Converting a maintenance and engineering system from a traditional paper-based system to a fully mobile configuration is a large challenge. Various levels of sophistication are possible. Airlines and MROs need to consider the levels of technological change and the associated costs.

The challenge of switching to a mobile and paperless system

The potential for airlines and independent maintenance providers to increase efficiencies and save costs by operating on a totally mobile and paperless basis for all maintenance and engineering (M&E) activities has been discussed for 20 years.

A key issue that has prevented airlines and maintenance organisations from making these improvements is that many technological changes are needed to switch from a paper-based to a paperless system.

A few airlines have led the way towards a mobile and paperless M&E operation. Most have done this for just one or two elements of their M&E activities, such as in-house base maintenance, while other processes continue as before.

A full grasp of a paper-based system's inefficiencies is needed to appreciate all the benefits of a fully mobile and paperless operation. The main elements of M&E are the engineering management functions, line maintenance, hangar and base maintenance, component management, and engine management and maintenance.

Engineering management

A main element of engineering management is managing manuals and each fleet type's maintenance programme.

Implementing regular updates to paper manuals and documents from the aircraft's original equipment manufacturer (OEM) requires a large number of man-hours (MH), as do maintenance programme management, and management of airworthiness directives (ADs), service bulletins (SBs) and engineering orders (EOs) to individual aircraft line numbers (L/Ns). Changes to an aircraft's modification status must be recorded manually in an operator's M&E IT system.

The cost of maintenance check preparation and planning with a paper system is therefore high, because of complications such as maintenance task applicability to aircraft L/Ns, and manually preparing parts and materials for a check.

Using paper task cards also makes it difficult to plan a sequence of tasks for an airframe check to reduce MH consumption and shorten the aircraft downtime.

Check planning is more complex for subcontracted maintenance. While technical document management is carried out electronically, subcontracting checks can involve preparing routine paper task cards, or transferring electronic task data to the maintenance provider's IT system.

Electronic data transfer is difficult because of the lack of data standards for M&E, such as the formats and number of characters used for part numbers (P/Ns). Data is translated for the maintenance provider, and translated back to the airline's standard on completion of the maintenance check *(see The complexities of data transfer between M&E & CMS systems, Aircraft Commerce, December 2014/January 2015, page 40)*.

With a paper-based system, recording task completion, findings, and MH, parts and materials used means manually keying them into the airline's M&E system. This adds to the MH used and the time needed to update the aircraft's maintenance status.

An aircraft's component configuration must be constantly monitored, which uses a large number of MH if done manually. This process has been automated by swiping barcodes to record component changes P/Ns and serial numbers (S/Ns).

Line maintenance

Most inefficiencies in line maintenance occur when rectifying faults. Faults that occur in the air are detected by built-in test equipment (BITE), generating a central maintenance computer (CMC) fault code, or are observed by the flightcrew, who record them in the flight and technical logs.

CMC codes can be relayed to the airline's flight operations and maintenance control centre (MCC) while an aircraft is flying, so preparations to rectify the defects can be made before it lands.

Non-CMC faults cannot be analysed until the aircraft has landed, so these can be entered into the M&E system up to two days after they have occurred on the aircraft, and only after they have been rectified by line mechanics on the ground. Rectification of the defect will therefore be recorded on the technical log up to two days before the defect is entered into the M&E system, so the aircraft's maintenance status on the technical log is often out of synch with the operator's M&E system.

CMC and non-CMC faults will be analysed using the troubleshooting manual (TSM) or fault isolation manual (FIM). These manuals have cross-references to other manuals, such as the aircraft wiring manual (AWM). It is time-consuming to go through these paper documents.

As soon as a fault has been identified, after receiving the CMC code, a work order must be written to rectify it. This may require a change in location, and will involve arranging labour, parts and materials, and tooling, all of which takes a lot of time when done manually.

The completed rectification task must be recorded on the aircraft's technical log,

and all the relevant information manually entered into the M&E system.

Hangar & base maintenance

Large airframe checks have multiple inefficiencies in all the steps performed, especially tasks that are managed on paper.

These include the need for a mechanic to manually record measurements or results, contact a supervisor, request a non-routine (NR) or defect work order, request or return parts and tools, record MH used, and inform managers of task completion.

The performance of tasks, the findings, the materials and labour used, and the changing of rotable components all have to be manually keyed into the M&E system.

Finally, the completed paper task cards are archived by scanning and converting them into PDFs to be read via an optical character recognition (OCR) system.

What is the perfect system?

The first stage of using engineering data is managing technical documents, which includes editing manuals, modifying the aircraft's standard maintenance planning document (MPD), and writing an approved maintenance programme (AMP).

The engineering department manages the regular revisions and updates. The appropriate electronic data format and standard allows revisions and upgrades to cascade through the system in just a few minutes. The best solution is for an airline to implement the change late at night when maintenance activity is low.

Many document functionalities require hyperlinks between pages or sections of the main manuals, adding to the intelligence, and eliminating manual cross-referencing and looking up content. This is only possible, however, if the data is in the right format, standard and language.

Standard generalised mark-up language (SGML) was introduced when the format of technical manuals was changed to Spec 2100. SGML provides manual content with most of the functionality and intelligence required. The introduction of extensible mark-up language (XML) proved the functionality and intelligence of document content. This includes the ability to make calculations, take measurements, and stipulate minimum and maximum values, in a truly interactive task card on a mobile device.

If all the actions taken by a mechanic performing routine tasks and rectifying defects in NR maintenance are made through the interactive task card, then level 2 electronic signature can be used.

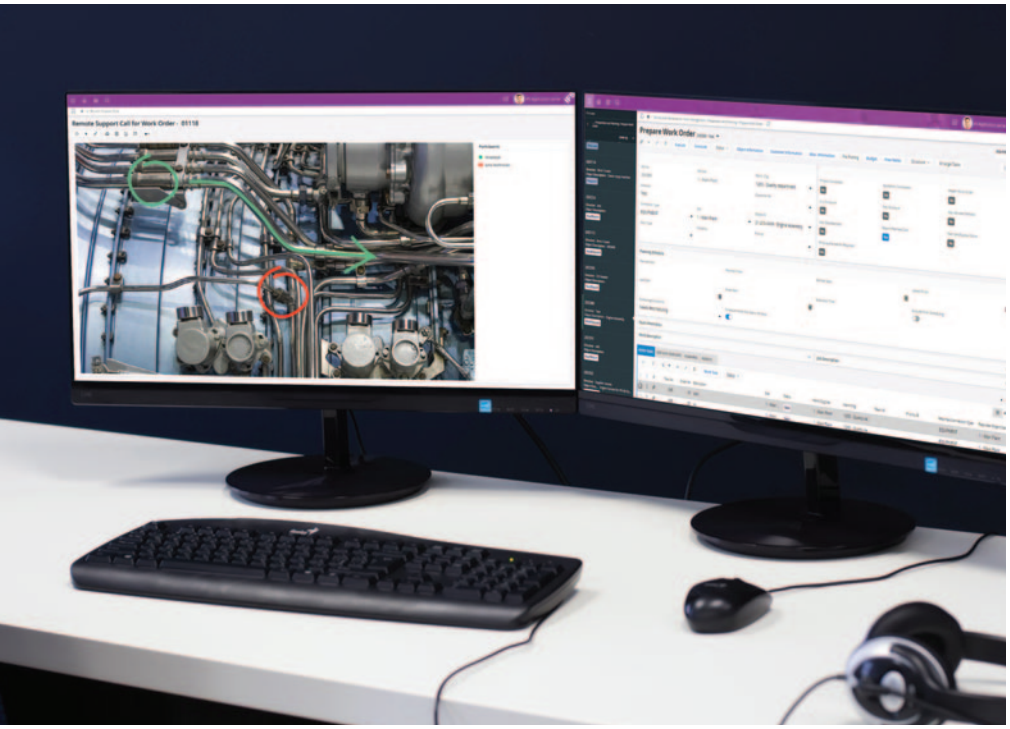
This is the basic concept of a mobile system, where an airline's engineering department creates task cards for a workpackage to be performed by its own mechanics at its own maintenance facilities. Outsourcing maintenance to different providers, however, adds to the complexity of configuring the system.

Transferring task cards and a workpackage to an independent maintenance provider in a mobile system needs to be seamless. Because of the large number of differences between information formats, the ATA has conceived Spec 2000 Chapter 18 to detail the standardisation of technical data. Data can be transferred seamlessly between related parties. From this, interactive task cards can be prepared and then rendered on mobile devices for use by mechanics, followed by level 2 signature. The completed task cards and related data are transferred back to the airline's M&E system, and the aircraft's maintenance status is updated.

Data transfer is further complicated by line maintenance carried out at a large number of airports, including outstations, by many different third-party providers.

The ATA has conceived Spec 2000 Chapter 17 to provide a standardised data format for line maintenance, and permit the seamless flow of data between all related parties in line maintenance. This is clearly necessary, given the time-sensitive nature of maintenance-related information, and the need to quickly generate work orders to clear defects.

A mechanic's mobile device is used to consult all the technical manuals when diagnosing a CMC code received on the ground for a technical fault. The use of an



A high level of sophistication in a mobile line maintenance system provides two-way data and visual communication between a mechanic working in situ to rectify a fault, and the aircraft operator's maintenance control and line maintenance departments.

electronic technical log (ETL) on the aircraft flightdeck allows flightcrew to record and transmit details of non-CMC faults. The details of the defect would be autopopulated in the M&E system to synchronise the aircraft's maintenance status with the aircraft's technical log.

After the fault is determined, routine and defect work cards are presented on mechanics' mobile devices. The request for parts and tooling is made via the device, as are communications between line mechanics and maintenance control, flight operations, spares stores, and engineering. Again, level 2 electronic signature would be used and digital technical records created. Data is automatically transferred.

Solutions

The three main levels of activity that an airline can make mobile and paperless are: engineering management, line maintenance and base maintenance. It needs to take several key considerations into account: configuration of the system; the data language and standard that the system will use throughout the organisation, and together with its subcontractors; the ability to achieve level 2 electronic signature with the chosen configuration and data standard; and whether a CMS is required.

Most M&E system providers believe the configuration should be at least a three-tier system if mobile applications are going to be used: the first tier will be a database server; the second will be several application servers with identical sets of the required applications; and the third will be the desktop computers and mobile devices used by engineers and mechanics. "I would actually say that an airline should consider an N-tier configuration," says John Stone, vice president product management at Ultramain. "Aircraft operate globally, and an international airline needs a diversified system, and therefore nodes all over the world. This means the system's structure could be more complex than just two- and three-tier."

Another main issue of configuration is how the system is accessed by line and base mechanics. This means many nodes are needed over a large area where mechanics and technicians must access the system to perform line maintenance. Several M&E systems use a cloud access architecture, such as Seabury Solutions' Alkym. "Many of our customers have Alkym stored in the cloud, from where their users can access all the data," says Diego Lopez, director of software engineering at Seabury Solutions. "The system works from different airports. Technicians log onto the app, record all work performed and the items used, and the system is automatically populated.

"The data is the start of the going mobile process," says Dan Dutton, vice president for research and development at IFS Aerospace. "A system user needs to look at how the data resides in the system, and how it is being used. The complexity of configuring the system depends on differing levels of access to data, ability to hold data on the mobile devices, exchanging and transferring data, having on-line or off-line systems, and degrees of task card interactivity. The system must be resilient."

"XML provides the highest level of functionality and sophistication because it allows maintenance task cards to be prepared digitally. Task cards can be rendered in HTML on mobile devices. XML, however, is only used by a few airlines and maintenance, repair & overhaul (MRO) providers," says Stone. "This raises the issue of what other choices the user has to create electronic task cards on a mobile device with all the functionality to make the system mobile, and avoid paper or manual input."

"Only a small percentage of airlines use M&E systems that ingest content from OEMs in an electronic data format," says Thanos Kaponeridis, chief executive officer at Aerosoft.

PDF is a simple but inefficient system. Airline engineering departments must cope with receiving very large volumes of data in PDF format, equal to 100 times more than receiving it as raw data in SGML.

The next step up in sophistication from performing maintenance with paper cards, derived from paper manuals, is using cards printed from content in PDF form. "The most basic mobile system can be based on task cards produced as PDFs, and present these on the screen of a mobile device for viewing, reading and reference purposes only," says Kaponeridis. "If an airline wants to be paperless, then the interactive functionality and the level 1 electronic signature capability would have to be provided via bespoke programming used on the mobile device and referenced on the PDF. Examples of interactive functions would be recording findings, requesting parts or writing measurements.."

The second level of sophistication is a system that produces an overlay over the PDF that reads its content. "The overlay then provides a layer of interactive functionality over the task card," explains Stone. "There are three other sophisticated ways to produce mobile task cards on screen from content data. These all involve rendering a card in HTML, which is an intelligent language that is used to display a task card on a screen."

The first way is to use SGML to provide a HTML card, but this is rare and requires the SGML to be converted to an improved format. The other two are to render XML data in HTML; or convert SGML content into XML, and render a card in HTML.

"An airline's or MRO's options for a mobile task card system mean that unless their system has the highest levels of capability and all data in XML, either a compromise or development work is required. There are many permutations for configuring a system," says Stone. "For example, Japan Airlines uses Ultramain to produce routine task cards in PDF, and uses an overlay system to give the card content interactive functionality when

A complete mobile line maintenance system can be achieved by providing an electronic device which hosts the aircraft's technical log and provides access to relevant technical manuals for fault and defect diagnosis. This device can be kept on board the aircraft.

viewed on a mobile device. It can then create NR cards in SGML or XML in Ultramain and an accompanying CMS, and renders them in HTML for viewing and using on screens."

Some system configurations have problems accurately displaying data, so the M&E and CMS systems must be certified by the aircraft OEMs to say that the data they have provided is being shown properly. This can be problematic.

"The ability to give intelligence to the data standard, such as applicability of P/Ns to a task, or applicability of a task card to an aircraft line number (L/N), requires the use of metadata. A very important function is the ability to build the associations between metadata. This is what gives the system its applicability, such as P/Ns to tasks," says Kaponeridis.

A modern relational database can create these relationships with different pieces of data. Associations between types of metadata and information are also needed to provide the functionality for the complex tasks that are a feature of interactive and fully mobile task cards.

"The advantage of using XML is that it contains a richer set of metadata. These are a wider range of categories of information, which increases the functionality of a task card," adds Kaponeridis.

Several systems can operate with XML, without a CMS, including Trax, Swiss AMOS and IFS Maintenix. "IFS Maintenix operates with XML data, and can produce a digitised task card, or job instruction card. The XML allows the card to use structured metadata and content," says Dutton. "Structured metadata can have relationships with other pieces of metadata, which makes it possible to have applicability between P/Ns and a task card, for example. It also allows the task card to be interactive, and provide a fully paperless and mobile system. If the system is truly digital, it allows communication between the task card and other parties.

"This is important for one aspect of engineering management," adds Dutton. "An aircraft has an allowable configuration in terms of part and rotable component P/Ns in particular positions and locations. A system's ability to manage this depends on its ability to create associations between pieces of metadata. A tool within IFS Maintenix streamlines the process of managing the allowed parts on the aircraft. This is the same as airlines managing their approved parts list (APL).

"This functionality is important because every time a task or a workpackage is finished, the system shows that the aircraft's maintenance status has been fully evaluated. This can be the green light for return to service," adds Dutton. "This functionality therefore provides real-time compliance status, and mechanics and engineers know if the aircraft is serviceable. The aircraft's allowable P/N configuration provides the rules for creating this function, so an audit is possible at every step of the maintenance process, from ordering to installing parts."

Some airlines and MROs may consider adding a CMS to their system for managing technical documents, managing revisions and updates, and editing and writing maintenance task cards. Several criteria determine whether a CMS is required, or the M&E system is sufficient. The first is the M&E system's ability to regularly ingest technical data from the OEMs in SGML or XML.

This raises the issue of how much authoring the airline wants to do in-house. If the airline wants to do this, the M&E system needs to ingest the data, and to have a bespoke application to mimic all the functionality of a CMS. Some systems have modules configured specifically to manage documents and provide the same or similar capabilities as a CMS. "Alkym operates on a relational database and SQL server. We offer the document management system (DMS) as an option," says Lopez.

Many M&E systems lack these capabilities. Adding them may be expensive and time-consuming, so it may be cheaper and faster to acquire a CMS.

"Most IFS Maintenix customers operate the system together with a CMS, and only a minority operate Maintenix on its own," says Dutton.

Another type of system configuration, engineering management, and data standards and language is Spec 2000 Chapter 17 and 18 for use in line and base maintenance. The adoption of these would standardise electronic content and allow the seamless transfer of data between airline system users, and MROs and other maintenance providers.

Neither of these standards has been widely adopted, however, so airlines and MROs have been forced to develop other systems for transferring data so that mobile operations become possible, usually by creating conversion tables or software.

The airline can avoid this by preparing a work package for a subcontracted maintenance check on its M&E system, and making this accessible via the cloud to the maintenance provider. "While this removes the problem of data and routine card transfer from airline to MRO, it is unlikely to be favoured by independent maintenance providers," says Chris Reed, managing director at Trax. "This is because MROs quote many maintenance checks on a fixed price or 'capped' basis, which does not reflect the actual MH and materials used. The MRO therefore does not want an airline to see what inputs it has used to complete task cards, but this will be recorded as part of the SFDC functionality."

Another issue is the system being configured to work only on-line or off-line. "Clearly being on-line means a line or base mechanic will be connected to the M&E system, and will be able to access relevant manuals and engineering data as needed," says Reed. "The reality is that connectivity is intermittent, so it is essential for a mobile system to have off-line capability for both main types of maintenance. An off-line system provides all documents and data for a task on the mechanic's mobile device so that they can continue working without

connectivity. The M&E system synchronises with the mechanic's device when connectivity is restored."

Line maintenance

Rectification of technical faults and defects have several practical implications and difficulties.

"We have a mobile app called Maintenance Mobile that works with Alkym, and no other external M&E system," says Lopez. "The app divides into two user types: heavy and hangar maintenance, and line maintenance. The latter has on-line and off-line functionality.

"A mobile app user needs off-line capability, since connectivity is always being lost out on the line," adds Lopez. "All our mobile apps on Alkym use a local database to store information. Recording a defect or a new NR task is done on a local device. The app on the mobile device sends the information to the M&E system when connectivity is restored."

Dealing with technical faults and defects in line maintenance involves several steps. The first is MCC departments, and the line mechanics dealing with the affected aircraft being informed of the fault and defects. The second is analysing and identifying the fault, and communicating this to the M&E system and engineering department. Next, a rectification workpackage is prepared, followed by completion of the NR work, recording inputs, reporting and auditing the aircraft's maintenance status, and returning the aircraft to service.

"Chapter 17 is designed to receive information relating to work orders," says Lopez. "Our Alkym system can work with XML files, and with all technical modules. One example is the DMS. The NR job card to correct a technical fault is received from the DMS, which is also used to store pictures taken by mechanics, and information on findings."

Similarly, Swiss AMOS has a mobile line maintenance application, and AMOS works with ML data and uses Spec 2000 Chapter 17 standard for line maintenance work. "This is required when exporting data to and from the app. Our mobile application is really just an extension of AMOS," says Clements. "The AMOS mobile app is accessed from the mechanic's PED or device via a web browser."

Reporting technical defects requires a mobile system to work with ETLs and technical logs so that data from the ETL can be fed into a mobile app.

Defects and the NRs that rectify them can be created on a mobile app and sent to the M&E system in real time when there is connectivity. A maintenance planner can create the NR card and send it back to the line mechanic in just a few minutes.

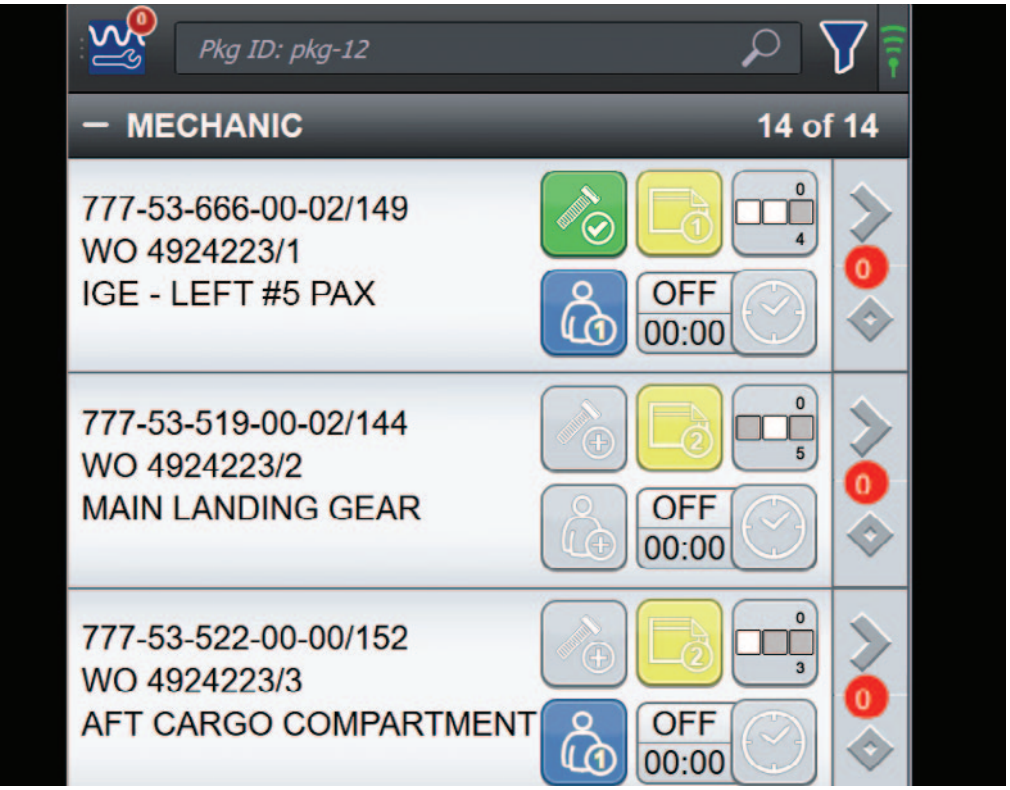
"We wrote our apps to work with Spec 2000 Chapter 17," says Reed. "Once defects are reported by mechanics, or received from the flightdeck, they are automatically recorded and populated in the M&E system."

Off-line capability is essential, since the mechanic has to consult technical manuals to resolve a fault. "These are held by the app on an iPad when operating off-line," says Reed. "Another problem is being unable to request parts, contact a supervisor, or report findings due to lost connectivity. Our mobile app works on a traffic light system, with a green light to show connectivity is established.

"There are always problems when working with remote line maintenance," adds Reed. "The worst situation is dealing with an aircraft on the ground without connectivity."

As soon as a defect is typed into AMOS Mobile, the aircraft maintenance status is updated. "The defect status is also categorised at the same time with the aid of the minimum equipment list (MEL), which is loaded into AMOS," says Clements.

When a fault is reported a fast response is usually needed, so situational awareness is essential. "Deferring the defect is clearly the preferred option," says Dutton. "The mechanic can talk to engineering through the mobile system. It also provides explanations relating to the technical fault,



Ultramain is one M&E system provider that has developed an overlay system for PDF task cards. This overlay system provides functionality for the mechanic to request parts, contract management personnel, and report findings.

including the effect on the flight plan, and for how long the defect can be deferred.

IFS Maintenix's IFS Remote Assistance module provides augmented reality so that the line mechanic can start a video-sharing session and communicate with a specialist. It is also possible to screen-share so that the specialist can understand the problem and give advice.

The engineers receiving the notification often complete the diagnosis and generate the rectification. "AMOS can do this in seconds, but not if troubleshooting is needed," says Clements.

It is important to update the M&E system with the true status of a defect, and therefore an aircraft's maintenance status, in real time, because some defects are critical. "AMOS Mobile works in an on-line mode, but the next version will be a hybrid and work partly on-line and partly off-line," says Clements.

Two other line maintenance challenges are dealing with non-CMC technical faults, and working with a large number of third-party sub-contractors across a route network. "Our electronic logbook (ELB) and Mobile Mechanic application in Ultramain operate on the same tablet or handheld device," says Stone. "Two such devices are carried on the aircraft so that they can be used by the line maintenance sub-contractor at any line station. This is more efficient and user-friendly than the subcontractor accessing Ultramain via their own device, and trying to find information on a non-CMC fault as well. Cathay Pacific's line mechanics, who use Mobile Mechanic, use their own iPad to perform tasks at Hong Kong and a few outstations where the airline's own mechanics are based. The ELB is hosted on the aircraft's tablet, which can be used by line mechanics across the rest of the route network."

Base maintenance

Few airlines have their technical data in XML, and most still use paper or PDF. This does not eliminate the possibility of having some form of interactive task card.

"Most base and heavy maintenance checks are subcontracted by airlines, so data must be transferred between airline and MRO," says Reed. "This would not be a problem if Spec 2000 Chapter 18 were already used as a standard format for data transfer. A data standard means there is a 99% chance of getting the data transfer right the first time.

"The problem is that the definition of Chapter 18 is incomplete, and only 10-15% of airlines have adopted it," adds Reed. "Many airlines are therefore forced to use staging databases and programmes to convert the data in both directions."

Transferring data with the least difficulty is just one benefit of the Chapter 18 standard. "If the standard is adopted, an airline can receive regular updates on the performance of base and heavy checks from the MRO provider," says Clements.

"It will be a long time before airlines convert the data in their M&E systems to XML," says Dinakara Nagalla, president and chief executive officer, EmpowerMX. "We therefore have an artificial intelligence module within our FleetMX M&E system. This takes task cards in PDF and paper, identifies signatures and authorised staff, reads the content on the card, and creates XML data from it. Our main aim is to make the shop floor digital.

"We do this by making the task card executable and intelligent, and configuring it for digital sign-off," continues Nagarra. "The PDF is interactive, so the mechanic can order parts, report findings, and communicate with the check supervisor. There are no changes or editing, which would be needed with XML."

Some M&E systems have to make tags on each card manually before each check. "Our new PDF overlay system is being used in a hangar bay at Delta Tech Ops, which is the first user. The second will be Embraer in Nashville," says Nagalla. "There is little cost for the airline to get this functionality if they are already using FleetMX. All they need is a licence to use the module, and the programme takes the content. The new module is the ePDF module. EmpowerMX already has an electronic task card (ETC) module, and has been used to generate interactive task cards from XML data. It can now do PDF conversion with new code."

Ultramain also has a PDF task card overlay system for use with its Mobile Mechanic application. "The system has a basic entry screen, with a summary of the total task cards to complete," says Stone. "The icons on each card provide basic information, together with the task card PDF. There is also a place on the card to place the mechanic's signature scan.

"The system audits the signature stamps being placed, and audits compliance as the task card progresses," adds Stone. "Photos can be taken and attached for transmission. The user can also click on tabs to request parts and ask for an NR card. There are icons to record the changing of rotable parts."

"Other features include collecting SFDC data," continues Stone. "This is easily programmed, with check-in and check-out times for recording task MH and parts. Supervisors can monitor the progress of a check with the system. A full report is provided at the end of the check."

Ultramain's Mobile Mechanic links with other M&E systems, such as Swiss AMOS, which is used by Cathay Pacific for preparing base checks on some of its fleet.

"Customers quickly gain efficiencies from using the Mobile Mechanic system," says Stone. "Everything is done the same way as with paper task cards. All details had to look totally familiar for mechanics to get used to it within 10 minutes." AC