Maintenance operations control is an intensive task that has to coordinate flight operations, aircraft dispatch and line maintenance. While this has traditionally been managed with paper-based systems, MRO IT systems now exist that give maintenance controllers control over the process.

IT systems for maintenance operations control

Managing maintenance operations control is an intensive job and and places those responsible at the sharp end of an airline's operation. Maintenance control involves logging technical defects and faults that occur on an aircraft in flight, correctly reporting and diagnosing them, deciding whether they can be deferred or have to be rectified, assessing what resources are required to deal with the problem and arranging them, coordinating the fault rectification with flight operations, and maintaining an up to date list of technical defects.

This process has traditionally been managed manually, and is still handled with paper records and manual coordination between the flight operations, maintenance control and line maintenance departments of many airlines. Manual management requires wide margins in terms of aircraft turn times, staff numbers, spares inventory and line maintenance capacity to keep an acceptable rate of schedule reliability. IT systems now exist, however, which manage the whole maintenance control process, allowing airlines to improve efficiencies.

Component faults

Accepting and dealing with technical faults follows a logical process. Aircraft develop technical faults and defects in operation, the nature of which varies and falls into two broad categories. The first of these is simple physical damage and wear, and includes items such as worn tyres, physical damage dents noted in a walk-around inspection, failed light bulbs, damaged seat covers and broken seat belts.

The second category includes complex problems involving system failures, such as failed or faulty avionics, and problems with hydraulics, electronics, pneumatics, engines and the auxiliary power unit.

Failures or faults of components are classified as 'no-go' or 'go' items: a no-go failure prevents operation of the aircraft until it is fixed; and 'go' item is a fault that can be deferred and later cleared, thus allowing the aircraft to operate.

Each aircraft also has a minimum equipment list (MEL), which specifies parts on the aircraft that can have the rectification of technical defaults deferred to allow continued operation. Faults on some MEL items may impose some extended range operations restrictions.

There are four categories of deferral: A, B, C and D. Times allowed for deferral are three, 10 and 120 days for B, C and D class deferrals. The length of deferral varies and is specified for A class deferrals.

It is a legal requirement to carry a copy of the MEL on the flightdeck of each aircraft, and maintenance control departments also have copies. Each MEL item is listed, and can be found by air transport association (ATA) Chapter number. This is accompanied by an MEL reference number, part number, description of the fault, the deferral category of the fault and list of operational restrictions that occur as a result of that fault.

Rectification of a fault on all MEL items can be deferred. This means they can be cleared during the various scheduled events in line maintenance.

There are other types of faults which are not MEL items, and therefore cannot be deferred making them 'no-go' items as a consequence. Examples are a broken pilot's seat, or an engine that has suffered foreign object damage.

Aircraft operations

Aircraft in operation accumulate flight hours (FH) and flight cycles (FC). Actual FH and FC are recorded and have traditionally first been given by the flight crew to flight dispatchers in flight and technical logs. These have then been entered manually into other paper records often several days after the flights in many cases. FH and FC times recorded by crews have not always been accurate. On-board flight management systems (FMSs) now record FH and FC automatically, allowing the data to be transmitted electronically and instantly to electronic technical logs after a flight is completed. Not only does this save paperwork and time, it also provides real-time, accurate data.

Airline flight operations departments plan operating schedules for each aircraft, which are coordinated with maintenance schedules provided by maintenance and engineering departments. Maintenance schedules are a series of planned events, and have intervals based on FH and FC. As each flight is operated and FH and FC are logged, the time due to each scheduled maintenance event becomes closer. Actual FH and FC will differ from forecast rates of utilisation. The physical location of aircraft after each flight, the need to keep to the planned flight schedule, and the capacity of maintenance facilities means aircraft cannot always be grounded at the exact time each planned maintenance event comes due. An accurate recording of FH and FC, however, allows closer monitoring of an aircraft's cumulative utilisation and allows better coordination between flight operations and the maintenance department. Higher rates of maintenance event interval utilisation are therefore possible.

Aircraft operating schedules, and therefore the expected rate of utilisation, will also change, so maintenance events will have to be re-scheduled. Accurate FH and FC data allow better management of this; high rates of maintenance interval utilisation are only possible with accurate FH and FC data.

Line maintenance programmes are typically built around overnight, daily and pre-flight checks. Overnight checks are performed once every 24 or 48 hours and present line maintenance and maintenance operations control departments with the opportunity to clear deferred defects, as well as to perform scheduled maintenance. Daily checks are performed before the first flight of each day, and pre-flight checks before all other flights during the day. It is in these checks that defects might be reported and recorded, and simple ones cleared.

Higher line checks can then be weekly and A checks. A check intervals for most aircraft types are 400-600FH, equal to two or three months of operation.

Technical faults that arise during operation can be deferred for varying lengths of time, as described, but have to be scheduled to be cleared during overnight and higher line checks. Clearing each technical defect therefore has to be correctly timed, so that it is performed within the time allowed in the MEL. It also has to be planned in relation to the aircraft's physical location at the optimum time for clearing a defect. An aircraft may be at a line station when a defect has to be cleared. In this case the operator is unlikely to have all the required resources in place if the defect is a complex one, and third party contractors will have to be involved. If an aircraft is at a primary or secondary hub instead all the relevant mechanics with the appropriate skills, the right facilities and tooling and correct parts will have to be available to clear the defect. Coordinating this may require more time than the defect is permitted to be outstanding, and so it will have to be fixed at another location at an earlier time, possibly requiring the aircraft to be removed from its planned schedule for an unscheduled maintenance event. The list of outstanding defects and their remaining time to be cleared have to be coordinated with the order and FH and FC remaining of scheduled maintenance events by the maintenance operations control and line maintenance departments.

Fault reporting

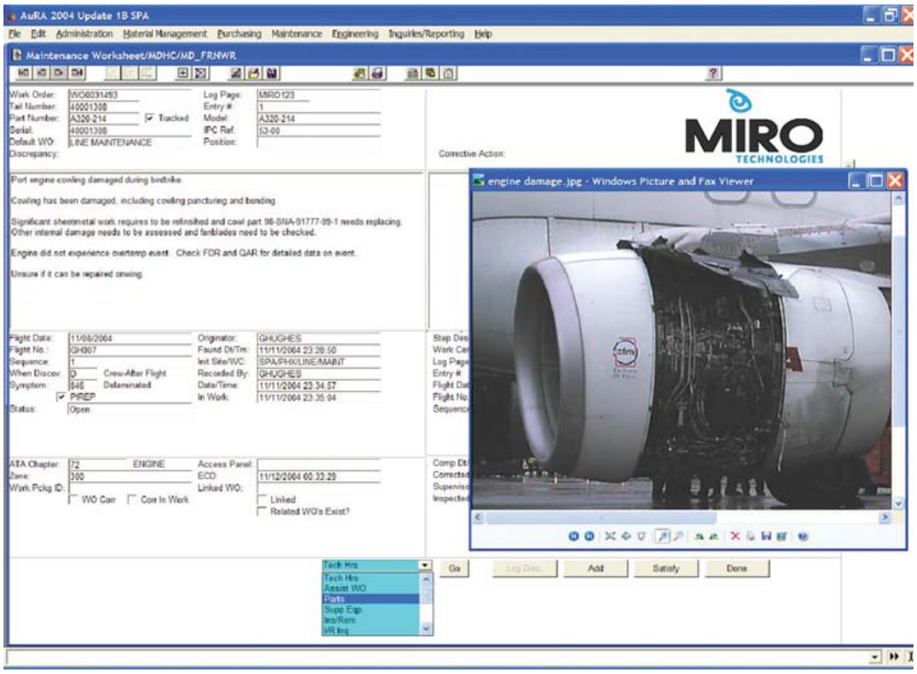
Technical logs and pilot reports (PIREPs) are made at the end of each flight, recording technical defects as they arise.

Central maintenance computers (CMCs) in aircraft generate fault codes, and are related to ATA Chapter indicating where the fault has arisen. These codes are only for problems that relate to systems on the aircraft. These codes can be manually entered in technical logs, and line mechanics can analyse and diagnose the fault codes and troubleshoot the faults using a fault isolation manual (FIM) or flight reference manuals (FRM). "Fault codes were originally looked up in printed FIMs and FRMs, but these are now available electronically and are provided by the original equipment manufacturers," says Stein Bruch, director of business development at VISaer. "The FIM is a fault diagnosis manual, and systems are also available which diagnose fault codes."

Faster diagnosis of CMC codes has been made possible with aircraft communication and reporting systems (ACARS) in recent years. ACARS transmit fault codes to the operator's maintenance operations control station during flight. This allows diagnosis and planning for fault rectification to be made before the aircraft lands, thereby reducing or eliminating the delay incurred from fixing a fault.

Faults that cannot be detected by CMCs or transmitted by ACARS to maintenance control stations still have to be reported by crews or line mechanics to maintenance control centres. These have to be handwritten by crews in technical logs. "Physical faults or ones that do not have CMC codes are manually written by maintenance controllers and refer to ATA Chapters to provide a reference to locate and diagnose the fault," explains Bruch.

"Maintenance control centres in many airlines have three main areas: the maintenance control system; flight operations system; and dispatch. Dispatch deals with passenger loading, weight and balance, fuel, freight, catering and aircraft departure," continues Bruch. "Maintenance control is informed of faults that arise in different ways. Those that can be transmitted by ACARS are sent to a maintenance controller, which enters them into an MRO IT system, such as VISaer, which is the first part of recording a technical log. Another method of reporting is technicians writing



An example of a PIREP with picture attached by MIRO Technologies' AuRA.

faults by hand either on paper Pireps or on tablet computers, or some other handheld electronic device."

Current IT systems for flight operations, dispatch and MRO require links to be made between aircraft and MRO systems. The automation of the transfer of aircraft operation, utilisation and technical fault data is likely to be available to airlines from 2006. There are, however, various types of software and hardware for transmitting flight operations and PIREPs data to MRO systems. These are referred to as electronic pilot flight bags, and Core Wing provided by DS&S is one example. When maintenance control centres receive reports of faults they are entered into technical logs on MRO systems, which is the first step in managing technical faults with maintenance operations control.

MRO systems first have to coordinate flight operations data with technical logs written by maintenance controllers in operations control. "Technical faults are entered into a maintenance worksheet, similar to a technical log entry, in AuRA," says Geoff Hughes, sales director at MIRO Technologies. "These describe the fault, have a symptom code and a when-discovered code that all help the line mechanic or maintenance controller diagnose the fault. The description of the code may be written in by the line mechanic, either as a manual code or a description in words, if the fault is something such as a worn tyre or thin brake disc. If the fault has a CMC code then this can be entered manually or electronically, and the code can then be looked up in the FIM. The MRO system can read CMC, and so diagnose it automatically. A manually written description may include an air transport association (ATA) code that helps locate the origin of the code. AuRA also has the ability to embed or attach pictures of the fault, which might for example be engine fan blade damage, to the technical log. These technical logs can also be sent to engineering departments or manufacturers if their opinions are required on a fault."

The pages for entering technical logs into MRO systems should also be interactively linked to flight operations data, so that real-time information is given to maintenance controllers about an aircraft's location during its operation and exact time remaining for fault rectification. The rectification of new faults also has to be scheduled or coordinated with outstanding faults. "Not only do faults get entered, but they also have an MEL tracking number in VISaer," explains Bruch. "This tracking number is specific to the fault and so allows the maintenance controllers to quickly determine if the fault affects the dispatch of the aircraft. Faults occur regularly in a fleet, and so codes can be given to faults. This first allows quick diagnosis for a recurring fault at a later date, but also allows templates to be written for their rectification."

The flight logs for each aircraft entered into TRAX are presented in a summary line for each aircraft. This shows the availability of each aircraft for operation by using a system of traffic lights. A green light denotes an aircraft without a technical problem, while a red one shows an unserviceable aircraft that has a defect on a 'no-go' item.

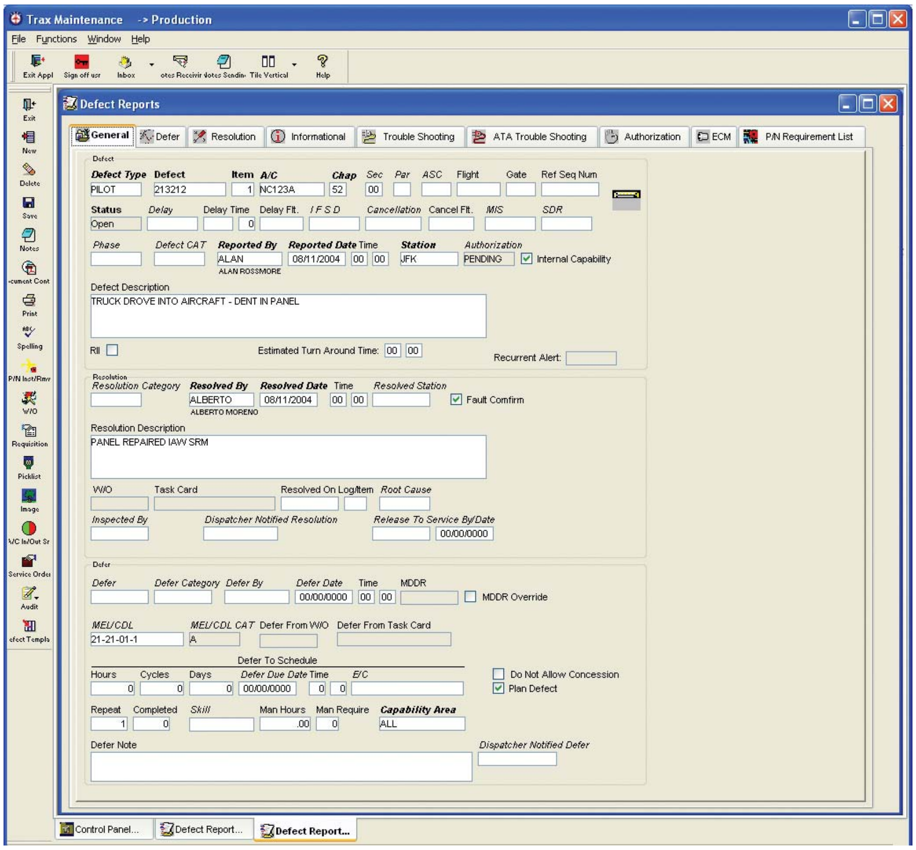
"Adding a technical default puts the aircraft in an unserviceable status while line mechanics decide how long it will take to fix the problem," explains Chris Reed, managing director of TRAX Software. "Line maintenance can also send a 'hold passenger boarding message' to flight operations or departure control while a problem is being fixed. Another message can then be sent when the problem is fixed and the aircraft becomes serviceable. An orange light denotes that the fix for a 'no-go' defect is pending, and that the aircraft is about to be released for service."

Avexus's Impresa has a system where a red light shows the aircraft is grounded and cannot be operated, and so is in an aircraft-on-ground (AOG) situation. "Each aircraft can be examined in Impresa, which shows all the flights it has operated and is scheduled to operate. The technical log for each flight can be examined, as can the maintenance log and list of technical faults outstanding on each aircraft," explains Paul Dibble, director of solutions management at Avexus. "Each maintenance log has an identification number created, and has a reference to an ATA Chapter number. The ATA Chapter number can then be used with the aircraft configuration management system to locate the part number that is affected and its serial number."

Fault diagnosis

Faults have to be diagnosed not only so that their rectification can be planned, but also so that their influence on the airline's operation can be analysed. Reference therefore has to be made to the MEL.

"The FIM is stored electronically in TRAX. TRAX cannot actually diagnose the fault itself with just the CMC code, but it does have a system, however, where faults can be compared with previous faults. The system can retrieve diagnostics for previous faults to speed up the process. Maintenance controllers still have to manually search for a diagnosis of the fault, however," says Reed. "The FIM is a troubleshooting manual and has flowcharts to assist line mechanics or maintenance controllers locate and diagnose faults. The fault code is looked up in the FIM, which provides a reference to the aircraft maintenance manual (AMM). The AMM provides instructions on how to rectify the fault, and may have a reference to the illustrated parts catalogue (IPC). TRAX pulls up a pdf file, which might be pages of the FIM, troubleshooting manual, IPC or AMM. Instructions on how to fix each fault can be standardised so they do not have to be worked out each time it occurs. The



An example of a defect report from the TRAX system. Defect reports are then stored in a list of defects, each one being analysed with respect to length of time that a deferral can be permitted.

rectification procedure may be just an instruction to look at a particular book or manual. Line mechanics have tablet computers or a laptop at line stations to look up a fault, or the FIM, AMM or workcards while on or near the aircraft, thereby saving time. Open defects, once analysed, can then be transferred to the maintenance production system so that task cards can be generated. Pages of the AMM can be attached to the rectification task cards."

The ability to transfer information about technical faults during flight via ACARS and have the information input into MRO systems automatically allows fast analysis and diagnosis.

"While there is still a manual bridge between faults developing and being recorded in the MRO system, this process will become automated in the next few years," says Bruch. "Some MRO systems still do not contain FIM or troubleshooting manuals and so cannot diagnose technical faults. This has to be done with a human interface at maintenance control or line maintenance. Other systems have diagnosis manuals in them and have to be used to diagnose a fault, but most MRO systems should have diagnosis manuals as an integral part in about two years."

Besides diagnosis, faults have to be analysed with reference to the MEL. This determines if they are 'go' or 'no-go' items and the length of deferral permitted by the fault.

Line mechanics and maintenance controllers traditionally had to consult both the FIM and MEL list when completing technical logs. MEL lists are included in MRO systems. "TRAX has a database of MEL items, and each contains a length of deferment, describing for how long they can be deferred before being rectified," says Reed. "The system can therefore state whether the fault is a 'no-go' or MEL item, and for how long the fault can be deferred if it is an MEL item. The system can then be used to display which MEL items are listed against each aircraft in the fleet."

The MRO systems know which items are MEL and those which are not. MEL faults are therefore flagged up, but the aircraft can still operate with them deferred. Bruch explains that fault deferral is not done automatically, and has to be done by the maintenance controller using the system. "If a fault cannot be found in the MEL then it is almost certainly a 'no-go' item and then the maintenance controller has to inform the engineering department or the original equipment manufacturer for assistance. The maintenance controller also still has to manually decide to ground the aircraft," explains Bruch. "The maintenance controller manually tells the system that an aircraft has a 'no-go' item and this grounds the aircraft."

MRO systems' ability to check faults against MEL codes allows maintenance control to analyse the severity of faults. Severe faults, which cause AOG situations or affect MEL items with a short rectification period should be prioritised, while parts with longer rectification periods can be given lower priority.

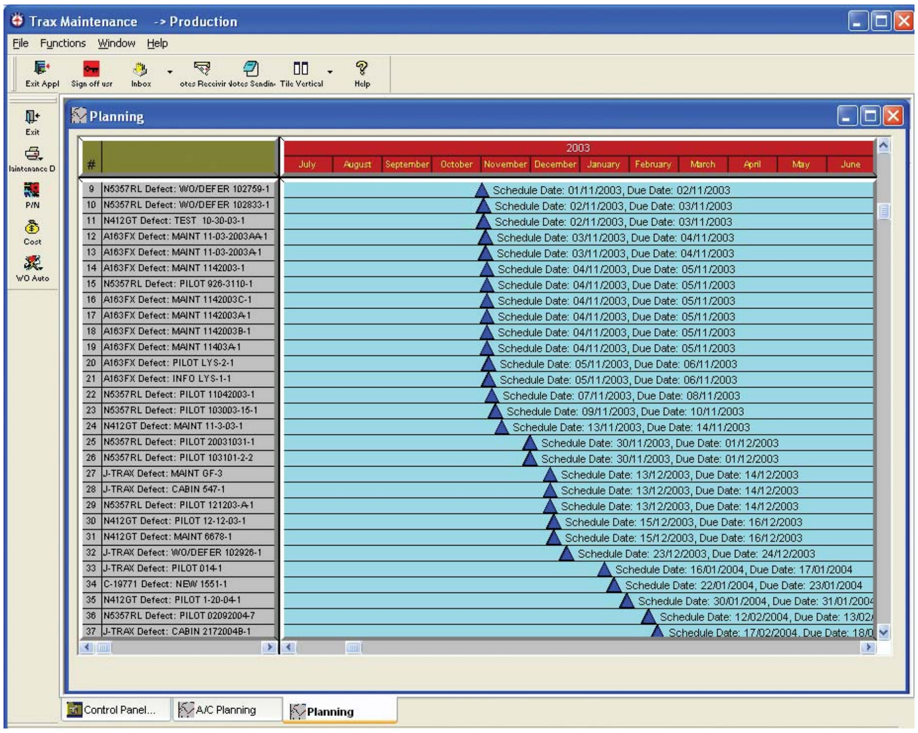
Once a fault has been entered, MRO systems also allow maintenance controllers and line mechanics to observe a list of open faults. "This can be done either by aircraft, by fleet, by ATA chapter, or by ATA chapter over a fleet of various other permutations," explains Bruch. "Observing a list of defects will show the time or number of flights remaining for rectification on each one, and whether or not the defect is an MEL item."

Planning fixes

Once faults have been entered into MRO systems, work cards or task cards to rectify them have to be written and an estimate of the labour and materials required is also made.

Instructions to fix a fault can be found in the AMM, supplied by the OEM or written by the airline's engineering department. Most faults can have standard work cards, but Bruch explains that some work cards still have to be written manually, since it is not possible to have a standard work card for every possible type of fault. This also makes it impossible to automate MH estimates and reservations, and ordering parts for this type of work order. Some engineering orders for rare or unique faults have to be written. Task cards have estimates for MH, materials and parts required to make a fix.

"Templates of work cards for rectification for most faults can be held in MRO systems," explains Hughes. "This will be a list of relevant maintenance manuals, an estimate of downtime to fix the fault, skill types required by line mechanics, parts and components needed, as well as a list of tools and equipment required. Historical work orders can also provide an estimate of the man-hours (MH) and cost of materials that will be used for rectification. A profile or work card to rectify a fault can thus be set up as experience is gained of faults occurring in a fleet is gained. Some of these can be standard, as shown in the AMM, or written manually by line mechanics. Thus once a fault is diagnosed, the rectification template or workcard can be picked up and attached to the technical log. AuRA can also be set up to automatically order parts and reserve tooling to complete the rectification. AuRA can also automatically make a decision about where to send material and parts to get



All deferred defects have to be managed with respect to coordination with scheduled line maintenance visits. Outstanding defects can be analysed in terms of time remaining for fix, and then planned in accordance with scheduled maintenance visits.

the faults rectified."

The removal and exchange of parts will also affect an aircraft's component configuration, which also has to be considered and managed by MRO systems. Ordering parts for technical fixes must take into account the inventory of available parts and reserving of parts for particular jobs. While an inventory may have the part required for a fix, it may have already been reserved to rectify another fault and so systems need the facility to reserve individual parts.

Reed explains that standard rectification and workcards have part numbers required attached. "TRAX also has a parts reservation function which checks an airline's inventory. The system reserves the parts required until the repair is due and then delivers them to the appropriate line station," says Reed. "Line maintenance also has to consider the possibility of there not being the right dash number of a part number available, and so TRAX is programmed with the alternative part numbers that the aircraft could accept. There is also the issue of intermixing parts, where alternative dash numbers can only be used in conjunction with other particular dash numbers of other parts or components that are working together with the affected parts. This facility comes from the aircraft configuration system in TRAX."

Coordination with operation

Once task cards are written and checked they are sent to maintenance production for completion. Clearing technical defects still has to be coordinated by maintenance controllers, taking operating schedules into consideration.

"Impresa has a maintenance planning screen which analyses an aircraft's planned schedule and list of scheduled maintenance events. The flight operations data allow the time remaining to each maintenance event to be viewed. Each flight in the schedule can be clicked on to see how the time left to each maintenance event changes, so that maintenance controllers can see the optimum time for clearing open defects," explains Dibble. "The system also shows where aircraft will be at the end of each flight. Location is important since different numbers of line mechanics, tools and facilities, quantities of materials and components are available at each line station and main operating base. The system also estimates the MH and materials required to fix each fault so that fixing a group of open defects can be scheduled and coordinated with the aircraft's operating schedule. Once each group of open defects is selected and planned, a complete work package for the whole group and an estimate of the labour, materials and parts required can be compiled. Impresa has a graphical system to show the number of MH available for each skill type at each line station and main base on each day, to check if there is sufficient labour available on the day required. This then allows some defects to be deferred further, or the aircraft to be repositioned to another base where there is sufficient labour available. Initial estimates of labour to clear a defect are or course, done manually and with experience."

Systems will further display each outstanding defect to show the total amount of time allowed for a fix, the time already used and the time left for a fix. "TRAX can also summarise outstanding defects and order them in terms of time left," says Reed. "Repairing defects is started using a service order, and these are sent by maintenance control to line maintenance stations all over an airline's network. These can be sent by e-mail to the sub-contractor or line maintenance personnel at an outstation. Not only do systems have to be able to display the total amount of labour for each skill type at each station for every day, they also have to show the inventory and tools available at each station on each day. While estimates of labour required can be made, it is not possible for maintenance control and line maintenance to accurately predict how much labour is required. Over the long term the amount of labour required for scheduled line checks and clearing defects for each fleet type can be compared to the amount of labour supplied, thereby allowing possible savings to be made."

Once a fault has been cleared the work cards should be signed by line mechanics, which clears the technical fault and registers it as cleared on the technical log in the maintenance system. The amount of labour, materials and parts used should all ideally be recorded, so that estimates for defect rectification can be constantly revised, and aircraft configuration kept up to date and accurate.

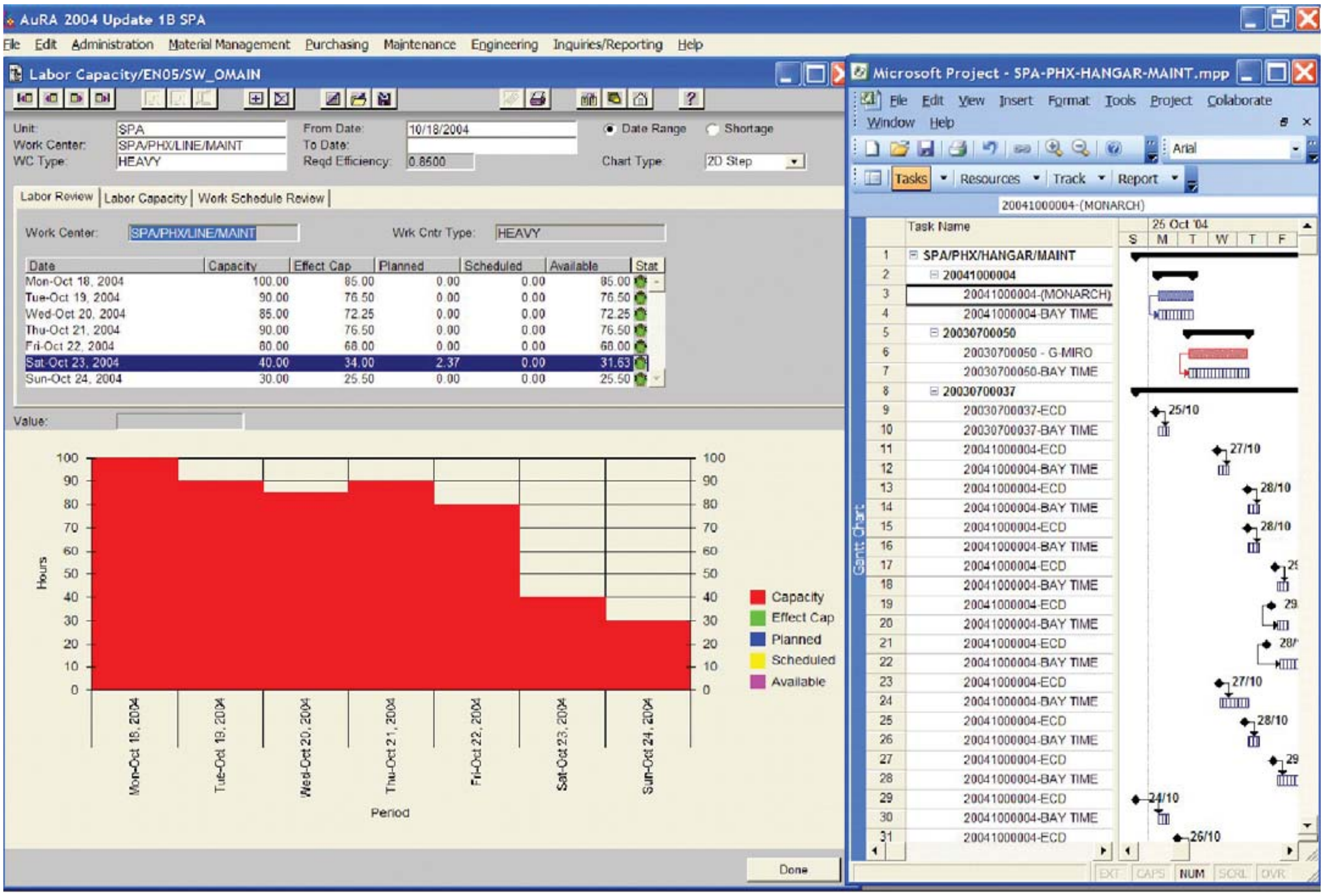
"Once faults and defects are cleared then the aircraft management system in TRAX will turn the traffic light in the aircraft's operational status to green, and a message can be sent to dispatch to allow the subsequent flight to proceed," says Reed.

Benefits & savings

The savings that can be gained from automating the maintenance control process can be substantial, since it affects many aspects of aircraft operation, maintenance and engineering.

The first of these comes from the electronic reporting of flight and technical logs and PIREPs, because it avoids the repetition of manually writing information in several systems: this would otherwise involve manually writing these reports, transferring them to maintenance control and line maintenance departments and several people re-entering the data into different systems.

Faster transfer of data and



Rectification of defects can be planned so that maintenance controllers can check that sufficient labour, materials, tools & the right parts are available at the planned time of defect rectification.

information also allows faults to be diagnosed faster. If a system is established whereby faults and defects are recognised by codes and are standardised, they can be diagnosed more quickly. Electronic fault isolation and maintenance manuals also allow faults to be diagnosed in the maintenance control centre, while the aircraft is still in flight, rather than by line mechanics having to sort through paper manuals on the flightdeck at the line station after the aircraft has landed. This will bring a saving in line labour requirements.

The ability to analyse technical faults more quickly allows rectification or a decision to defer a fault to be made faster by MRO systems. This can save downtime that would otherwise result in lost aircraft utilisation. Faster diagnosis of faults allows them to be deferred and grouped with other unscheduled line maintenance items and scheduled line maintenance checks. Streamlined management of line maintenance work, and coordination with the aircraft operating schedule to optimise when and where to best perform line maintenance, result in a higher rate of maintenance interval utilisation. "The average airline only achieves a 60-70% utilisation of line check intervals," says Dibble. "While it is possible to get an 85% utilisation of heavy check intervals, a higher rate of line check intervals is not easy because of the complex process of coordinating line maintenance with flight operations. Better coordination of line maintenance and flight operations allows a higher rate of interval utilisation to be realised. The overall effect of this is to reduce line maintenance expenditure per FH. This is not only because scheduled line checks are not performed so frequently, but also because unscheduled tasks can be deferred for as long as possible."

An improved level of control over line maintenance and defects also means that maintenance controllers will not ground aircraft unnecessarily with defects; this occurs with the poorer control that results from manual management. The result of this will be a higher rate of aircraft technical dispatch reliability and so higher rate of utilisation.

Another major benefit of managing the rectification of defects is being able to plan them when labour and required components are available, rather than rectifying them as they occur. This practice increases labour and spare parts inventory requirements, since rectification of faults is reaction-driven rather than planned or managed. Airlines consequently need to have excessive amounts of line maintenance labour available in reserve. The same applies to inventory of spare parts, since rotables and line replaceable units will be required sooner than if defects can be managed.

The long-term management of maintenance control and line maintenance also allows the amount of labour used and that supplied to be monitored and so more closely managed and matched. Long-term planning estimates of the labour and facilities required for line maintenance can thus be made more accurately and savings ultimately be made. Another major saving that can be realised is that related to spare parts and rotable inventories. Inventory volumes in most airlines are often excessive and parts often ordered and purchased on a reactionary basis. If the rectification of defects can be deferred, planned and managed then some savings in inventories are possible. Further savings can be made because maintenance control can schedule fault rectification when parts are going to be available. This prevents line maintenance ordering parts when fixing defects sooner than permitted in the MEL.

This higher level of control gives line maintenance and maintenance control greater visibility in the true requirements of their fleets. "It should ultimately be possible to create a full maintenance budget for an entire fleet, even taking unscheduled maintenance into account," says Dibble. **AC**