inventories. This leads to difficulty in identifying surplus or obsolete stock, as well as in determining the optimum quantity of inventory that needs to be held to keep a fleet operational. It therefore often leads to surplus or obsolete stock being held by an airline unnecessarily, thereby tying up precious capital.

It is also important that airlines claim for parts that fail and are removed within their warranty period.

Another issue is that operators have to track, record and report removal intervals and reliability data for rotables and LRUs. This requires a lot of labour when managed manually, and data quality is inevitably poor.

Tracking rotables

The first element of an IT system used for tracking and optimising stocks of rotables tracks each individual part or serial number.

"With new aircraft, this starts with listing all the serial numbers installed on the aircraft that have been provided by the original equipment manufacturer (OEM)," says Chris Reed, managing director at Trax. "New stock being supplied has to be listed, as does the stock in inventory stores and other locations. When new aircraft are delivered, the text file which lists all installed rotables is then loaded into Trax. This allows the user to view the aircraft's component configuration."

Rusada's Enterprise system can be programmed to show which part and dash numbers can and cannot be installed on the aircraft. "This prevents the installation of any wrong part numbers on the aircraft," says Tim Alden, pre-sales director at Rusada. "The system has a master configuration of the aircraft, which specifies the types of components and part numbers allowed on it. Once parts for an aircraft have been loaded, Enterprise can list all the serial numbers installed on the aircraft. The system highlights in red where part and serial numbers have not been entered. The system will track parts, but parts that do not need to be tracked can be highlighted in green by the user. If the user is unsure

of the part or serial number installed on the aircraft, this can be highlighted in gold."

Maintenance, repair & overhaul (MRO) IT systems then track the FH and flight cycles (FC) accumulated by the aircraft as it operates each flight. This is necessary in order to monitor the aircraft's progress in relation to airframe checks as they come due. FH and FC data also provide reliability and removal data for rotable components.

Parts which have hard-time removals must also be monitored so that they can be removed at the optimum time.

Each serial number therefore has to be tracked by the MRO IT system, in most cases using barcodes. In the future, components used on the 787 and A350 will have radio frequency identification (RFID) tags.

The current system supplies purchased components with paper documents, including an EASA Form 1 for parts supplied in Europe, and Form 8130s for parts supplied in the US. The information on these paper forms includes the component's part and serial numbers, and its repair shop. This information has to be entered manually by mechanics into MRO IT systems if the part does not have a barcode. Usually this information is entered into the system during receiving and goods inspection by the certified inspector.

Once data has been entered manually or from an electronic data file, the part can then be tracked, and information, such as the time since the last shop visit or overhaul, can be obtained.

There are several 'events' in the cycle that each rotable goes through, including: installation on the aircraft; operational problems or failures; removal from the aircraft; testing; transportation; repair and certification; and being placed in inventory stores.

"In many cases these events are typed into Trax manually, but this will change with the introduction of RFID tags," says Reed.

By tracking parts information such as the location, the number of items in spares inventory, and the time remaining on the warranty of the part, each part's repair and transaction history can be followed by MRO IT systems. "When a part is removed from the aircraft, for example, its condition has to be entered from a list of choices," continues Reed. "The mechanic records whether the part is put in quarantine to be tested for no fault found (NFF), or the reason for removal from the aircraft. The date and time of the transaction is also recorded. An unserviceable barcode tag is also created for the component. The repair administrator then decides what to do with the part. If it has been sent for repair, the system user creates a repair order. Parts can be repaired under contract, sent to a repair shop and the repair charged according to labour and material used, or repaired internally in the operator's own repair shops. Trax then informs the user if a part is still within its warranty period, in which case a warranty claim can be made. Finally, the part is shipped."

Several systems, including AMICOS, use a barcode feature to track each part. "This not only allows removal intervals to be followed, but also enables the monitoring of the maintenance programme for hard-timed components, pending modifications and possible warranty," says Rune Hagen, president and chief executive officer at Cimber Air Data.

A further benefit of barcoding and tracking each part is that a system can be programmed to provide alerts. MXi's Maintenix system has a cradle-to-grave capability for tracking each component.

Every transaction is tracked using a barcoding system. As each part is tracked, automated alerts inform the user that an action has to be completed. "For example, when a part is removed the repair person responsible is notified. When parts are shipped or repaired an alert to order a new rotable can be given, since it may then be possible that stock levels could be running low," explains Kent Fowlie, aviation business specialist at MXi. "Another important aspect is claiming warranties. This is done automatically by Maintenix, which can even have the terms and conditions of the warranties programmed into it.

"The further benefit of tracking rotables is that it provides full visibility of parts," continues Fowlie, "so that the aircraft on which a particular part number is installed, and the repair shops and inventory stores in which the parts are kept, can all be listed. The user therefore types in a part number, and Maintenix will list all the parts held by the carrier, including the different aircraft on which the part is installed, as well as the locations of all the other parts held by the airline. The system can also identify whether a part is a ship item, which is awaiting shipment for test or repair, or a shelf item, which is available and serviceable."

A 'to do' list is triggered in Maintenix when a part is removed, which creates the workflow for the part. "The properties for each part, such as tooling, or a list of shops able to carry out repairs, therefore have to be programmed into Maintenix," says Fowlie.

Optimum stocks

The optimum number of spare items of each part will result in availability rates of 95-99%. MRO IT systems are required to identify surplus parts and a shortage of parts that could result in lower availability.

Rusada's Enterprise has a 'min and max' function to control stock levels. "This calculation can be performed for all of an operator's bases," says Alden. "The table lists all rotable parts, including columns listing the calculated minimum and maximum number of parts that are required for each part number. Another column in the table also lists the actual stock levels held, so that the surplus or deficit of parts can quickly be seen.

"At its simplest, the min and max levels for each part can be set manually," continues Alden. "At a higher level the system has an algorithm to calculate the required level of stock, using certain data, such as historic usage of the part, its lead time, its safety factor (the number of parts that should be held above the minimum level), and the multiplication factor (the maximum number of parts over the minimum level). This information can be adjusted and reviewed periodically in order to assess the min and max quantities for each part number. The system will then list and analyse all part numbers with stock levels below the minimum level, and specify the number needed to bring stock levels up to the minimum. Parts are automatically tracked by the system. Every time an event associated with a part occurs, relevant FH and FC information is recorded. There is also a document function that allows all documents that relate to an event to be recorded."

AMICOS has a dynamic screen showing all components whose numbers have fallen below the established minimum service level. This helps the operator to take action prior to the actual need for a specific part, by expediting transactions such as increased priority on repair or purchase, borrowing or pooling parts.

"Maintenix has an alert page which lists all the part numbers that are low in stock," says Fowlie. "This is an actionable to-do list that expedites the repair or purchase of parts. It can automate purchasing and be programmed with airline policies such as when new

parts should be ordered, and when they should be taken from another location."

The objective of a rotable tracking and management system is to constantly re-assess what stock levels are required by monitoring rates of aircraft utilisation, component removal and reliability data, and fleet size.

"One technique is to use the system's ability to provide visibility and tracking of parts to prevent their premature removal" says Fowlie. "Understanding the reasons why parts are removed improves the predictability of non-routines, which therefore leads to better inventory management. This allows the airline user to re-define the supply model, and reduce required inventory levels without affecting availability rates.

Trax has tools to indicate the service levels of individual part numbers. "If stock falls to a certain level, the system warns the user," says Reed. "Trax also has reports to show the amount of movement of each part number: how often a part is removed, sent for repair and installed on aircraft. Part numbers with low movement levels may have their surplus sold, for example."

A lot of detailed information is required to optimise quantities of inventory. Component Control's Quantum Control software specialises in rotable inventory management. The system has several modules, with its core module managing inventory and purchase parts. "The core module helps users optimise rotable inventories. This starts with an inventory screen where a part number can be inserted," says Frank Scales, director of training services at Component Control. "This summarises what is in stock for that part number, what is in reserve, and the number due on purchase order or from repair shops.

"The user can then drill down to get detailed information," continues Scales. "The page is also customisable. The purchase order history and current stock reservations for each part, open purchase orders, the invoice history for each part, and the complete records of parts no longer held by the user can all be viewed. A document-imaging module in the system can be used to attach electronic images, paperwork, maintenance records and certification paperwork to a rotable's record.

"Quantum Control also allows the user to drill down into the history of each serial or part number to retrieve the relevant history," continues Scales. "The system also has forecasting tools, and it can analyse how often each part number is removed from aircraft or stored, in order to calculate the airline's inventory requirements."

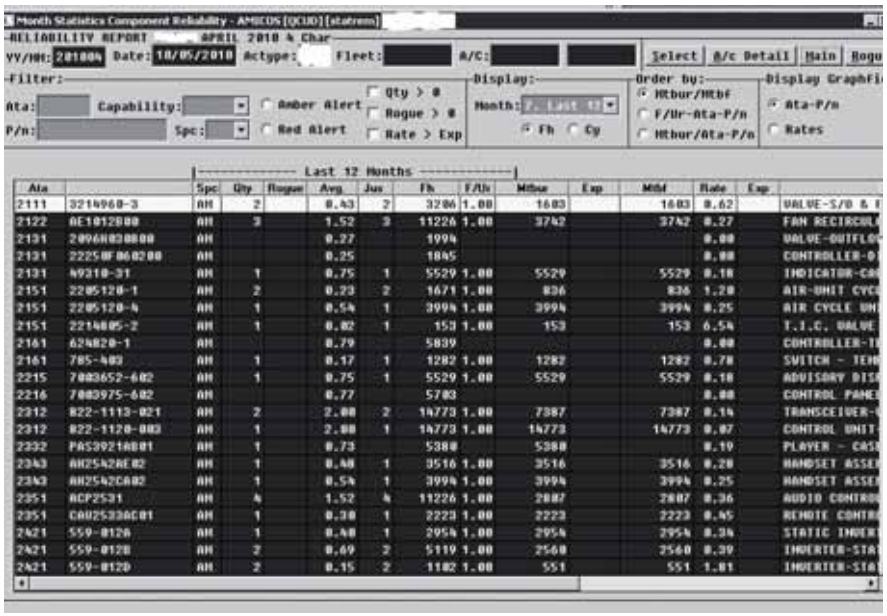
AMICOS has a statistic and reliability module, which calculates each component's reliability, and identifies rogue components that may cost the operator several thousands of US dollars if they are not removed from operation. A rogue component is a specific serial number that repeatedly fails in operation, and also frequently has no-fault found when returning from a shop visit. AMICOS also calculates the MTBR, mean time between failure (MTBF), and failure rate, to optimise and predict the stock requirements to a more correct level.

Obsolete parts

As older fleets and engine types are phased out, and components are constantly being upgraded to higher dash numbers, parts and rotables inevitably become obsolete. This inventory should be identified so that it can be disposed of through the aftermarket.

"Maintenix identifies parts that are no longer applicable to the fleet in use," says Fowlie. "The obsolete tab will list all obsolete part numbers, as well as the quantity and location of each one."

Other systems have similar functionalities to allow this identification. "Trax can be programmed with information relating to part and dash numbers that have been superseded,"



Optimum stock levels required for each part are determined by factors that include mean time between failure (MTBF), fleet size, repair and turnaround time, and route network. Cimber Data's AMICOS lists these parameters in table. These parameters and stock levels can be continuously re-assessed.

says Reed. "Those parts that apply to older aircraft types can then be sold, if they are surplus to requirements, or upgraded to later part numbers if more stock is required."

In addition to identifying obsolete parts, AMICOS prevents the installation of irrelevant or incorrect parts on an aircraft type. "An example is where a particular SB has not been performed, so the upgraded variant of the part is required," says Hagen. "By being programmed with each part and serial number that cannot be installed on the aircraft and a fleet due to an SB or a modification, AMICOS is able to put an installation and issue stop on the part."

Surplus parts

Systems also need to identify those parts that are surplus to requirements for a fleet or sub-fleet. This again allows the airline user to either sell or upgrade parts.

"AMICOS calculates the service level for each part," says Hagen. "This is the percentage of times that a part is actually available when it is required. Most airlines aim for 95-99%, but the service level varies by airline and type of operation, and usually ranges from 85% to 96%. Going from 96% to 98% for no-go items will double the value of the stock. The user of AMICOS defines the service factor for each category of minimum equipment list (MEL) items (the go, no-go and go-if parts) so that the number of units that have to be stocked for each part number can be calculated. With regular removals and other data relating to repair turn times, the quantity of stock can constantly be updated. By simulating the airline's operation, AMICOS can also calculate how many parts are needed if there are changes to the removal intervals, repair turn times, fleet size, and rates of aircraft utilisation."

Maintenix has a surplus stock tab. "This shows when there is more inventory than just the re-order level," says Fowlie. "Surplus stock means that more is being held than is actually planned for. Maintenix has another tab to show moving stock. This indicates where too many units of a particular part number are being stocked, and how the stocking levels compare to the number used over a particular period. Maintenix allows the user to programme the percentage of surplus parts it is happy to operate with. By fine-tuning stock requirements and identifying surplus stock, it is possible for an airline to save as much as $80,000-100,000 per aircraft per year.

Enterprise also lists the number of surplus parts held for each part number. Some parts will be provided under a fixed-rate contract or will have been acquired by exchange. Enterprise can list all contract parts so that their stock levels are kept up to date as specified in the contract.

Borrowed parts

"Airlines also borrow parts from other carriers, sometimes through the international airline technical pool (IATP)," continues Fowlie. "Borrowing these parts is often free, or fixed at a low rate, for the first few days, but a borrowing fee is applied thereafter, usually on a daily basis. Maintenix identifies items that have been borrowed, and records when they are due for return prior to the application of a fee. The system also has a record of the borrowing charges imposed after the free period ends, and calculates the cost of borrowing to date."

Borrowed parts represent a cost to the airline, especially if they have been borrowed for extensive periods. Airlines that have managed rotables with manual systems often have borrowed parts that have not been tracked, resulting in excessive fees for the carrier.

The reverse side of this is that airlines can generate revenues from parts they lend to other carriers. A system to track lent and borrowed parts accurately, monitors revenues that are being generated, and allows borrowing costs to be minimised and managed. AMICOS, for example, alerts the user to the parts on an aircraft that have been borrowed when maintenance checks are being planned, and alerts the operator to remove a borrowed part as soon as an equal part is available. This is done automatically, by adding a removal task on the due list in the same second that an owned part has passed inspection and quality assurance. By maintaining control of loaned parts, and removing borrowed ones as early as possible, the operator may save large amounts of money every year.

AMICOS is also able to inform the user of the costs of all borrowed parts, and can translate this into a cost per day or FH. It can also list all borrowed parts and their associated cost from each vendor.

Warranty claims

Claiming warranties is another complex element of managing rotables that cannot be performed effectively using a manual management system. Each part has a limited warranty period, within which any failures will be repaired at zero cost by the repair shop.

Warranty periods are typically 500-2,000FH from the date of the part's return from the repair shop. It is only possible to ensure that all warranties are claimed if the parts are tracked using an MRO IT system, which can alert users when parts fail within the warranty period. Moreover, it can automate warranty claims and combine them with the work order when a part is sent for repair. AC