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SPECIAL TOPIC

EMERGING TECHNOLOGIES IN MRO

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EMERGING TECHNOLOGIES IN MRO

It's a very dynamic time in the aviation aftermarket as new aircraft and engine types enter into service and mature platforms continue to fly—typically longer than expected given the relatively low fuel prices and strong passenger and cargo demand. At the same time, technologies such as robotics, artificial intelligence, machine learning, additive manufacturing, blockchain and augmented reality are making their way into the maintenance, repair and overhaul (MRO) market to provide new efficiencies, insights and savings.

The combination creates digital tools and innovations that could be dynamic, and disruptive.

Companies are exploring and trialing new technologies through innovation labs set up within their own structure or with partners. Some have established separate investment arms dedicated to finding new technologies to incorporate into their businesses. Others are partnering with Starburst Accelerator, which is dedicated to connecting aviation companies with innovative startups.

No matter how aviation aftermarket companies are finding and testing new technologies such as these, it's pretty clear that these technologies will be incorporated into the MRO industry—the question is just when. Expect most of them to become mainstream in the next one to five years.

LeeAnn Shay
Chief Editor MRO

Pace Of Printing 3D Metal Aviation Parts Picking Up

Henry Canaday

Three-D printing, or additive manufacturing, of polymer parts for aircraft interiors is decades old. But metal is not naturally a convenient liquid, and metal aircraft parts tend to be safety-critical, so printing metal parts has taken longer to advance.

HONEYWELL AEROSPACE

Honeywell's additive-manufacturing lab in Shanghai.

Nevertheless, the pace of metal printing is picking up. It started with an OEM of engines, where weight and performance are critical. It is now spreading well beyond to a variety of components and structures.

OEMs are also diversifying their use of 3D technologies. Metal powders as well as wires are being used, and different techniques for printing metal materials are being exploited.

The two simplest appeals of printing have been cutting waste and producing parts quickly in small volumes. The first can cut costs, while the second speeds parts to market, eliminating the need for massive inventories.

But, 3D printing's real potential is in redesigning whole systems and components to the exact configuration and content required for their functions, not designing a part or collection of parts just to ease manufacture by conven

So there is much more coming in additive manufacturing. Smart OEMs are taking early steps, partly for reasons specific to each printed piece, but also to gain experience for the future additive aerospace industry.

Honeywell Aerospace has already begun printing metal parts for its auxiliary power units (APU). Donald Godfrey, an engineering fellow in additive manufacturing at Honeywell, explains the change: If a component already is in use, then printing it replaces sheet-metal forming, welding, casting or forging. "Honeywell is going through this exercise on many parts and applying additive manufacturing technology where it makes sense," he says.

One reason for printing a part might be that conventional manufacturing is not yielding timely production. Honeywell might also decide to print a part if the traditional supplier moved away or is no longer associated with the company. Or Honeywell might print a component if the vendor is having problems meeting quality standards.

Godfrey notes that the basic differences between propulsion engines—the first to use printed parts—and APUs are simply size and horsepower. "Both are turbines and have the same sections: compressor, combustor, high-pressure and low-pressure turbines and exhaust," he says. Printing APU components has thus been a high priority at Honeywell.

The OEM's first printed part, a splash guard for an APU, was shipped to a customer Dec. 18, 2015. Godfrey says it was a very simple part and printed mostly so that Honeywell could understand what it took to get printed parts through its own quality-control system, engineering approvals and acceptance by the FAA and the customer.

Honeywell is now printing ducts and oil tubes for APUs. These parts were selected for one of four reasons: the OEM was having difficulty with vendors, printing could reduce lead times, printing could improve quality or printing could reduce costs.

To print these parts, Honeywell is using two 3D technologies. Most printing is done with laser powder bed fusion, also called direct metal laser sintering (DMLS). A smaller portion uses electron beam (EB) melting, also known as EB powder bed fusion. The OEM is also looking at binder jet printing and direct energy deposition (DED).

Honeywell is evaluating all nonrotating components of APUs as candidates for additive manufacturing. These include compressor and turbine cases, brackets, mounts, tubes, vanes and diffusers.

In addition to APUs, Honeywell is looking at additive manufacturing for propulsion engine components. It already has certified some non-APU parts for space applications. "Also, several mechanical component projects are due for certified production in 2018," Godfrey says.

A much smaller, younger company, Norsk Titanium, has chosen a very different additive approach. The 140-person manufacturer uses its version of DED with wire to print footlong titanium fittings to hold aft galleys in place for 10 Boeing 787s each month.

Chief Commercial Officer Chet Fuller says small, intricate parts such as GE Aviation's fuel nozzle are best printed by powder bed fusion techniques. For the big, structural titanium parts that Norsk wants to print, wire-fed technology is better. Norsk uses argon gas torches in a patented process called Rapid Plasma Deposition. "[Our parts] start at a pound or larger. Powder takes too long for that," says Fuller. Indeed, the Norsk machines print kilograms per hour, not ounces per hour, as powder bed fusion does.

The wire-fed approach only produces parts to near net shape, after which excess metal must be machined away. But it is fast and economical for any volumes. And its great advantage is that it cuts the buy-to-fly (BTF) ratio for pricey titanium substantially, compared with cutting titanium blocks. Conventionally cutting a titanium structural part results in a 15:1 BTF, Fuller estimates. Norsk's wire-fed printing has a BTF of about 3:1. That saves 24 kg (53 lb.) of titanium on a 2-kg part.

And because it is using wire, Norsk is not paying the exorbitant costs of metal powders. These can reduce or offset BTF gains. Titanium wire costs more per kilogram than titanium block, Fuller acknowledges, "but not dramatically more." The OEM uses standard rolls of Ti64 titanium, made to its own specifications for twist and cleanliness.

The road to becoming a Boeing supplier was long. It took Norsk 10 years to develop its fourth-generation nonvacuum printing machine, which prints parts cleanly, quietly and quickly. Important for certification, the machine measures 600 parameters per second, ensuring control of the melt pool and a homogenous grain structure in all printed parts. Fuller says his company's three Norwegian machines and nine New York machines can thus all guarantee production of the same part every time. Certification by the FAA took 10 months.

The current Norsk machine has a work envelope of 900 X 600 X 300 mm (35 X 24 X 12 in.). The company is now deciding whether its next machine will aim for larger parts or just more complex ones. Fuller says that the best targets for his equipment are the latest aircraft—787s, Airbus A350s and the Bombardier C Series—that make heavy use of titanium.

Norsk is producing hundreds of test parts in various shapes and sizes to demonstrate to regulators and various OEMs the suitability of its methods for many more parts. Once it has proved the capabilities and consistency of its deposition process, certifying individual parts is much easier and takes much less time. The OEM can now use simulation software for some tasks leading to certification.

Fuller says the best candidates for printing are parts with a significant vertical dimension. In any case, the Norwegian OEM should have plenty of work ahead. It has partnered with Spirit AeroSystems, which builds thousands of titanium parts. Spirit executives expect that at least 30% of these parts could be candidates for Norsk's rapid-deposition process.

Major aerospace companies that are not yet printing parts are eager to begin doing so. Eaton's Aerospace Group is investing aggressively in additive manufacturing, with Mike York, director of aerospace additive manufacturing, leading a team of Eaton business lines dedicated to specific additive applications.

Eaton maintains a center of excellence in Southfield, Michigan, for developing both polymer and metal additives. The center is piloting initial development and will provide low-rate production parts.

In addition, the center is developing its own high-temperature polymer materials for use in additive manufacturing. Eaton will go to market to source metal material for 3D printing. Additionally, a larger Eaton team in Pune, India, is working on simulation of additive processes and products.

"We see this as a good opportunity in aerospace—to gain a competitive advantage in speed, cost and performance," York says.

Eaton is chiefly interested in DMLS, EB, DED and cold spray techniques for metal additives. For polymers, it is concentrating on direct laser sintering and fused deposition modeling while also exploring other processes.

Eaton has identified manifolds, valves, filtration components and other products as candidates for metal additives. For polymers, its investigations include replacing some aluminum parts with additive polymers to save costs and reduce weight.

One critical factor in deciding the suitability of an additive for making a part is that part's complexity. Traditional methods meant complexity increased cost, in either manufacturing or welding. With additives, the mantra is "complexity is free." York says that as additive processes improve, the degree of complexity required to make it the less expensive option decreases. "Applications that did not look attractive two to three years ago now do," he says.

And it is not just cost that can be saved. York says the new designs that additive manufacturing enables can improve performance by reducing weight or size, or improving fluid flows or pressures.

Eaton plans to launch its first additive-manufactured aerospace parts by the end of 2019, but most of the additive portfolio will come later. York predicts that in 5-10 years, a significant portion of the Eaton portfolio will be made through the additive process.

Airbus BizLab Nurtures Startups And Entrepreneurs

Thierry Dubois Lyon, France

What about a radio-control system that can remotely seal doors and inspection hatches—up to 32 on an Airbus? While the idea sounds perfectly relevant, providing the technology is available, it did not make it to product launch. Potential customers were not willing to pay the price.

This was one of the first ideas Airbus BizLab, the airframer's business-accelerator division, supported when it was created in 2015. That lack of success did not challenge the BizLab's raison d'etre. Without the "acceleration" scheme, Airbus might not have studied the idea, an approach that can lead to missing key innovations. Meanwhile, the system promoters could have wasted a couple of years looking for a business case.

The Airbus BizLab is part of a wide-ranging bid to reinvent a century-old industry. Major aerospace manufacturers are devising new ways to bring younger companies closer and help new ideas thrive.

A difficulty is to find the right distance between the large sponsoring company and the emerging startup. Taking over a startup company may cause its employees to feel impeded by red tape in a larger group. Simply providing funding may be only part of the support a new business needs.

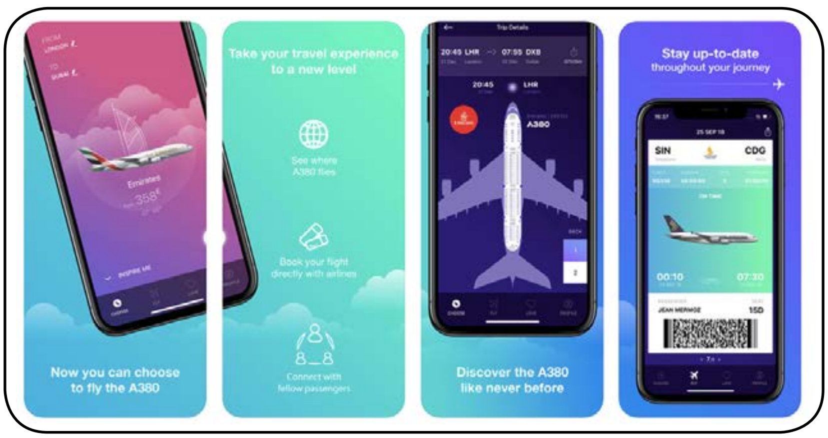
Airbus' view seems to be that there is no one-size-fits-all solution and the airframer has, during the past 10 years, created various interfaces with the entrepreneurial world. A3, described as "Airbus' outpost in the Silicon Valley," has gained the highest profile and has its own programs. Airbus Ventures, which also hoped to benefit from creativity specific to the region, invests in up-and-coming companies. Both divisions were started in 2015. Airbus' Fly Your Ideas, launched in 2008, is a biennial competition for students where the selected teams can prototype their solutions.

Airbus BizLab takes companies at an early stage, too, except their founders are no longer students. By the number and variety of projects it has helped, it is arguably the most spectacular of Airbus' efforts in moving to a more entrepreneurial culture.

"Our identity has a hybrid aspect. We welcome startups and intrapreneurs," Bruno Gutierres, head of Airbus BizLab, tells Aviation Week. The former's founders are described as free agents and the latter are Airbus employees with innovative ideas that are "a bit formatted." All bring wealth to Airbus BizLab when it comes to morph an idea into a business, according to Gutierres.

During the past three years, BizLab has hosted 50 startups and 40 of Airbus' internal projects. The performance metric will be the success rate of the transformations, says Gutierres. An authoritative number may not be released soon, however, as the viability of new companies usually is measured after five years.

The ideas pitched to Airbus BizLab have to "surprise us," Gutierres says. A criterion for selection to the acceleration program is proposing a technology or service "in a field we see as strategic such as autonomous flight, more-electric architectures, artificial intelligence [AI] and services around our fixed-wing, helicopter and satellite platforms," Gutierres explains. Inside the Airbus group, managers in charge of innovation still must network. As of mid-June, Gutierres did not know Tomasz Krysinski, Airbus Helicopters' outspoken head of research and innovation.



AIRBUS

The iflyA380 app, which enables a passenger to choose a flight on an A380, was developed by Airbus employees in a startup-like environment.

For a start-up company, the six-month acceleration program takes place in offices dedicated to the BizLab. It includes coaching from experts with skills ranging from technology to market, subcontracting, finance and law. The program's three pillars are "customer desirability, solution feasibility and business viability.

An amount of €50,000 ($58,000) is made available for a proof-of-concept, but not immediately. The six months are segmented into three "gates," at the end of which deliverables are expected. "It is a human adventure. The entrepreneurs we have selected have to show energy in overcoming obstacles, they have to be a true team," Gutierres emphasizes.

Could intrapreneurs be less motivated, as their jobs are not at risk? "It is true their situation is more comfortable, but they have the same passion," Gutierres answers. "Hence the relevance of a hybrid platform. They meet and speak the same language. They have the same problems, they do not care about their difference."

Intrapreneurs may want to start a spinoff company, but not necessarily. "Our main focus is on how these projects can create value for Airbus," says Gutierres.

The iflyA380 app, which enables a passenger to choose a flight on an A380, was developed by Airbus employees in the framework of the BizLab. "They moved mountains: With the app, we are talking to the passenger, which was not our customer thus far and a psychological barrier had to be broken down; we have created a new business line," says Gutierres.

Neewee, a startup inducted by the Bangalore BizLab, already has a contract with Airbus' factory in Hamburg. It collects data from manufacturing processes and the supply chain, on, for instance, quality defects and production lead times. Using AI, the company's engineers then predict a non-quality rate and possible supply disruption.

Airbus BizLab has just added Madrid as a fourth location, after Toulouse; Hamburg; and Bangalore, India. No further site is planned, but other ways to build the geographic footprint are in the cards. A contest was launched last year in Kenya and South Africa, where startup companies were selected in such businesses as unmanned aerial crop-spraying, delivery by drones and connected greenhouses.

Cold Spray Progressing for Structural Repairs

Lindsay Bjerregaard

Additive metal technologies have received plenty of notice in recent years as processes to transform how aircraft parts are created, but repair methods also can benefit from these techniques.

Enter cold spray, an additive surface-repair technique that allows replacement parts to be eliminated without the pitfalls of using traditional metal-repair processes such as welding or thermal spray.

Cold spray takes metal particles and accelerates them at supersonic speeds within a jet of expanded gas toward a solid surface, where enough energy is generated for the particles to bond with the surface. As its name implies, cold spray has application temperatures that are much lower than for other thermal-spray and welding processes, which means the distortion and stresses associated with those repair techniques are avoided.

The repair technique has been around for well over a decade, but much of its research and development, as well as its usage for airframe component repairs, up until recently has been limited to military applications. The U.S. Army Research Laboratory (ARL) began working on applications for aerospace in 2000 and established its Center for Cold Spray Research and Development in 2001. The center has implemented cold-spray repairs on aircraft such as the B-1 bomber, F/A-18 fighter, and Black Hawk and Seahawk helicopters. According to Victor Champagne, team leader at the ARL Cold Spray Center in Aberdeen, Maryland, the center has been spearheading implementation and development of the technology and works with all of the major companies that use cold-spray repairs. Champagne says many of the military applications have now been spun off to the commercial side.


AVIOAERO

Avio Aero is hoping to replace legacy repair techniques with cold spray.

Moog, which has worked with the ARL on the development and qualification of cold spray for civilian and military MRO, has been developing its cold-spray repair techniques since 2007. Its solutions use titanium, stainless steel, copper and other feedstock powders for repairs on a wide variety of components such as wheels or body panels. Moog says its most common cold-spray application is for restoring material lost to wear or corrosion—often on magnesium and aluminum substrates. Transmission housings and gearboxes of all types have been popular items.

"Although the technology is robust, we are still early in its lifespan," a company spokesman notes. "As more and more repairs are developed, more aviation maintenance professionals will see those repairs and want to use cold spray for their own needs."

One company following suit is GE Aviation subsidiary Avio Aero. The company began researching cold spray in 2010 in partnership with various universities and research centers in Europe. Right now, Avio Aero's research is focused mainly on aluminum components, but the company is looking into increasing the range of materials and components it uses for cold spray. It also hopes to replace legacy repair techniques.

StandardAero has been conducting in-depth testing of cold spray for a variety of components and metals since 2016. According to Keegan Smith, a special process engineer there, the company has been looking at the viability of cold-spray repairs for various parts within turbine engines. “Because the process is still new and unproven, the substantiation has required StandardAero to continuously work with various OEMs in order to investigate repairs,” he explains. “StandardAero hopes to turn more and more of these repair investigations into standard repairs that can be located in any engine manual for use across the industry.”

Smith adds that as standard practice manuals evolve along with the technology, this evolution could drive the industry to accept both softer metals such as aluminum and copper and more complex materials such as nickel-based alloys.

Another company that has become heavily involved in cold-spray repairs is Honeywell. According to Daniel Greving, Honeywell Aerospace’s director for global repair and overhaul engineering, the company began investigating the technique as early as 2004. “Over the course of four to five years, we developed a better understanding of the process, and more capable equipment became available. Much of the development was done with capable suppliers who possessed the most modern cold-spray equipment,” says Greving.

MOOG

A technician uses a hand-held cold-spray system.

Honeywell put its first cold-spray repairs into service in 2009 and now has approximately 70 parts that are repaired that way. These include aluminum and magnesium static structures such as gearboxes, pump housings and valve bodies for turbine engines—all of which are dimensional and not structural in nature. “High-pressure cold-spray technology will be the breakthrough that enables structural applications,” notes Greving.

One project that incorporates research into making cold-spray repairs for structural applications a reality is underway at the University of Akron’s National Center for Education and Research on Corrosion and Materials Performance. Through funding from the State of Ohio, the university is partnered with Airborne Maintenance and Engineering Services (AMES) and SAFE Inc. to obtain FAA approval for cold-spray repair of corroded and worn parts on commercial aircraft.

According to Greg Smith, director of engineering and manufacturing at AMES, approved cold-spray repaired aircraft parts have been limited to accessory components such as gearboxes or housings. “What we’re trying to prove is that it can be used for actual airframe components. The premise is that we can restore those to an airworthy condition—to meet or exceed the original design strength of each item,” he says.

For the first phase of the project, secondary structural items with a lower impact on airworthiness were chosen, among them panels, an air load rib and a Boeing 767 wheel.

“The other piece that made this somewhat unique is that most all previous applications of cold spray were done using helium, whereas the application we are seeking approval for uses nitrogen,” notes Smith. He says the project is using nitrogen because of its lower cost and greater environmental availability.

Although it has been used for cold spray in military applications, SAFE Inc. President Scott Fawaz says this project to their knowledge represents the first commercial cold-spray application of nitrogen. According to Rex Ramsier, the University of Akron’s executive vice president and chief administrative officer, nitrogen’s lower cost also fits with the

project's goal of receiving FAA approval and then helping to create jobs and grow the local economy.

With all research and testing completed, the project's repair specifications have been submitted, and the team is awaiting the FAA certification office's final review. Smith says they hope the review will be completed soon so cold spray can be added to AMES' repair-station capability list.

"This is a first step. The next step will be taking it into primary structural elements," says Smith. "That will make it more attractive because those are typically the more expensive components on an aircraft."

Once cold spray moves into primary structural elements, Smith says, it may become more commonplace within the industry—especially for aging aircraft that are expected to be in service for longer periods.

As a believer in cold spray's structural applications, Honeywell sees the technology as having more substantial use in the future, including development of environmental coatings for hot-section protection.

"Honeywell will continue to aggressively develop cold-spray repair technology," says Greving. "Cold spray is considered a primary repair technology and a focus area for our development efforts." He adds that the company this year plans to install a high-pressure system at its Phoenix repair station to enable structural repairs and allow for continued development of new opportunities.

EasyJet Rolls Out AI-Based Tool To Aid MRO Planning

James Pozzi

While most of EasyJet's maintenance for its aircraft fleet takes place outside of its hangars using third-party providers, its investment in technology across its UK facilities has remained consistent. In 2014, it began trials using drones for inspection work on airframes to identify potential damage after events such as lightning strikes. More recently, it has explored predictive analytics, and this year it signed up to Airbus' Skywise platform aimed at helping its engineers anticipate problems by removing and replacing at-risk components ahead of failure.

With operational and cost advantages important for any airline, particularly low-cost carriers, EasyJet is now using an artificial intelligence-based simulation tool to help with the day-to-day maintenance planning for its entire fleet of Airbus A319-100s, A320-200s, A320neos and, starting in July, the A321neo. Last year, it teamed up with London-based logistics software startup Aerogility to roll out the system, which went live last November.

Operational data about each aircraft in the fleet is extracted from EasyJet's existing AMOS management software system and integrated into Aerogility's system. Aerogility says the planners can then forecast when heavy maintenance must be scheduled, factoring in existing plans with third-party suppliers while incorporating other fleet upgrades and modifications programs.

The first discussions about a possible collaboration took place in 2014, with EasyJet looking for more effective ways to manage its maintenance workload given the anticipated expansion of its fleet in 2017-22. In the development phase, Aerogility built a test system for the British low-cost carrier, which allowed it to explore the capabilities of the software at its Luton headquarters before committing to it long-term. "The test environment allowed us to implement different scenarios and explore what various outcomes would arise from them," says Swaran Sidhu, head of fleet technical management at EasyJet.

EasyJet's planning requirements for its maintenance operations are perhaps less standard than for most carriers. The airline's MRO strategy previously focused on operating on an equalized maintenance schedule—combining A and C checks into a schedule of work packages performed overnight, rather than the more common block maintenance workload. However, as of last year, this was adjusted somewhat, Sidhu says. "Last year we carried out another detailed review of our maintenance philosophy and took the decision to convert aircraft to a block program after six years," he says.

Despite a relatively smooth implementation process with the Aerogility tool, Sidhu says there were some challenges, which is not uncommon in IT-related projects. One of these was around standardization with the AMOS interface. Another was inputting some scheduling data into the existing IT system. "Given our equalized maintenance philosophy, the combined A and C check packages are classified as light base maintenance inputs performed overnight at our five MRO network stations," Sidhu says. "The number of inputs ranges from 25 to 45 packages per week based on our 300-aircraft fleet size, and factoring them through the planning tool in addition to the heavy base maintenance inputs would have created a very congested view of the plan." He adds that EasyJet is working with Aerogility to develop the software's capability to include the equalized checks.

EasyJet is also implementing plans for its engine fleet and its landing gears using the Aerogility tool, with the latter set for completion first. "This will be an enhanced version of the software delivered last November but with this added capability," says Gary Vickers, CEO of Aerogility, who previously worked on military aviation maintenance planning projects, including Lockheed Martin on the F-35 and F-22 fleets, as well as BAE Systems, before expanding into the civil segment.

Having linked up with EasyJet for its first commercial aviation collaboration, Vickers believes Aerogility has been on a learning curve but is continuing to build a solid foundation. Talks are now ongoing with airline operators. In the future, he predicts software innovations will have an ever-greater role to play in commercial aviation. "Airline operators work in a business involving competitive pricing through to managing complex engineering assets that have to be maintained to critical levels of safety, availability and cost management," he says. "Airlines have to be innovative with the software they employ."

Can We Handle the Truth? Data Veracity in MRO

Craig Gottlieb

We love precision. As leaders in an industry steeped in engineering and product innovation, nothing pleases aerospace executives more than the certainty of an outcome.

There is no small irony then that uncertainty has long been the leading threat to asset availability, operator revenue and aftermarket service provider margins. Today, this uncertainty faces a precision-driven assault from OEM and MRO investments in the Internet of Things, applied intelligence and big data. These investments promise precision through predictive and prescriptive insight-driven improvements to flight operations, operating economics and asset availability. These investments may not, however, reveal the truth.

As others in these pages have noted, the present and future success of digital investments is fueled by data. Getting access to data from aircraft, aligning the industry around data standards and providing data security are all essential to maximizing return on digital investments.

Yet something more fundamental also is required: confidence in the veracity of the data entering the system. As good as physical mechanisms for collecting data may be, and as far as industry agreement on standards may take us, the promise of digital MRO solutions can be realized only when parties across the aftermarket can truly trust the data that drive business decisions.

There is a measurable gap between aerospace and defense (A&D) companies' desire to employ data to make decisions and their trust in those data. For example, take the findings of Accenture's 2018 Technology Vision. On one hand, 80% of the A&D executives involved in our research indicated their organizations are increasingly using data to drive critical decisions and automated decision-making. On the other hand, 73% believed that while A&D companies are basing their most critical systems and strategies on data, many have not invested in the capabilities to verify the truth within those data.

In short, while we agree data must be trustworthy, we do not necessarily agree they are. That is the fundamental irony of the modern aviation aftermarket.

Investment is focused on new digital services, but we are not sure we can trust the data upon which those services will rely.

The aftermarket segment is turning to digitalization to improve customer experience and interactions, improve the reliability and safety of operations and introduce value-added services. These are transformational business efforts, not a new set of transactional IT databases. While data have long been considered an IT responsibility—for data and the digital technologies they feed to be trusted to deliver their intended value—there must be a movement to develop a culture of stewardship for the quality of those data within the businesses using them. While IT still maintains the systems in which data reside, it is the business functions using those data as the foundation for aftermarket services that ultimately must be accountable for data veracity.

The journey to that veracity begins with a cruel admission: Not all data are created equal. The promise of big data is not an exhaustive exercise in collecting and investing in more storage, but one of curation. Some data are more important than others in achieving business outcomes and trust.

That trust emerges through three steps:

- Defining the framework for data governance.
- Applying the framework to establish standardized rules and procedures.
- Using that framework to establish control through data governance.

A governance framework is based on common business definitions for data. Definitions drive standardized rules and procedures that evolve to become the governance model for data quality.

Our experience indicates millions of dollars of benefit can be achieved when aerospace companies establish basic rules around seemingly innocuous data elements like spare-part units of measure. As data definitions take hold, they can be extended to form the rules under which data are governed. This governance model provides a control plan to ensure the stability and accountability of an organization to its data-governance framework. These rules gradually can be extended outside the enterprise to build trust not only within it but across the extended supply chain.

These are interesting times in the aviation aftermarket. Digital investments promise substantial improvements in asset availability, safety and the cost of operations. Yet for these investments to succeed, a commensurate focus must be placed on ensuring the veracity of the data fueling these digital engines. There is much trust to be earned, and the clock is ticking.

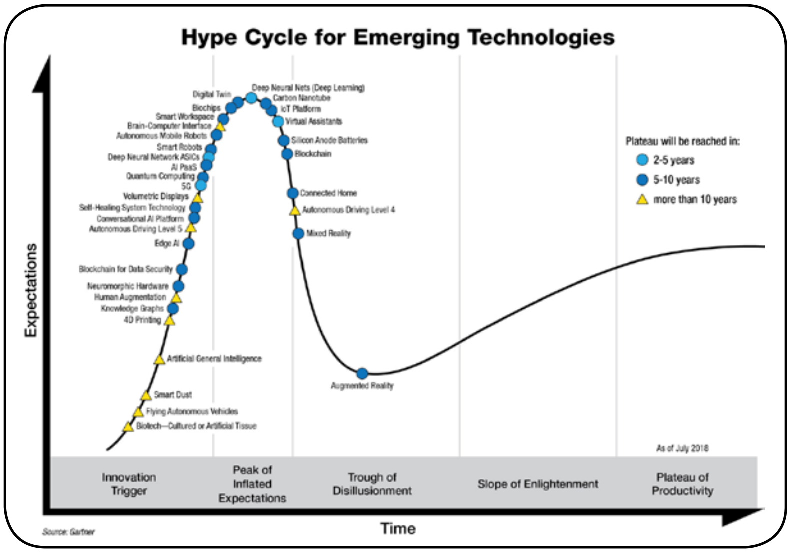
The Hype Factor Behind Emerging Technologies And Blockchain

Lee Ann Shay

New technologies such as blockchain, artificial intelligence and robotic inspections conjure excitement about potential outcomes they can produce. Heads swirl with creative ideas about possible ways to apply them.

These same technologies, however, cause angst to company leaders who aren't exactly sure if, or how, to apply them—so they cautiously wait to see how early adopters do it.

There's also the hype effect. Each year, Gartner identifies emerging technologies that will have the most impact on businesses and places them on a curve to show where they fall in the hype cycle. Its 2018 curve pegs autonomous mobile robots, digital twins and Internet of Things platforms close to the peak of inflated expectations, with blockchain past the peak, and augmented reality in the "trough of disillusionment." The newest innovations on the curve—on their way up—include flying autonomous vehicles, artificial general intelligence and 4D printing—all of which Gartner forecasts will take more than 10 years to reach their peak.



GARTNER

Blockchain is important to follow, as it has enormous potential for MRO—to show the full nose-to-tail configuration of an aircraft, to streamline lease returns and to make the supply chain system for parts much more efficient—but it also could impose new business models, be very disruptive to distributors and require new technical foundations.

Blockchain requires collaboration, and in this very process-driven industry with complex supply chains, creating shared records—or blocks of records—requires trust. To get there, no entity can do it solely.

This is why companies are looking for partners and trying to build consortiums. One is PwC; it hopes to have its proof of concept with real data available within the next quarter, says Rachel Parker Sealy, a PwC Advisory partner. She says a viable, production-scale solution could be ready within 1-2 years.

The tipping point—when companies are populating the blockchain with nose-to-nail data—could be within 2-3 years, "but that could be me being optimistic," she says, pointing out that the rate of adoption will hinge on the change-management process, not technology roadblocks.

A related roadblock to change management is data ownership, which is a concern for many in the industry.

Blockchain will require industry buy-in and faith that digital information is secure and available to the right parties. The same holds true for big data platforms, with almost a dozen available to the aviation aftermarket now.

This is part of the reason Lufthansa Technik, which built Aviatar as an open platform for the industry, plans to separate Aviatar into a separate company and attract multiple stakeholders. "I'm pretty sure we won't be the sole owner 12 months from now," says Johannes Bussmann, the MRO's chairman.

"The competition then will become: who does good things with the data—not who has access to it. That is our vision," he says.

Positive business outcomes are the goal of emerging technologies and big data, but resolving data ownership and data-rights issues will probably be the harder part.

How These Emerging Technologies Will Deliver Results Soon

Alex Derber

Given aviation's position at the forefront of high-tech engineering, it is surprising how slowly the aircraft maintenance sector has evolved. Clever new inspection techniques have sped up and improved damage detection, and new repair processes have been developed to fix the latest composite materials, but maintenance largely remains a human endeavor, almost as reliant on touch labor as it ever was.

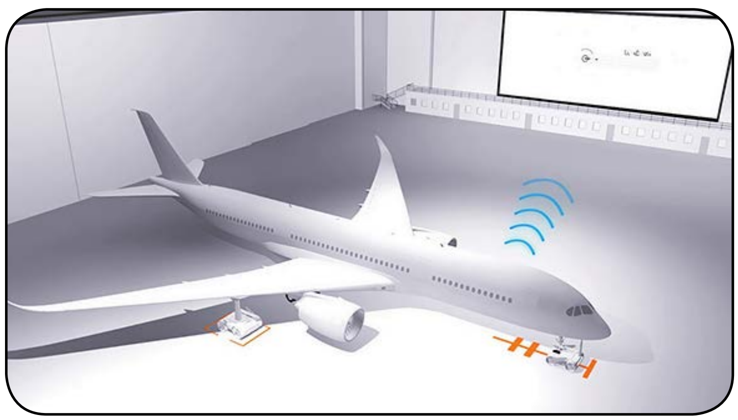
On several fronts, though, technology is threatening to disrupt the paradigm. This is not to say that robots will replace mechanics en masse any time soon; instead, new hardware and software developments have unlocked the door to automation, while also promising to reduce overall MRO costs for aircraft operators and lessors.

Robotics

"For certain applications in the field of engine and structural overhaul, the use of robotics is appropriate," says Alexander Simon-Sichart, head of corporate technology innovation and research and development at Lufthansa Technik. "This applies especially to repetitive activities, as well as wherever high precision and reproducibility are required."

Examples of such tasks include single part repairs and carbon fiber machining. Miniaturization also promises to help the inspection of difficult-to-access components, especially in the engine. One of the most eye-catching developments in this field is Rolls-Royce's recent announcement of plans to develop 1-cm-long (0.4-in) "swarm" robots to crawl through the guts of engines, feeding back imagery.

Although this would represent a "step change" in inspection capability, Rolls-Royce's ambitions go significantly further, and include using bug-like robots to remove and replace defective material, says James Kell, on-wing technology specialist at the OEM. "In short, we would like to miniaturize the overhaul facility and deploy it on the end of a snake robot [which deploys the swarm robots]."



AIRBUS

The Airbus Hangar of the Future project aims to explore digitalization and automation opportunities for aircraft maintenance.

However, Kell admits there are "major hurdles" to overcome to realize such ideas, and he estimates that it will be at least five years before the initial generation of tiny robots is operational. Already in use, in contrast, are automated drones for simpler tasks such as external airframe checks.

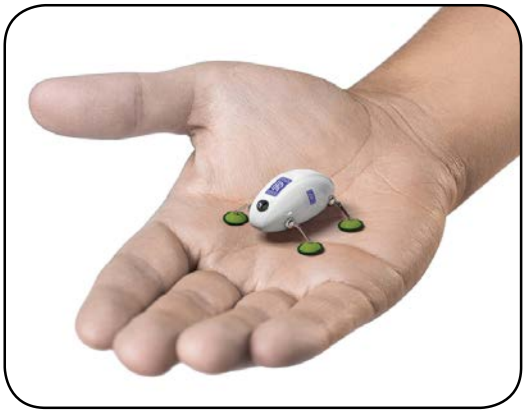
Airbus demonstrated one at MRO Americas and aims to have the system available in late 2018.

EasyJet and Thomas Cook Airlines have tried out a different autonomous drone that can inspect a full narrowbody exterior in 30 min. and a widebody in 1 hr. Developed by MRO Drone—a joint venture between Blue Bear Systems Research and Output 42—the RAPID (Remote Automated Plane Inspection and Dissemination) system can also inspect specific structures such as after reports of a bird strike. It is an evolution of the RISER drone originally developed by Blue Bear for nuclear reactor work. "A key progression under the [joint venture] was recognizing that RISER, although highly capable as a hazardous environment inspection system, was not suited to the demanding environment of MRO," says Gavin Goudie, operations director for Blue Bear.

The value of purpose-built robotics for MRO has been demonstrated by Lufthansa Technik, which has industrial-

ized its automated inspection technology, AutoInspect (see Inside MRO cover above), for CFM56 and CF34 combustor components. Development of an automated repair process, AutoRep, for any cracks found in those parts is also near completion, allowing the MRO provider to offer an end-to-end service that can function with minimal human input.

Simon-Sichart says Lufthansa Technik is developing mobile robots and movable, multifunctional ones that use image recognition and artificial intelligence to choose the right work scenario. “We see these kinds of robots ready for use by the end of the decade,” he says.



ROLLS ROYCE

Rolls-Royce has a long-term goal to miniaturize the overhaul facility by using bug-like robots to navigate, inspect and repair the insides of engines.

Additive Manufacturing

In addition to inspecting and repairing components, machines can also produce replacement parts via additive manufacturing (AM). The advantages are clear: shorter lead times for spares and lower inventory costs for maintenance providers. In-service feedback also allows for continuous improvement to the durability and performance of AM parts, which can be reengineered at each new printing.

Most large MRO providers are now developing AM capabilities, either in-house or through joint ventures with specialists. Their typical starting point is non-load-bearing cabin components printed in plastic. For now, development of AM for critical structural components is being left to OEMs, but companies such as Lufthansa Technik and Air France Industries KLM Engineering & Maintenance are also pursuing metal printing for rapid tooling. In conjunction with its laser-cladding projects, the latter is also looking into metallic wire deposition to help it rebuild specific areas of certain engine components.

AIRBUS

Airbus is already using smart glasses to assist its production work, and GE Aviation has tested its own version, combined with smart tools, to assist maintenance.

Artificial Intelligence

Fancy new robots make for great publicity shots, but sometimes what is under the hood is even more important. However, assessing whether hardware or software advances will have the biggest impact on future MRO practice is a moot point, says Kell at Rolls-Royce, adding: “I would suggest that you cannot benefit from software advances without hardware advances and vice versa.”

What is undoubtedly true is that data analytics, artificial intelligence (AI) and machine learning will have a huge influence on how machines operate and on where the efforts of robots and human workers are directed in the aftermarket. For instance, it is tougher to develop robots for maintenance than it is for manufacturing because the tasks in the former are more varied. “AI and machine learning will help deal with this variability,” says Serge Panabiere, Airbus head of services business development.

The proliferation of sensors on modern aircraft combined with better data routers has led to a sixtyfold increase in the number of data parameters collected from each Airbus flight, says Panabiere. The newest engines, meanwhile, can generate up to one terabyte of data each cycle.

Yet all this information is effectively useless without the means to analyze and act upon it. All aircraft and engine manufacturers now offer data tools as a services product, and although the technology is still in its infancy—with plenty of data still left unanalyzed—the ambitions for it are clear.

"Airbus developed the Skywise open platform, launched in June 2017, precisely to collect the vast amount of data coming from Airbus in-service aircraft, combine them with airline and OEM data and conduct in-depth data analysis to develop applications aiming at anticipating and optimizing maintenance and, more generally, improving airline operations and fleet performance," says Panabiere.

As he indicates, the information to drive better maintenance planning extends beyond sensor inputs to other factors such as operational practice, weather and technical data based on the experience and knowledge of MRO providers and OEMs. "Combining operations data with weather and sensor data gives us an increasing understanding of fault analysis and prediction of reliability," confirms Simon-Sichart, adding: "These insights improve the fleet reliability of our customers and reduce unplanned maintenance."

Accordingly, each player in the aftermarket—airlines, MRO providers and OEMs—generates its own valuable data, and the lengths to which each goes to protect, monetize and co-opt such information will be a major feature of the aftermarket going forward. Under the Skywise platform, for example, Airbus offers free access to anonymized operational data to any airline that submits its own. Thus, participating airlines benefit from a useful benchmarking tool, while Airbus receives the data it needs to refine its paid-for predictive maintenance product.

Independent software providers offer alternatives and supplements to OEM platforms for maintenance planning. "Intelligent predictive maintenance planning allows MRO managers to create an accurate forecast of required maintenance activity on aircraft and aircraft systems, based on their predicted flying patterns over a defined period," says Gary Vickers, CEO of one such provider, Aerogility.

He adds that "intelligent" platforms such as his company's provide the ability to include unscheduled maintenance and repair activity based on a probabilistic modeling of the failure rates of key systems.

Intelligent Machines

Connectivity and the cloud-based resources of the internet have made it possible to smarten up even the simplest tools, which join the Internet of Things (IoT) once you add a Wi-Fi connection. Improvements to issues such as latency and lag are still needed for these networks to function seamlessly, but the potential is obvious.

The Airbus Hangar of the Future project envisages the use of Skywise data with IoT equipment such as collaborative robots, drones, scanners, cameras and nondestructive sensors to optimize maintenance planning and task execution.

LUFTHANSA TECHNIK

Lufthansa Technik's automated repair robot tests for combustor cracks.

Combining machine learning with advanced robotics will lead to some startling new tools for maintenance providers. Add a human, too, and even greater benefits should result. "AI will help us to build new user interfaces by voice and image recognition and to find defects in structures and components resulting in more efficiency and reduced maintenance costs," says Simon-Sichart.

Lufthansa Technik is enhancing "classic" industrial robots such as automated arms with additional sensors and wireless communications. Not only does this make them more capable at existing functions, such as applying component coatings, it also allows them to be used in novel ways, such as human-robot collaboration. One example might

be a robotic arm that uses voice and image recognition to pass tools to an engineer on request. A less intelligent—but equally useful—development in other parts of industry are power-assisted suits that ease the lifting of heavy loads by workers.

Other technology-based assistants already in limited use are virtual reality applications to train engineers and augmented reality systems to improve situational awareness, declutter the workspace and improve performance. Smart glasses tested by GE Aviation, for example, alert mechanics about the correct amount of torque to apply when tightening engine bolts with a Wi-Fi-connected torque wrench. Other applications might allow MRO workers to call up technical documentation or instruction videos without breaking from their work to consult paper manuals or laptops.

The Path Ahead

Although some emerging maintenance technologies are already in operational use, others are little more than concepts or aspirations. Some build on or combine well-refined technologies and subsystems; others require further breakthroughs to fully realize their potential.

"The major subtechnology we are investing in for in situ robotics is deployment technology like snake robotics. These techniques are key enablers to allow us to make use of other processes that we are developing, such as miniaturizing coating deposition equipment," says Kell at Rolls-Royce.

At Airbus, Panabiere highlights AI, augmented reality and collaborative robotics as three key enabling technologies going forward. He also points to four realizable goals for technology in the next few years: faster troubleshooting, thanks to cognitive assistance; automated aircraft inspection to reduce aircraft downtime; better maintenance task planning and preparation; and optimized spare-parts stock management and delivery.

Despite these advances, aviation remains a conservative industry—one in which the benefits of new systems rest not just on the technology but also the will and regulatory acceptance to implement it.

"Working with the innovations leads and commercial departments has shown that there is a huge appetite for drone-based inspection, but there is still some reticence in adopting such technology in what is traditionally a very risk-aware, highly regulated and cautious industry," says Goudie.

He adds that MRO Drone had "no illusions from the outset that this would be a challenging environment to push new ways of doing things, when the traditional methods are so well understood and have been developed over such a long period of time."

In some cases, new ways of working will require new regulation. The RAPID drone's sensors mean that it can work inside and outside the hangar, for example, but the idea of drones operating on the ramp and near runways can be disconcerting and is, indeed, expressly forbidden by many aviation authorities. However, Goudie reports that several airlines in the U.S. have expressed interest in outdoor inspections to take advantage of the favorable weather enjoyed in certain states.

"We actively engage with the regulators and stakeholders in the territories [where] RAPID is garnering interest, and find that our position as a U.K.-based unmanned systems company facilitates practical discussions on how to achieve outdoor airside operations, where it may not have been considered in the past," he says.

Some have questioned whether the final hurdle for advanced technology will be pushback from unions that fear for workers' jobs. In some industries this is a valid concern, but virtually no maintenance managers believe they will lose their reliance on touch labor in the foreseeable future. Despite some huge leaps, our robotics and AI capabilities are still too immature to put humans out of a job in a sector as complex as aircraft MRO.

Overcoming Reticence To Drive Technology Adoption

Alex Farr

As the newly appointed head of information technology (IT) at Monarch Aircraft Engineering (MAEL), I've been evaluating where the business is today and where it aims to be in five years, and I am gaining a deeper understanding of the industry.

Throughout this discovery process via conversations with colleagues far and wide, I see nearly endless possibilities for digitalization.

My recent background, albeit within transport innovation rather than aviation specifically, has been focused on partnering with forward-thinking, innovative startup companies to help drive technological change. On each occasion, this called for an agile environment with a compelling business offering, much like what we aim to create at MAEL. I have witnessed that these startups can bring a fresh outlook to industry issues.

Opportunities to use machine learning or artificial intelligence for predictive and preventative maintenance abound, but few organizations in the industry are actually adopting this technology. Remote inspections using drones or automation have been developed without really taking off. While 3D printing seems to be leading the disruption within the manufacturing industry and is being tried in some places in aviation, it hasn't been picked up at scale in the MRO sector.

So what accounts for this reticence within the MRO sphere?

There are many factors behind this behavior. Obviously, a key requirement for any MRO is to ensure that aircraft are kept airworthy in a timely manner, remembering that they are all governed by national regulatory bodies. Maintaining proper compliance and safety standards is a No. 1 priority, and rightly so.

Automation on the shop floor might still be viewed as a risk to engineers' jobs and, even if not the case, could be perceived as a cost burden rather than an investment in growing revenue streams. I surmise that the ownership of any data, whether aircraft- or maintenance-related, could also cause friction.

Align all this with human factors—including how people and organizations react to change—and you see that the industry falls within the late majority end of the innovative bell curve.

The MRO industry could help itself by adopting a standard approach to the acceptance of technology. For example, different authorities impose rules and regulations all with slight variations when it comes to digitalizing maintenance records, conducting remote inspections or using electronic approvals for tasks.

Where does this leave MRO businesses? There is an argument to say that we cannot influence the adoption and that it must be driven by the OEMs or operators. But if we do nothing, do we run the risk of being left behind or disrupted by new innovators in the industry?

Organizations already have started digitalizing their back office with varied examples of automation—use of virtual reality, digitalized planning tools and/or logistics. The industry now needs to ask the questions that challenge the current standards.

Why does technology need to be a threat to people's jobs? Skilled manual labor will be essential for years to come, but surely technology—used in the right way—can only enhance or improve on this need. Can the use of machine-learning make aircraft even safer by predicting behavior? And crucially, why does there need to be an owner of the data? Why couldn't some digital ledger such as blockchain be applied to take that argument away and provide data when it is needed in real time? There are efficiency, safety and environmental benefits to all of these, so why not implement them?

Regulators' long-awaited promises to help speed technology adoption are now underway, but I believe there is also an onus on us, as businesses within industry and technology leaders, to act. There is a need for a fresh, more collaborative approach, and we all have a part to play in that.

I see an opportunity to create an industry-wide steering group comprising OEMs, airports, airline operators, owners and MROs to begin sharing ideas, innovating and exploring opportunities to work together for technology use in the future.

The group's long-term remit would be twofold. First, influence and engage individual businesses, which can also be resistant to change, and then collectively work with the various regulators to drive technological change. The Lufthansa and Oerlikon model, with its memorandum of understanding for testing out additive manufacturing, is the type of initiative the ideal steering group should pursue. Second, proofs of concepts with OEMs that are openly trying to embrace technology could be established to demonstrate the value. We already have seen the use of drones for remote inspections being developed but not adopted; the group could be used as a platform for those ideas and more.

This is an exciting time for the aerospace sector, and the MRO industry has a significant role. Although the deployment of technology is challenging, managing the change and driving adoption are long-term goals we should all be pursuing.