Built on long-standing processes that have become the foundation of maintenance management and the MRO industry, paper-based documentation is becoming increasingly outmoded with the advancement of cloud-based, mobile IT software. The viability of applying wearable technology to this development is explored here.

The application of wearable technologies in aircraft maintenance

Wearable technology has the potential to allow real-time, efficient maintenance processes. Wearable technology can take the form of a device, such as a watch or pair of glasses. It can provide the user instant access to technical documents through voice control or keyboard entry, and save time in relaying information by sending photos, or through video chats. It is reasonable to assume that the performance of the mechanic carrying out tasks is further optimised, because wearables are operated hands-free. Wearables also offer on-the-spot IT support, suggesting that multiple tasks could be performed simultaneously, thereby increasing labour efficiency.

To apply wearable technology, a business must be mobile and paperless. This requires digital information to be readily transferrable between content management systems (CMS) and maintenance & engineering (M&E) systems. As many manufacturers of wearables also produce handheld devices such as smartphones and tablets, the processes required to interface wearable and other mobile devices with these systems is generally similar.

Paperless maintenance

Recent developments in M&E software mean that there is increased demand for the use of paper in the maintenance repair & overhaul (MRO) sector to be gradually phased out. Supporting this is the industry's drive to become as environmentally efficient as possible. A lot of paper is wasted in traditional maintenance.

Digital signatures, and electronic maintenance records and regulatory documents have also begun to emerge as desired industry practice. A fully paperless aircraft operation, from flightdeck to maintenance shop and the associated financial and administrative processes, is yet to become a mainstream reality. This limits the ready development of wearables in the MRO business.

Most operators are not operating 100% digitally, and the paperless process is incomplete. Mechanics in hangar might relay information using a handheld device or tablet via a WiFi signal. If the line mechanic, however, is operating in a remote location with a computer, then task cards may have to be printed off and signed manually. Work is, therefore, duplicated, and the benefits of wearables are ultimately voided or not realised.

"The emphasis, therefore, needs to be on achieving 100% paperless operations before applying and take advantage of wearable technologies," says John Stone, vice president of product management at Ultramain. "While other industries focussed on becoming fully paperless, the aviation industry has been slow to react.

"I believe this is in part due to the fracturing of aircraft ownership structures," adds Stone. "Traditionally the original equipment manufacturer (OEM) providing the aircraft to an owner/operator, which rarely used a third-party maintenance provider to maintain it.

"These days, there are also lessors, separate owner and operator structures, and in many cases more than one maintenance provider involved with the aircraft's maintenance," continues Stone. "The relationships now involve more parties. The key is extracting data from each party, and representing the data seamlessly throughout an IT chain."

"Operators are now replacing some paper elements of maintenance, but paperless is not present through their entire processes," says Paul Saunders, solution manager at Flatirons Solutions.

"An example is when airlines and MROs use scanning and indexing software to integrate into their in-house maintenance operations to create electronic workpacks. This allows the operator to take a paper record, index it and convert the content into usable data, including task numbers. These data then populate an MRO system while retaining the original data as a standard PDF, allowing the user to dispose of the paper copy of the record. The operator, therefore, does not have to pay to store paper, the cost of which adds up with a large fleet."

Document-scanning software is designed for airlines, banks and leasing companies to manage complex records. "Some of the aircraft are managed or leased, so eventually the aircraft, plus all of its records, get returned to the lessor," continues Saunders. "Leasing companies traditionally do not have the same IT systems for managing maintenance, and may not use the same system for indexing aircraft records. All of the technical records, including the workpacks accumulated over years or decades, will need to be printed off and sent to the lessor. The consistency in the paperless data-sharing chain would be broken in this scenario. One main reason that MRO is behind the curve with paperless technology is because maintenance providers have used paper-based processes for decades. Building a business case for paperless takes several phases of development and increased industry demand, before MROs start to explore these options."

It is arguably an M&E system's

While there is an interest or even a desire for all maintenance activities to become fully paperless in the long-term, it is not near reality. Maintenance activities need to become almost or completely 100% paperless before most airlines and MROs can take advantage of wearable technologies.

effectiveness that allows an operator's fleet to achieve shorter downtimes and more efficient maintenance. Paperless maintenance increases a mechanic's labour efficiency. A mechanic would not have to continually revert to a fixed, central computing station, for example, to input data or look up a manual reference as is typically the case. This lengthens the time spent on tasks.

Mobile systems have gradually been integrated to support paperless processes. While entry-level M&E systems allowed task cards to be signed off by scanning an ID card that contained a barcode, emerging M&E systems incorporate the use of handheld devices that can be connected through WiFi or mobile data connections. This feeds data entries to the MRO's CMS.

Wearable technology further enhances this, since it can interface between mechanics, engineers, and the IT infrastructure that allows the paperless processes. An MRO provider will want to see paperless processes implemented, even when taking into consideration software developments and staff training.

Wearable devices

Wearable technology can take several forms. The most prominent involves a spectacle frame supporting an optical head-mounted display (OHMD). India-based Ramco Systems develops cloud-based aircraft maintenance software. "Instant actions with real-time data, on-board wearable devices such as Google Glass, Microsoft Hololens, Meta 1 glass and a smartwatch all save time for mechanics when moving between the hangar and their laptops and terminal systems. The time factor is key for improving workforce productivity," explains RH Chalapathy, global head of aviation business consulting at Ramco Aviation. Ramco software is available on iOS, Android and Windows operating platforms. All Ramco applications can be used on smartphones and tablets.

An example of how this technology can be applied to an MRO environment is where a flightcrew reports a fault. The line maintenance department could prepare and analyse fault data ahead of aircraft arrival through a wearable device displaying the communication. Line maintenance could, therefore, raise appropriate tasks and order parts, either through voice or typed instruction before the aircraft's arrival.

The processes required for paperless maintenance need to be explored.

One advantage of a mobile, paperless maintenance infrastructure is real-time data recording. Relaying information as it happens should optimise the accuracy of event reporting and subsequent defect analysis, while the direct transfer of data should limit human error.

Most of these products are still being developed. Google glass has experienced production difficulties and has been temporarily withdrawn from the market, pending technological revisions and restructuring. The M100 Smart Glass is commercially available but wearable products are still in their infancy.

Electronic data can be presented in several formats. This affects how M&E systems are interfaced, since data come from various sources.

OEMs will supply aircraft and engine maintenance manuals (AMMs and EMMs), component maintenance manuals, illustrated parts catalogues (IPC) and other manufacturer-based information to the owner in one format. The owner or operator will supply flight hour and cycle data. This will influence the aircraft's maintenance programme, alongside the status of life-limited parts (LLPs). In turn, the MRO provider will supply workpack documentation, task cards, release-to-service certificates and modification information relating to the replacement or repair of parts.

All aircraft-related documentation, like the maintenance planning document (MPD), AMM, EMM and IPC, must be stored digitally to make accessing information possible at any time.

Finally, regulatory authorities will supply approvals and airworthiness directives (ADs) relating to aircraft types, which also have to be interfaced with an M&E IT system in order to update.

The degree of difficulty of integrating all the data onto one system, and making an MRO business paperless, affects how receptive a business is to implementing mobile and wearable technologies.

Data formats

Data comes in several forms, including standard generalised markup language (SGML), hypertext markup language (HTML), portable document format (PDF), and extensible markup language (XML) formats.

Both SGML and XML formats are entirely written in code. To view and make sense of the information within, the code needs to be rendered and presented in a viewable format that the reader can understand. A document would have to be viewed as a PDF on a computer monitor, which presents the code in a paper view setting. The data needs to be presented in HTML when viewed via a tablet, iPad or wearable device.

Writing algorithms that allow XML or SGML data to be viewed on a wearable device, such as Google glass, is costly. A typical XML conversion into HTML and sent to view on a Google glass screen, for example, will view the document in A4 size. This is clearly not suitable for wearable viewing. Further conversions are, therefore, required to adapt the data to a small screen.

"Different styling may have to be

applied to content for all of the devices used by an airline or MRO provider," says Saunders. "Style sheets will have to be developed depending on whether it is a wearable, tablet or smartphone device. This is assuming they have different screen sizes and interaction methods."

There are also several manuals for each aircraft type, including the CMM, IPC and AMM. Their formats may vary between types, and also require separate conversions and stylesheets. It is easy to see how complexity and cost to apply the electronic data to wearable and mobile devices can mount," explains Saunders.

Ramco anticipates that some of the more complex areas of maintenance management will prove most difficult to integrate into wearables. "It is all about fighting for screen area on a tiny projected screen. Areas where large amounts of information management is needed, such as maintenance planning, would be difficult unless it is processed and displayed in a comprehensive manner," says Chalapathy.

The complexities of going fully paperless are limiting the industry's progress onto mobile and wearable technologies. M&E systems, for example, each have different database structures, which makes integrating two separate systems more difficult. For instance, an airline's and an independent engine shop's systems may have different ways of storing and displaying data in their CMSs. Reference numbers, such as part numbers in IPCs, vary in character length between OEMs.

Synchronising these data is complicated. To align data between aircraft and enable data transfer to be simplified, data standards were created, but these are only guidelines. Although industry demand has meant that most providers at least pay attention to the structures outlined, standards are not always followed precisely. Due to the inherent precision required in data-sharing and coding, if standards are not met 100%, then transferring and rendering data can be just as difficult for system integrators.

iSpec2200 provides specifications and models for transferring and exchanging data. Most older generation aircraft conform to iSpec2200 standards.

S1000D is used by the latest generation aircraft. An operator with aircraft in its fleet that use both standards will have problems when integrating a paperless system.

Current devices & software

There are several mobile devices that support paperless processes. Although not wearable, smartphones and tablets are accessible, light and easy to use. They are only able to present certain formats, however, and the size of the screen is limiting for viewing detailed information.

Wearable devices are less obtrusive because the operator can work hands-free. Wearables are also interactive, but are more expensive than mobile devices.

Several large airlines and manufacturers have trialled integrating wearables and mobile technologies into flight and maintenance operations.

Ramco is involved in trials relating to task sign-off and maintenance task deferrals. Virgin Atlantic is evaluating the functionality of the Sony SmartEyeglass and SmartWatch wearables in line maintenance.

Line mechanics can stream video and data via the SmartEyeglass almost instantly to a base maintenance hangar. These data can be viewed and analysed as required. The Smartwatch is then used to relay job allocations and rectification instructions back to the mechanic.

Other factors have to be considered for electronic applications. MRO activities include base maintenance, scheduled and unscheduled tasks, phase and out-of-phase tasks, task card and work order creation, and parts distribution and rotables management.

Ramco's software applies mobile technology to the daily activities of line

Honeywell's Vocollect system works by software converting maintenance instructions to speech. The mechanic can also with the host M&E system entirely by voice. The mechanic verbally confirms completion of maintenance tasks.

and base maintenance mechanics. The solution currently allows engineers on the line and in the hangar to:

- Complete a scheduled job and sign-off.
- Report a defect or discrepancy, either with reference to a scheduled job, or closing it with various options such as:
  - Corrective actions
  - Transfer to sub-assemblies or components
  - Deferral under the minimum equipment list
- Refer to the fault isolation manual or troubleshooting manual as required for corrective actions.
- Refer to OEM manuals, like the AMM and IPC online using links.
- Complete component replacements with options, like cannibalisation and component swaps.
- Request material and reporting consumption.

This solution is web-centric, meaning it is completely available on the cloud.

Ramco M&E MRO solution aims at a completely paperless process across all areas of aircraft and component maintenance. Ramco is currently focused on task execution. "We are implementing this through the Smart card-based sign-offs, which totally remove the 'dirty fingerprint' document requirements," says Chalapathy.

Task card management is essential for fully paperless operations. Regulatory authorities recognise the need to incorporate electronic signatures and technical records. Compliance standards have, therefore, been outlined by the Federal Aviation Administration (FAA) in Chapter AC 120-78.

"Ramco ePublications™ manages the maintenance task card publishing and work package publishing process via a built-in interface with the Ramco M&E system," says Chalapathy. "The solution has a module to process and view SGML-based OEM documents, and author task cards based on the content from various reference manuals."

Becoming fully integrated onboard a paperless system, however, is still a problem. "Incorporating OEM documents in various formats, such as SGML, PDF, HTML and XML is a task in itself. Documents relating to the aircraft and its equipment are commonly provided in either PDF or SGML by the OEM," explains Chalapathy.

"Ramco's wearable technology can now be used for work reporting in areas outside and inside the hangar. Mechanics can use devices, such as the smartwatch and wearable glass technology, to report various jobs like time sheets and component changes," adds Chalapathy.

Ultramain has produced software called Mobile Mechanic. This allows mobile applications on handheld devices for airlines and MRO providers. It can also operate with iOS, Android and Windows8, so it is compatible with most mobile devices on the market.

Ultramain's wearable technology research has led it to focus on developing the mobile capabilities of its software, rather than apply it to wearable devices. "Our discussions with MRO providers show that they are not yet interested in wearable devices," explains Stone.

Ultramain continues to progress in the mobile software and maintenance areas, and to apply its technology to wearable printers. mobile devices and bar code scanners.

Voice directed-work

One capability offered through the use of wearable technology is voice-enabled working. This eliminates the need for technicians performing tasks to manually fill in paper documents or use the keyboard on handheld or mobile devices. Mechanics operate hands- and eyes-free, while performing tasks.

Honeywell integrates Vocollect voice solutions into maintenance processes. While this is through a headset connected to a mobile computer or a handheld device, the technology could also be interfaced with emerging wearables.

"Traditionally, information would have been communicated in the form of paper printouts and manual data entry," says Jan Harmstorf, strategic account manager at Honeywell Vocollect Solutions. "More recently, information has been exchanged via mobile devices and tablets. With Vocollect solutions, we take worker efficiency to the next level by effecting that communication by voice. Good workflow design and well-structured host system interfaces help to eliminate the potential difficulties in integrating with the business's core IT systems. The voice system, which includes both the software that defines a voice-enabled workflow and the hardware, is used by mechanics to interact with the host system and update it in real time.

"Instructions are sent from the host system over a wireless network to a mobile device where it is converted to speech," says Harmstorf. "It is communicated via headset to a technician. The mechanic and the M&E system interact with each other entirely by voice. The mechanic verbally confirms each step and continues through the check list until the workflow is complete. The documentation and host system are updated in real-time."

Harmstorf illustrates how the processes can be applied to an engine shop. "The MRO provider might receive an auxiliary power unit (APU) and processes it through different stages to identify and resolve mechanical issues. "For example, Stage 1 could be for the induction, breakdown and analytical review of the APU. Stage 2 focuses on the repair, overhaul, replacement of parts. Stage 3 rebuilds the APU.

"The work steps at induction might include: visual inspection and capturing

the engine's status; identifying the missing parts; taking photos; and then performing tests," continues Harmstorf. "For every complex assembly inducted, a technician will typically capture 50-200 pieces of data about the unit's condition. This data has traditionally been manually captured on paper, and then recorded at a nearby computer after the induction process is completed.

"With voice the process is simplified, productivity increased and errors reduced," says Harmstorf. "The process for reporting and managing defects can be encompassed in a voice-directed workflow, using a set of interactive, pre-determined procedural actions."

While voice-enabled software clearly aids the maintenance processes, it is the wearable technology with which it integrates that provides the interactive software required to fully realise the potential of hands-free data access. Due to the large amount of data, provisions need to be made in order to store it in its entirety, in an accessible server or device.

Accessing data

Generally, the aviation industry can use three main methods of data distribution, each of which is compatible with wearable devices. The most popular method is via a 'cloud', whereby the data are stored in a network that is connected as long as there is a WiFi or data signal, and remains constantly updated. This, however, raises the question of what provisions are in place in the event of no data signal.

The second method is to store data on a phone or handheld device. This means that data are all downloaded directly onto the device in question rather than offset onto a remote cloud network. This raises the question of how much data a wearable device can store, and also how it connects its updates and information with the rest of the network of mobile users within the company.

It is apparent that MRO software is becoming increasingly interfaced with wearable devices, however, at varying levels and extents from operator and maintenance providers alike. Apps have been developed that can take the place of a traditional paper flight log. These record flight cycles and hours, crew information, and technical faults. This information is interfaced with M&E and operations systems.

The this method is combination of the above. It consists of a cloud-interactive platform that relays information onto your device locally, as and when requested. This may offer greater flexibility in off-line conditions, where manual sections relevant to the maintenance being performed can be accessed outside the cloud without impacting the device's storage limits.

Off-line operations

In the event of no accessible internet, for example in line maintenance, being able to provide real-time updates remains crucial. The question, however, is how much can be done when a line mechanic is unable to access an internet or a data connection. While he may be able to look up chapter references in the AMM or EMM, or identify parts using the IPC, going on-line to order replacement parts is impossible. This means that the length of time a mechanic is off-line and disconnected is crucial to optimising the benefits of real-time data processes.

"Operators and MRO providers cannot rely on a constant connection to the internet. There are too many limitations inherent in the hangar and airport environments," explains Saunders. "At base, the amount of metal in a hangar means that connections are often blocked. In aircraft operations, relying on connectivity is a huge gamble when flying to remote airports."

Applications, therefore, need to be able to work on a standalone device, with the means to regularly synchronise the mobile or wearable device with a

Ultramain has produced an application called Mobile Mechanic. This allows mobile applications on mobile devices. It is compatible with most mobile devices on the market.

server, so that the user is working with updated information. Business processes and standard operating procedures (SOPs), therefore, need to be built to ensure the user is not using overwritten or altered data. "Business rules need to ensure the integrity of data while being used off-line. This may include locking the task or applying incremental synchronisation and overwriting rules when updates are received," adds Saunders.

E-signatures can also be made off-line, should connectivity to WiFi or mobile data be lost. These will then automatically update the server once connectivity is re-established.

Certifications

Using emerging and little-known technology obviously raises questions from regulators. But, as demand for the development of paperless processes increases, so will airline and MRO demand to use wearable technology.

It is not, however, the software or the device that needs to be approved by regulators. "It is the business processes surrounding all the operations involved, while using the device or software," explains Saunders. "The MRO or operator will need to thoroughly prove to, and instil confidence in, the regulators that its operations, while supported by the software, are backed up with easily achievable 'plan B' SOPs. An MRO may also consider plan C and D SOPs. Regulators need to be convinced that the SOPs could be swiftly adhered to if a wearable breaks or connectivity is lost."

Wearables that are sophisticated enough to support MRO paperless processes are still emerging. It takes time for a business to fully investigate its true potential to support the processes.

Key considerations for MROs

The factors encouraging a company to integrate wearables into its maintenance processes will vary, depending on the area of the business in question. The screen size supplied by a device, for example, will be important to those regularly viewing large volumes of information. Compared to a tablet, a wearable, such as Google glass, may not be suitable in some situations.

When drawing up a business model, MROs need to take some important factors into consideration.

For example, battery life is important in achieving the increased efficiencies that wearable devices are anticipated to offer. Considering the inherent processes in daily maintenance operations, a battery life of about one day would be required. This will be a basic requirement for maintenance operators. The cost of supplying duplicate devices may also have to be considered.

Weight is also a consideration. When looking to adopt wearable technology into the maintenance environment, operating the wearable device must be as unobtrusive and natural as possible. The weight must not be a distraction to users.

Obviously, cost is another major consideration that an MRO will apply to any speculative business model. Industry reports to date have indicated that businesses will want to pay $550 or less for wearables. Given the cost of the first-stage Google glass was about $1,500, prices will have to fall drastically before wearables become attractive to maintenance businesses.

Multifunctional abilities also have to be considered. If a wearable device can provide a camera, RFID capabilities, and receive data signals while taking and receiving calls, it may save further costs.

Wearable limitations

"Right now, wearables are very good at viewing data, but other required interaction capabilities remain limited," explains Stone. "Keyboard entry and voice recognition, for example, is not near the maturity level required to make wearable technology viable. Airlines and MROs are already slow to adopt tablets and basic mobility. These problems need to be ironed out before wearables can reach their potential.

"Cost is also a factor. While a computing station on the shop floor can be used by more than one mechanic during a shift, companies will need to provide a minimum of one wearable device for each person on shift," continues Stone. "In the case of tablets, these are already increasing overheads."

"Approval of aviation authorities for letting wearables into the strictly fenced aviation industry is probably one of the first hurdles that stand in the way, but not the biggest," says Chalapathy. "The biggest is the willingness to adopt a technology that will augment end user engagement and productivity to a vast extent from day one. Problems related to regulatory compliance and finding visionary adopters are the key speed-breakers to overcome before we usher in this technology."

Further to this, durability of the wearable devices remains uncertain at this stage. Wearables are fragile and can break if dropped. The battery life also needs to be improved. "It is the laptop problem, 20 years later," surmises Stone. "Durability needs to be proven, and wearables need to become tougher before the industry takes a serious look.

"While wearable technology remains in its early stages of development, airlines and maintenance providers will continue to be sceptical to invest," continues Stone. As industry reports have shown, high initial cost prohibits investing in new mobile processes."

"Consolidation in the industry will drive requirements to make processes, including MRO, universally paperless," says Saunders. "Also, the next generation of influencers will drive the move towards commoditised, wearable technology, as the use of tablets and wearables becomes more common." AC