Innovative digital solutions that improve traceability, visibility and accountability are making maintenance workflows more efficient. These include inspection drones, Chat BOTs, interactive dashboards, electronic task cards, and artifical intelligence and machine learning.

The progress of hi-tech digital & paperless solutions in maintenance

Maintenance & engineering (M&E) IT Systems continue to develop innovative and bespoke solutions for digitised or paperless maintenance. Automation, artificial intelligence (AI) and machine learning (ML) are increasingly being leveraged with direct benefits for maintenance execution and efficiency gains, not to mention predictability. These might be stand-alone solutions or fully integrated into the core platform. Reduced manual interaction with the M&E systems through agile platforms maximises time that mechanics spend on the aircraft.

Drone inspections

Aircraft manufacturers and regulatory bodies alike require regular visual inspections of the external surface of an aircraft, whether as part of scheduled maintenance or an unplanned event.

Donecle, based in Toulouse, has brought digitisation to the fore through its bespoke and agile end-to-end solution that offers 100% automated aircraft visual inspections, with advanced image analysis algorithms, using unmanned aerial vehicles (UAV) or drones. This involves three main steps: inspect; analyse and report; and trace and predict. The solution requires only a single operator and no pilot. The drone weighs less than 4kg and has a width of 1 metre, a depth of 1 metre, and a height of 0.3 metre.

Founded in 2015, Donecle's co-founders have cumulatively filed more than 10 patents. Donecle has active customers in Europe and North America, notably Air France Industries KLM Engineering & Maintenance, and Airbus. The latter uses the platform internally as the 'Airbus Advanced Inspection Drone'. Donecle is looking to go on board with its first independent maintenance repair and overhaul (MRO) organisation this summer.

The platform's versatility allows three key inspections to be made simultaneously during one scan of the fuselage:

- General visual inspections (GVI)
- Paint quality evaluation
- Quality control of regulatory markings and placards

The solution extends to the A320 and 737 families with further capabilities for narrowbody aircraft in development. To date, more than 500 inspection flights have been conducted. They have also integrated military fighter aircraft.

"Whenever an aircraft has to be inspected visually, whether during planned checks or unscheduled maintenance, it always involves an inspector climbing on the aircraft to look at what is happening directly on the surface, on top of the fuselage and wings," says Josselin Bequet, chief executive officer and co-founder of Donecle. "This is obviously a long and costly process for airlines when the aircraft is grounded just because it has to be inspected. There is little traceability because it is a very manual process. People look at the aircraft and record any damage. There are rarely any pictures, or any digital traceability to show how the aircraft looks over time."

"If they do not see anything specifically, they will not take a picture, so it is hard to say during the next inspection if something was present on the aircraft previously or not," continues Bequet. "They cannot go back and look at how the aircraft was at that moment in time."

Bequet explains that Donecle found it astonishing that no one had tried to address the problem differently. So Donecle focused on developing drone technology to inspect aircraft seamlessly and negate the need for cherry-pickers, platforms and docks to access the upper areas of the aircraft. "The main concern for us was to automate solutions over the entire process," says Bequet. "Most of the drones out there were either manually piloted or relied heavily on the Global Positioning System (GPS), but once we go inside an aircraft maintenance hangar, we obviously do not have any GPS signal.

"Quite a few of our customers and airlines have tried to buy semi-professional drones. Some of them have crashed into the aircraft. Not only are the drone platforms not adapted, but there is no end-to-end automation. So the operators need to be trained until they can control them," explains Bequet. "Our customers have several gigabytes of data that they do not know what to do with because the people who have sold them the drones are unable to provide image acquisition software and a full one-turn solution to not only fly the drone, but conduct an entire inspection without assistance."

No one from Donecle is present when flying the drone. Initial training is provided to an operator within an airline or MRO, which is then able to launch the platform. The entire solution is a leasing model with Donecle providing the hardware, software and cloud platform. A fee, based on the type of aircraft and inspection, is charged. The drone is delivered in a flight case, designed to protect it during transportation and storage, together with a tablet, batteries and accessories.

Interfacing is coordinated through the tablet which communicates with the drone via a secure WiFi connection. Flight software, embedded on the tablet, manages

the flight plan that is pre-programmed onto a 3-D digital model of the aircraft type. The drone flies about one metre from the fuselage.

"The launch process is quite easy," explains Hélène Druet, vice president of marketing at Donecle. "The drone has to be positioned close to the aircraft, in a clean area for safety purposes. Basic parameters, such as aircraft type, winglet type and engine type, have to be configured in the drone software. The operator presses the 'start' button to launch the flight, which is then automatic."

"Our laser-positioning technology will enable the drone to compare its environment with the 3-D model and thereby determine its position relative to the aircraft and follow suitable trajectories for that aircraft type," says Bequet.

One of the key objectives of development was making sure the drone could fly safely in all conditions. "Testing for loss of connectivity, loss of on-board sensors, electronic and propulsion failures, and making sure that we address all of those safely, so that the drone does not collide with the aircraft or personnel on the ground was a priority," continues Bequet. "We are always being asked what we do with obstacles. One of the benefits of having a laser-positioning system and laser sensors on board the drone is that we can see most of the environment around the drone. Anything that it sees that should not be there or is a discrepancy compared to the aircraft model is going to be detected as a potential obstacle. It is going to stop and obviously not going to collide with that particular obstacle. This is whether it is personnel, hangar equipment, or any other kind of item that would be in the hangar."

Image acquisition is captured by 2-D sensors and overlaid in real time onto the 3-D model to enable precise positioning against frames and stringers. Proprietary image analysis software, drawing on annotated databases developed in conjunction with partners and other companies, uses algorithms based on ML to recognise specific types of damage.

"We provide image resolution of several pixels per square millimetre and guarantee that defects or damage as small as 1mm or 2mm are visible on images acquired by our drones," adds Bequet.

On completion of the scan, the image analysis software generates a damage report suggesting areas of interest, with a certain degree of tolerance. "Since all inspections are heavily regulated, there is always a person in the loop at the end to validate what the software has found," says Bequet. A qualified inspector can visualise and assess the images thanks to intuitive 3-D navigation and issue the final report.

After every inspection, both the collected images and the damage report are uploaded to the Donecle cloud platform, with each customer allocated a dedicated server, enabling remote access, cross-fleet comparisons, data mining and deep learning to unlock the potential for predictive maintenance. "Our platform enables operators to track how the aircraft has been over time so they are not only looking at the aircraft at a given moment during a given check, but from check to check, and inspection to inspection. It is essential to have a full digital trace and logbook of the aircraft to be able to see how its structural status evolves," explains Bequet.

The ability to accomplish the GVI before the check begins has clear benefits. "When the aircraft enters the hangar, the Donecle platform allows the visual inspections to start. The damage report for the aircraft helps the MRO make decisions and adapt the job cards for the rest of the check. Inspectors can then focus their time on analysis and allocating maintenance tasks to be performed based on the inspection report," explains Druet.

"We estimate that the drone takes an hour to carry out a GVI, compared to 10 hours for inspectors," adds Bequet. "But after we acquire the images, we do not want to have someone go through them manually, looking at images one by one. So we have developed computer vision

algorithms and ML tools to automatically find items on the aircraft surface and help the operator to pinpoint which potential damage needs addressing."

Paint wear evaluation can be subjective, depending on the individual 'human' inspector. In less than one hour, the drone can collect images of the aircraft surface, mapping the density of paint wear, abrasions, rivet and screw rash. In a similar vein to the GVI, it provides consistent and objective reporting to optimise painting programmes by prioritising those tails requiring it, and also to trigger warranty claims with the original equipment manufacturer (OEM) and paint shops.

The drone also handles the inspection of regulatory markings and placards with speed, objectivity and a paperless workflow. "One of our customers told us that marking checks manually take four to five hours. It is a tedious job that essentially involves someone going through several dozen sheets of paper, checking every single marking on the aircraft. There are 150-300 placards or markings on the outside of the fuselage, and a mistake will have undesirable consequences," says Bequet. "If the aircraft is ramp checked at an airport by a European Aviation Safety Agency (EASA) inspector, and a regulatory marking is not present, the airline can be fined, or the aircraft can even be grounded in the worst case scenario.

"The drone, however, can reduce the inspection time from five hours to 40-50 minutes," continues Bequet. "Since the drone has an entirely digitised database for the markings that should be present on the aircraft, it can speedily indicate which are absent or present, or should be changed because they are damaged or not in a flyable condition. That allows the airline to say very quickly which markings need to be changed. The system provides the part numbers, so there is no possible mistake in reordering the right placard."

The reciprocal benefits of the solution are evident: a multi-application platform generating a single scan and set of images to address distinct use cases, precision through enhanced damage location and objective algorithmic evaluation, reduced inspection time and maintenance costs, improved quality of reports, a highly repeatable process with full traceability of past scans, and predictability of inspection downtime. These are decisive factors, given that the cost of a one-hour aircraft-on-the-ground (AOG) situation to an airline is about $10,000.

Donecle has identified three major areas for future product development. The first is the capability to perform inspections outdoors.

"We have been doing tests outdoors for the past two or three years, but there are two major constraints for us right now. The first is making sure that the drone can fly safely in all weather conditions. The second constraint is regulation, which is the hardest to navigate, since most airports and aviation authorities prohibit drone flights in airport airspace for obvious reasons," explains Bequet.

The second product development area involves detecting further kinds of damage. This requires the integration of new sensors, such as 3-D scanners, with the capability to accurately gauge depth, and development of new ML tools to detect different types of damage on the images. Applications would cover hail and lightning strike inspections. The latter, in collaboration with OEMs and regulators, has undergone testing for the past 18 months to obtain initial approvals. The aim is to complete automated inspection in under two hours, rather than the three to 12 hours needed for manual inspection. Donecle plans to make an announcement in the second half of 2019.

Finally, the aim is to add more aircraft types, including widebodies. "Integrating a

new aircraft type requires iterative testing, to ensure the 3-D model we provide is accurate and suitable for precise flight, and that the flight trajectories are safe to fly in a variety of conditions and environments. We want to look at things like A350s, Dreamliners and A380s," says Bequet.

Interest in drones for aircraft inspections has been growing steadily for the past few years with MROs using the technology, as well as evaluating and testing. "Until recently, the market and the technology were not ready. The industry was maybe still a bit conservative," says Druet. "However, this is changing in the right direction. The digitisation and innovation projects that are being conducted in more MROs and airlines, as well as the need to find solutions to face the challenges of labour supply shortages and the increasing cost of labour and materials, are telling us that this is now the right time for such a solution, as shown by the market's interest in, and adoption of, Donecle's automated aircraft inspection solution."

"Many people see drone inspections as just saving time on the inspection itself. However, many errors are made, and a lot of time is wasted in hangar environments because damage is misreported or not located accurately on the airframe, or paperwork is incomplete. The time taken is not necessarily quantified accurately by the operators. But our full software solution dramatically reduces all those problems. It provides much more consistency and less dependence on the tracking opinion of a 'human' inspector," explains Bequet.

Passive to active ERP

Ramco Systems Corporation is an end-to-end integrated MRO Enterprise Resource Planning (ERP) solution whose current focus is on creating an active ERP in a world of passive ERPs by leveraging AI and ML on daily transactions and drawing on insights based on historical data to automate and improve processes. Ramco's active ERP framework is designed to improve productivity by minimising user intervention and interaction levels with the software. Conversely, a system requiring constant inputs might otherwise impact productivity.

"We are moving towards a framework of intelligent enterprise applications rather than passive applications. This means we are actively and intelligently serving users based on context, event and available data," explains Manoj K. Singh, senior vice president at Ramco Systems Corporation.

One of the key tenets of Ramco's solution, which is driving software development, is Zero User Interface (UI).

"We provide the end user with the facility to perform the transaction without actively having to log into the main application. In a traditional ERP you may have to log in and go through multiple screens to perform the transactions. Instead, we are achieving this by Zero UI through multiple sources. One method is through interactive voice-based transactions similar to the functionality of Google Home or Amazon Echo. You can perform the transaction simply by talking to the system. For instance, if you want to look up part availability while in a warehouse, you can instantly talk to the voice-enabled device and query the system. You can also ask the system to perform the transaction. That is what we call Zero UI. The system also puts together all the right security measures so that only an authorised user can access it, using several of our authentication methodologies," explains Singh. "It really drives the industry to be able to interact with the system in real time, which is what we call an active ERP. This is in contrast to physically performing the job or updating the system retrospectively, which many user groups feel is an additional responsibility and taking up their regular work time. We want to break that 'pain point', and give this 'frictionless' experience to the end user."

This 'frictionless' experience goes further and allows the user to seamlessly perform transactions using AI and ML technology. Cognitive discrepancy reporting minimises data entry for the mechanic and suggests a list of all possible recommendations for the discrepancy the moment the mechanic starts to type the content. This is based on the history and

Picture supplied by Donecle

The Donecle inspection drone is able to inspect and record the condition of an aircraft's skin without the requirement for a certified operator. Drone operations outside the hangar are currently not possible due to regulations.

context of repetitive transactions for the aircraft and type in question. The system also has the ability to suggest possible corrective actions based on the history and probability of occurrences. It helps the user in providing the right information to perform the transaction.

"We talk about a cognitive assistance e-Log for recording discrepancies. If a mechanic needs to report a discrepancy, such as a broken landing-gear light, as soon as the mechanic starts to type 'landing light', the system understands the context of which aircraft is being reported and historically looks for the same aircraft with this discrepancy that has been previously reported. The system brings up a list of all recommendations. The mechanic simply selects one, and the system autofills all the relevant details about that discrepancy with no interaction required by the user. Not only does the system autofill the transaction, but it will take the mechanic to the next step. It knows what part is needed for the discrepancy and will help set up the material request to resolve it. That is what we mean by frictionless," says Singh.

Event-based notifications communicated to mobile devices are designed to surround the user with actionable events and insights by providing real-time updates, rather than waiting for users to log in to the system, wherever and whenever that might be. Updates are sent once an action is initiated, in progress, or completed, based on the user contextual role. The user can also take direct actions by selecting a message from the notification panel and dynamically linking it to the relevant screen without the need for opening the application. For instance, when a mechanic is assigned a job, he is sent a notification of aircraft registration, work package and location. Further updates could advise on material requests that are ready for collection, customer approvals for estimates with instructions to initiate work, and upcoming training requirements.

"When work is assigned to a mechanic, what we have seen in traditional ERPs is an email notification or the requirement that someone has to log into the application to access a specific screen. But with event-based notification, the system sends a contextual notification for all of the critical events that need the mechanic's attention. It is not just a notification. When the mechanic clicks on that notification, it takes him directly into the contextual screen so that is also part of our frictionless approach. It directly launches the context of that screen to directly perform those jobs. It saves a lot of time. Instead of being a reactive ERP, it is an active ERP where the system keeps pinging the respective user with all the right information," says Singh.

Chat BOT is an internal, intelligent messaging platform that allows the user to interact with the system by asking questions by keying in dialogue via an interface. Chat BOT responds and provides recommendations for the next steps to be performed based on the behaviour and contextual role of that user. The system knows how the user typically interacts and accordingly provides the right options.

"Chat BOT is again a combination of our AI and ML technology. In many cases when a user needs to perform a transaction, they are always bound to a specific mobile app or even to a specific ERP. However, another very intelligent way of allowing the user to interact with the system is to chat with it. For example, I can ask the Chat BOT to pull up all the work that has been assigned to me. The system understands who is asking the question, because of the login credentials, and instantly pulls up all the activities that the specific user needs to perform. This is again based on the contextual learning system, which is where ML comes into the picture. For instance, a person logs in and asks the Chat BOT about a specific part status. The system knows that the part needs to be used for the next job, so it provides multiple options: 'Initiate Transfer', 'Expedite Repair', or 'Expedite Purchase.' All the user needs to do is select the option in the chat app and the system will perform the transaction. The user is not even required to type that information. This is applicable for multiple different uses, and is very easy to deploy as well," says Singh.

Facial recognition, used for authentication of electronic signatures, presents an efficient and secure method for signing off task cards. Ramco leverages the proprietary facial recognition technology present in mobile devices to achieve this.

"We are using facial recognition for electronic signatures. As soon as the user hits the sign-off button, the system recognises his or her face, then automatically signs the task card. Logging in using an email address, company username and password, is sufficient to enable facial recognition," says Singh.

Situational awareness

ULTRAMAIN ActionGraphics™ is a system that allows the user to create bespoke graphic representations of their business operation, supported by interactive analytic tools, to crucially visualise complex environments and information at a glance. By leveraging the use of scalable vector graphics (SVG), which is an XML-based vector image format for two-dimensional graphics, the user can equally view these representations on a desktop computer, tablet, or smart phone without any loss of resolution. The graphics can depict:

- Locations (hangars, line stations, airports)

- Forms (for example, serviceable tags, non-routines, and 8130s)
- Geographical Areas (for example, flight plans, and maps)
- Business Processes (for example, flow charts, diagrams, workflow)

"The primary goal of the framework is to empower our customers to create their own reports and visualisations," explains John F. Stone, vice president for product management at Ultramain. "There are standard graphical dashboards that are part of the core software delivery. In several cases (for example, hangar status board, hangar aircraft status board, and line aircraft status board) the ActionGraphics are delivered as templates that can be modified by the customer to incorporate the images they wish to use. For example, a hangar status board template would allow the customer to upload its own hangar image and link the dashboard widgets to their bay structure."

ActionGraphics is interactive in that it links to ULTRAMAIN Actions, which comprises any system action a user can perform, such as approving a non-routine task or purchase order, or deferring a defect. ULTRAMAIN Drilldowns, a hierarchical structure for navigating to a more detailed view of any data, can also be incorporated. For example, users can click on a parts status icon to view a detailed classification of all parts ordered for an aircraft package and shortages, or transition from a multi-location overview dashboard to a specific location analysing aircraft status. Other actions available include pinning progress bars, task status, alerts, and essentially any artefact within ULTRAMAIN including other ActionGraphics. The framework is fully integrated into the core product.

In addition, user-generated content facilitated through ULTRAMAIN ActionAnalytics™, a real-time reporting and analysis framework, enables creation of dashboards, reports, pivot tables, Gantt charts, statistical modelling, and excel exports that can be pinned to ActionGraphics and accessed via Drilldowns. Functionally, ActionAnalytics is accessible via a toolbar in every data view within the system.

The resulting visualisation of the user's environment and binding of customised parameters delivers instant awareness and actionable intelligence from within ActionGraphics itself.

To demonstrate the scope and value, Stone highlights a recent project that Ultramain developed for an undisclosed customer: "A line MRO that works on multiple customer aircraft at multiple airports has an ActionGraphic for each airport. The graphic is a terminal map and shows all aircraft arriving within the next hour, all aircraft on the ground, and all recently departed aircraft. All aircraft on the ground are shown at their gate location with their status. The dashboard provides warnings in the event that employees have not reported to the gate, parts are not in stock or work is not performed on time.

"Drilling into a specific aircraft displays a second ActionGraphic that provides details of all tasks scheduled, all employees assigned, any material demands and the status of each," continues Stone. "Our customer went from having no visibility of upcoming work or available manpower, to being able to take on more work with the current workforce.

"Historically, well-run companies have always had good dashboards, whether on a printed report or on a large whiteboard. As we switched to computer systems, many of these dashboards have moved on-screen. With the advent of paperless and real-time mobile processes, we are now looking at real-time data being displayed on these dashboards," adds Stone. "A well-designed dashboard will give its intended user a quick snapshot of everything required for their daily work in a simple intuitive way. The idea is to present users with the familiar representation of their business so

Ultramain's ActionAnalytics and ActionGraphics frameworks can be used to create customised dashboards such as the live status of a major check.

that they can rapidly identify problems and priorities. This allows them to clear bottlenecks faster."

Electronic task cards

EmpowerMX FleetCycle® software provides an interactive electronic task card (ETC) which leverages the use of XML to realise the full advantages of a truly integrated and granular platform. XML is a highly digestible format that enables up-to-date and effectivity driven work step instructions to be extracted from primary sources, such as a content management system (CMS), when authoring in-house task cards. The solution is designed to work on tablets and smart phones alike.

FleetCycle's ETC is built around a digitised workflow.

Time capture starts the moment the mechanic logs onto the task card and stops when he signs out the task. If the mechanic fails to log off, the system will automatically sign off after a configurable time. Alternatively, other rules can be enforced for the time sign-off based on work schedule, duration, and approved overtime.

Dedicated hyperlinks to OEM data provide seamless access to the aircraft maintenance manual (AMM) and illustrated parts catalogue (IPC), relevant to the aircraft effectivity.

"Not only do we take the technician right to the location within the application, we also make sure he does not see anything that does not apply to that particular aircraft type. I think that's pretty powerful. Not only are you saving time and money by not doing the additional instructions, you are also making sure you are doing what applies to that configuration of the aircraft, thus by increasing the safety of the aircraft itself," explains Dinakara Nagalla, president at EmpowerMX.

Embedded graphics can be selected, zoomed in and out for optimal viewing, and even annotated on.

Measurements and calibration readings, such as tyre pressure and fluid levels, are recorded electronically via tabular data entry 'feedback fields' with dynamic validation against limits and thresholds.

Task card sign-off is facilitated by electronic signature. The system authenticates, in real-time, whether the mechanic possesses the correct skills, qualifications and licences to sign off that particular task. It also audits whether training and other applicable qualifications are current or have expired.

Further to the main task card, there are dedicated tabs for Asset Requests and Attachments.

The Asset Requests tab allows the mechanic to check stock availability and request parts from the Inventory Module, validating only matching and allowable part numbers as the information is keyed in.

"If I am working on the empennage and suddenly require a part, I do not need to come all the way down and walk over to a computer terminal or the Stores window. Thanks to the FleetCycle ETC, I will be able to look up part availability directly in the logistics system, generate a picklist or requisition straight from the task card I am working on, and track the status of my request," explains Roger Sixto, director worldwide sales, implementation & support at EmpowerMX.

The Attachments tab enables files, forms, photographs and videos to be uploaded to the task card and become a permanent record. A red exclamation mark on the tab gives visual indication of saved content.

When the mechanic is ready to call for an inspector to buyback his work, he can establish communication through the task card. This maintains a full audit trail internally and allows the efficiency of the process to be monitored.

"Instead of exiting the airplane to look for an inspector, the mechanic can call electronically. The inspection department will see the call coming through, who is calling, the area of the airplane the mechanic is located, and which task cards are being worked on. This way of managing calls gives us visibility of the average response time we are getting from inspection and other key departments supporting the production process. We are now evaluating ways of further enabling collaboration between mechanics, engineering, maintenance control, and other experts through virtual meetings," says Sixto.

Digitisation has seen reciprocal gains in the form of 'quality escapes': the reopening and reworking of task cards has seen a dramatic drop. An unexpected side benefit was a reduction in the number of accidents and injuries due to reduced 'travel time' because the platform enables the mechanic to remain at their place of work: the aircraft.

"The primary driver behind our electronic task cards is empowering technicians to remain where they matter the most, 'touching tin', instead of being forced to interact with a myriad of software solutions while trying to do their job. Our tools do not revolve around a single 'silver bullet'. Instead, we build efficiencies at every step of the preparation, distribution and execution of the human and software-based activities," adds Sixto.

The future

New cases for digitisation will continue to present themselves as will innovative solutions from software providers. *Aircraft Commerce* will follow how the industry responds and these capabilities develop. AC