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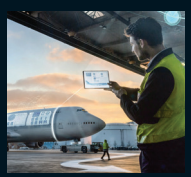
April / May 2017

MRO AMERICAS REPORT
INSIGHT AND NEWS FROM ORLANDO



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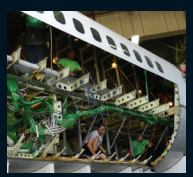

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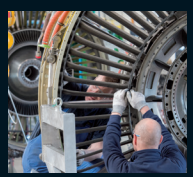

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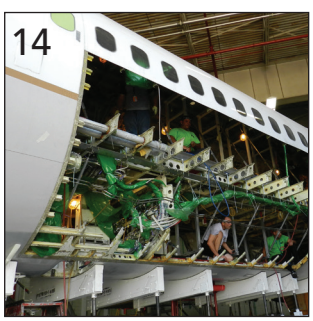

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Leadership Survey 2017

BY ANDREW DRWIEGA
EDITOR-IN-CHIEF

Welcome to the State of the Industry issue. The reason behind presenting this annual compilation of thoughts and statements from some of the more recogniseable MRO leaders and their organisations is to bring together this breadth of experience into one readable issue for you, our readers.

Recently we have heard many comments that the media makes (or fakes) the news. The objective of the team at Aviation Maintenance in presenting you with this survey, is to publicise a cross-section of opinions, in their own words, on some of the industry's most talked about issues. They discuss issues that they consider to be important, talk about their investments and how they are proactive or reactive to the MRO industry as it evolves.

While there are always so many questions that can be asked within any industry sector, we adhered to seven split between external, internal and training / education.

The three 'external' questions looked for thoughts and ideas about challenges and opportunities within the MRO sector that they believed their organisations were addressing, or needed to address, including any wider concerns. This section included getting their thoughts and experience of additive manufacturing.

The second set of 'internal' questions included the one subject being rasied in every international conversation, that of 'big data' (incidentally this issue contains a seperate article on this very subject written by contributor Charlotte Adams). We asked how a 'big data' strategy could be implemented and what the perceived (and expected) benefits it would bring.

Another high tech development being embraced my a number of organisations is virtual reality and the opportunities that it brings for training and maintenance practises.

Finally we looked at education and training, and whether the quality of education was preparing new hires for a variety of roles within MRO. Comapanies also volunteered some insight into their own training programs and how to motivate and continually develop existing employees.

Report from AEE

Two shows staged by Aerospace & Security Media, this magazine's parent company were a great success last month. The Aviation Electronics Europe (AEE) and Avionics & Space Testing Expo (AST) expositions and conferences were staged between 25/26th April 2017 in Munich, Germany. The two events attracted over 1,000 attendees from over 38 counties.

The AEE conference program started with joint opening keynotes presented by Hette Hoekema, senior expert navigation, communication, surveillance at the European Aviation Safety Agency (EASA) who gave an overview of Mandates, New Developments of our Regulatory Material and Future Plans in the avionics sector. Stefanie Erdmann, policy director at Airlines for Europe A4E discussed the latest challenges in policy and directives that could impact on the avionics and aerospace sector. These opening briefs led into a two day conference program.

The launch of the collocated testing event (AST) was welcomed by that community and both events will once again be collated on 19/20th June 2018 in Munich.

"These complimentary events were well received by an international audience and we have plans to make both bigger and further develop their content next year," said managing director Adrian Broadbent. AVM

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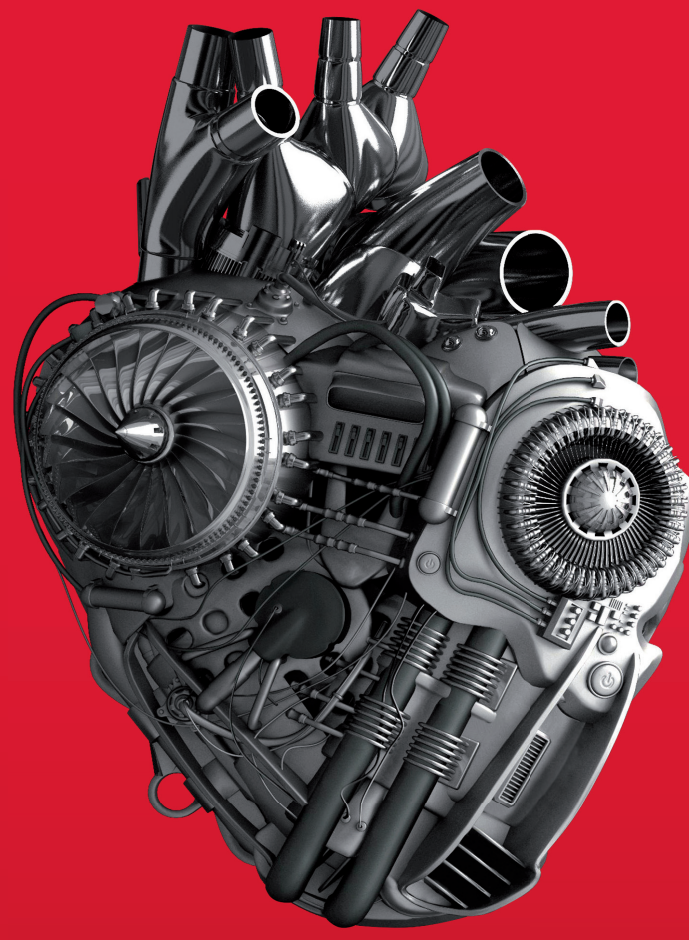

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MRO AMERICAS 2017

AVIATAR, from Lufthansa Technik is a web-based holistic platform that offers a variety of digital products and services for MRO by combining multiple apps. (Photo: Lufthansa Technik)

Bernie Baldwin reports from Orlando, Florida, on the discussions at the largest dedicated aviation maintenance event on the calendar.

Data, and how to get the most out of it, threatened to swamp the discussion at MRO Americas 2017, but the balance was restored when delegates were reminded of the physical nature of the industry.

That reminder came from Lufthansa Technik's chairman, Dr. Johannes Bussmann, during a presentation in which he was actually launching the company's Aviatar platform of MRO digital products and services. He emphasised though, the importance of bridging the digital–physical gap in the supply chain. "If I were an operator, it would not help me to know what is going to break if I cannot get the right part at the right time," he stressed.

As for Aviatar, Bussmann equated it to a "world where you can monitor your entire fleet at a glance, check the conditions of your components in real time, prevent failures before they occur, have the solution in the place when needed, while your supply chain perfectly matches your demand with no paper recording necessary".

L-r: Satair CEO, Bart Reijnen and VAS Aero Services executive chairman, Adi Bernstein. *(Photo: Bernie Baldwin)*

The system is an open platform, with app developers invited to contribute. Bussmann explained that while some apps may deliver modest savings on their own, added up they become truly significant. Currently there are seven apps on Aviatar, including the first third-party app from FLYdocs.

Peak passed?

In the regular forecast session opening the conference, Dave Marcontell, general manager, Oliver Wyman/CAVOK, reported his belief that the current airline industry financial cycle passed its peak in 2016. The MRO sector, however, will continue to grow from a value of around $72.1 billion this year to $103.8 billion in 2027.

An increase of 10,133 aircraft in service, to take the global fleet beyond 35,000 by 2027 will accompany that MRO industry growth, which means that 40 percent of today's in-service fleet is forecast to retire by 2027, Marcontell noted.

Richard Brown, principal at ICF, observed that more stable fuel costs have slowed aircraft retirements, which has had an effect on the MRO market. "For example, United has been putting 777-200s back into the domestic market," he remarked, adding that fewer aircraft are being cannibalised.

ICF expects the global MRO market to grow at 4.1 percent a year over 2016-26, faster than the predicted airline growth. North America's MRO market will grow from $18 billion in 2016 to $21.4 billion in 2026.

Both Marcontell and Brown offered trends to watch, the former focussing on an impending labour shortage of AMTs (aircraft maintenance technicians). "The median age of technicians is now 51, which nine years higher than average workforce," he warned.

Brown highlighted the rise of RONA (Return On Net Assets)-driven airlines. For these carriers, capacity management and asset utilisation are replacing market share as the key metrics of the business. "And it's all about sweating those assets," he added.

In a session examining the globalisation of the MRO sector, better delivery in the right place at the right time, and an increase in partnerships between global MRO players and regional players were the emerging themes.

Jim Sokol, president of MRO Services at HAECO Americas, epitomised the former when commenting on how globalisation plays out differently for heavy maintenance. described his company as being "agnostic" in its view and emphasised that it "makes sense to do the right work, with the right level of talent in the right place at the right time".

Hisham Nasser, chairman and consultant, Egyptair Maintenance and Engineering, believes globalisation will activate new ideas, including the possibility of affiliating with some major MROs, such as Air France Industries KLM Engineering and Maintenance (AF KLM E&M). "First, the region has to reach a certain level of stability, but I think we will see a lot of [these affiliations]," he commented.

One region not being seen as an attractive opportunity is Europe. Sokol confirmed that HAECO has "had some customers approach us to do that, but we're currently not seeing it. The cost of labour and the issues surrounding that need to be sorted out first," he explained.

One partnership announced at the show was a new services agreement between Airbus subsidiary Satair Group and VAS Aero Services to offer surplus and used serviceable material for Airbus aircraft to the market alongside new parts. VAS will assist Satair with servicing, certification, warehousing and distribution of OEM excess parts inventory, be it simply surplus or used serviceable material (USM).

Satair CEO Bart Reijnen called the deal "a clear commitment" to offer more to its customers, who will be able to view and purchase the surplus/USM parts through the Airbus online portals. His counterpart at VAS, Tommy Hughes, explained this his company will "bring all the intellectual property data of pricing, demand, fair market value assessment of each part to the partnership. By working with us, Satair will shorten the learning gap of utilising such data, as VAS is already there."

Such deals signal one way that the components sector is changing. Others include the increase in data available to predict the requirement for replacement parts plus a shift in the types of components which are most in demand.

Discussing the last of these, Tom Covella, group president of STS Component Solutions, highlighted how equipment and furnishings have become a driving force in components, representing 26% of the market. "That is almost equal to APUs, engine components, landing gear and thrust reversers combined," he commented.

According to Covella, interior retrofits represent a supply chain challenge. "You have to maintain two inventory levels – one for the existing parts and one for the parts going into the new configuration," Covella commented. Better use of data will help, he acknowledged, but "access to data is only relevant if you are using it to identify issues and change the way you operate".

Aiming to provide more key data to airlines is Aircraft Technical Publishers (ATP) which announced Custom Alerting, a new customer-driven addition to its ChronicX Solution that enables the automatic detection and management of chronic and critical defects. The company's vice-president of sales, Steve Lightstone, explained ChronicX 2.0 goes beyond simply bringing together defect reports identified by ATA codes. "It adds the ability to define rules for alerts through text searches in the Description field and/or the Corrective

about people

Morris Joins FlightSafety Commercial Team

Morris

Andrew Morris has joined FlightSafety International as director, commercial air transport simulator sales. John Van Maren, vice president, simulation products and services said of Morris: "His proven ability to develop strategic relationships with commercial airlines made him the ideal choice for this important position."

His main responsibilities are to identify and pursue new business opportunities for FlightSafety's advanced technology simulation products and comprehensive services among operators of commercial aircraft. This includes developing and promoting products and services that meet the current and future needs of this important segment.

Morris has a strong aerospace engineering background and broad experience in the development and sales of complex aerospace and defense systems. He has worked extensively in North America as well as international markets, including Europe, China and Australia.

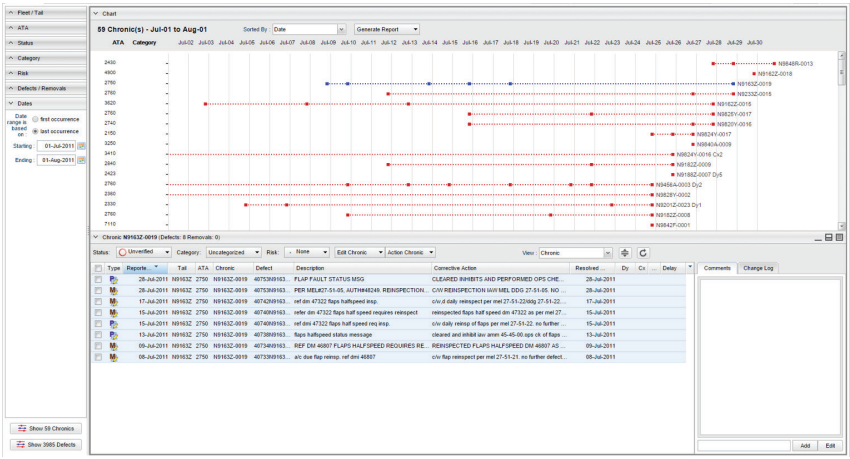
His prior experience includes positions in engineering and business development with CAE in Montreal, and in international sales and strategic development business for Rockwell Collins Simulation. He most recently served as vice president, business development for TRU Simulation and Training.

Flower Brings ME Experience Back to KLM

Ray Flower has been appointed head of technical college of KLM UK Engineering, a subsidiary of AFI KLM E&M specialising in maintenance & training solutions for regional and narrow-body aircraft fleets.

Flower has had a 30 year career with his latest roles including: head of aviation at Kingston University & chief academic officer (CAO) for Al Ain International Aviation Academy (AAIAA) in the UAE; engineering head at Qatar Aeronautical College; and head of aeronautical engineering at MTC Oman.

Flower commented: "I am very proud to be returning to KLM UK Engineering as head of technical College. With my previous experience with the Company and the newly acquired knowledge over the last few years in the Middle East I will bring a valuable contribution to both KLMUKE and its students. Being part of the new International Aviation Academy – Norwich and helping to educate and inspire the next generation of aviation engineers is an exciting prospect."



Aircraft Technical Publishers (ATP) announced Custom Alerting at MRO Americas. Part of the existing ChronicX Solution, it provides automatic detection and management of chronic and critical defects. (Photo: ATP)

"Ones and zeroes" – the MRO future

Data science – 'the ones and zeroes' – will be the key discipline for maintenance and support services of the future, whether in the military or civil arena, according to Lt Gen Lee Levy, Commander of the US Air Force Sustainment Center (AFSC), Air Force Material Command (AFMC).

Within the AFSC, there are eight unique organisations with 43,000 personnel operating as one team from 24 geographic locations. To enable combat air power those organisations must deal with a variety of tasks and act as a globally integrated MRO organisation.

"We also do software – the ones and zeroes – and are currently hiring more data specialists than qualified maintenance technicians," Levy reported.

As with civil aviation maintenance, the military has to move parts around the world. "With Logistics Command and Control, we have perhaps not kept pace with developments. We've not been able to do this as elegantly as we'd like around the globe. Civil aviation best practices have helped," Levy admitted. "We have to be prepared to operate in the air, in space, in cyber, on land and in maritime. And our C & C (command and control) is not where I'd like it to be.

"One of the things that drives us in the logistics 'Kill Chain' is what I term big E (Effectiveness) versus little e (efficiency). Our shareholders are the [US] public and when we're called upon they expect us to do one thing – win. That's where a decision has to be made to do something that may not be efficient, but will be effective," he added.

Levy noted that all this is done with a lot of old technology. "The average fleet age of the Air Force is 27 years old, which is pretty geriatric. There are many MRO challenges that come along with that," he declared.

Although many of the older aircraft are often considered less sophisticated than modern fighters, Levy again underlined the need for data specialists – but actually to work on the former. "The KC-46 (military version of the Boeing 767) has more lines of software code than an F-35 fighter," he pointed out. "Do we have enough STEM (science, technology, engineering and mathematics) graduates coming through? I don't think so and an inability to create STEM graduates is an issue for the whole country."

However, the Lieutenant General admitted that the supply chain risk "is what keeps me awake at night". The military cannot allow that to be the weakest link as it reduces "the big E", he observed. Military and civil MRO business are "remarkably the same," Levy concluded. "We each have an ageing workforce and fewer STEM graduates available to us. We must therefore continue to find mutually beneficial ways to work together."

Action field. It then sends and e-mail to the user when a rule is met," he said.

In those two fields, ChronicX can now find synonyms to identify recurring problems, for example when a problem with nose landing gear is not just entered as those three words, but also as "nlg" or "nose gear". Lightstone confirmed that the dictionaries for these synonyms are constantly being updated.

Pratt & Whitney has been investing considerably in data products and announced the bringing together of these under a new brand, EngineWise. According to head of marketing, John Renehan, the brand underlines the company's commitment to helping its customers run their businesses more efficiently.

Leading the EngineWise services portfolio are the aforementioned data analytics and real-time intelligence solutions for predictive maintenance, designed to prevent disruptions to service. These are particularly important as the amount of data being produced by aero engines is increasing by several orders of magnitude. "For example, the PW1100G-JM engine for the Airbus A320neo has 40 percent more sensors than the V2500 which powered the previous generation of A320s," explained Renehan. "And they are producing four million data points per engine per flight.

"The important thing is what you then do with the data," Renehan observed, highlighting that this is where EngineWise products support the customer. Other offerings under the brand include Fleet Management Programs (FMPs), engine overhaul services and material solutions.

Moving to slightly different materials, Sherwin-Williams Aerospace Coatings introduced a new clear, external coating for aircraft which provides a shimmering finish, extra protection and reduced costs. The SKYscapes Shimmer Basecoat 850 Series adds the type of finish provided by mica without affecting the colour of the paint underneath. This is something that can occur when mica is introduced into a paint. Any blemish can be rectified without having to touch the basic paint colour or go down to the metal of the aircraft skin.

Sherwin-Williams also displayed a new soft suede product, JetSuede, which is due for release in the third quarter of this year. Initially available in six colours, JetSuede can be used on interior surfaces including armrests. Here, when scuffs occur, repairs are easy as the surface is paint rather than leather.

Embraer arrived at MRO Americas with a new support structure – an integrated business unit focused on services and customer support, led by vice-president Johann Bordais. Previously each of the company's commercial, executive and military aviation businesses had its own customer service operation.

Bordais admitted that the previous strategy might not be one from the company would start nowadays but it was one which fitted its time. "For example, we now don't need three planning operations," he remarked.

The VP said that the new strategy has been driven partly by the rapid growth of the executive aviation division. "And then we have projects like the KC-390 [military transport aircraft], which require new, more efficient support methods," he noted. "We held a day to celebrate 20 years of the ERJ family and the military operators learned – and liked – a lot of what they saw about our support of the commercial community. Basically we are looking to deliver cross product packages."

Like others, Embraer is bringing in more data scientists than many other areas. "Smart integration of support is what the market wants," Bordais emphasised, before concluding that he expects the transfer of ideas on customer support to flow between all three areas of the company's products.

As one might expect at an event with 15,000 attendees plus around 850 exhibitors from 87 countries, the breadth and depth of topics at MRO Americas is vast. Solutions is a word often treated pejoratively, but among the maintenance community it is clearly everyday reality, whether electronic or physical.

about people

Lufthansa Technik's New Managers for VIP and Special Missions

Kai-Stefan Roepke, vice president commercials, and Thomas Decher, vice president operations, are leading the VIP & Special Mission Aircraft Services division with immediate effect, replacing Walter Heerdt who has retired.

"I thank Walter Heerdt for the excellent work that he has done in various positions at Lufthansa Technik over the past decades," said Constanze Hufenbecher, member of the Lufthansa Technik executive board for Finance, Corporate Services and VIP.

Hufenbecher said that his successors, Roepke and Decher would use their years of experience to further extend Lufthansa Technik's leading position as a provider of technical services in the VIP, special mission and government market.

Lui Heads Singapore for Werner Aero

Werner Aero Services has appointed Jimmy Lui as vice president and general manager of its Asia Pacific operations based in Singapore. He will be responsible for managing the daily operations and expanding Werner Aero Services' imprint in Asia Pacific.

Lui has over 12 years experience in the Asia Pacific aviation market and has held leadership positions with his previous companies which include OEMs, MROs, and suppliers. He holds an MBA in International Marketing and Finance as well as a Bachelor of Mechanical Engineering in Aerospace and Optics.

"Jimmy Lui's arrival at Werner Aero Services demonstrates our commitment to the Asia Pacific market and our belief in this very important business. We are excited to have him on board and look forward to having him lead our Asia Pacific team," said Mike Cazaz, CEO of Werner Aero Services.

Lufthansa Technik Middle East Dubai South Facility Fully Operational

Front row from left to right: Khalifa Al Zaffin, Guenter Rauer, Sheikh Ahmed bin Saeed Al Maktoum, Ziad Al Hazmi.

Sheikh Ahmed bin Saeed Al Maktoum, president of the Dubai Civil Aviation Authority, and chairman of the Emirates Group, together with Khalifa Al Zaffin, executive chairman of Dubai Aviation City Corporation and Dubai South inaugurated Lufthansa Technik's new operations centre.

The facility has been audited by the Federal Aviation Office of Germany and different customers from the region. It has already been used to repair parts on-site including thrust reversers, inlet cowls and radomes.

Khalifa Al Zaffin said that he expected Lufthansa Technik would "become a powerful player on the aviation landscape at Dubai South."

Responding, Ziad Al Hazmi, CEO Lufthansa Technik Middle East, said: "The official inauguration of our new site is a major milestone within our business strategy for this important region. Over the past weeks we have received high interest regarding our new capabilities from different commercial aircraft operators based in the Middle East. It makes us very proud to be the first company to run operations at the Aerospace Supply Chain."

LTME's capabilities will be further increased for other components. It currently offers Airframe Related Component (ARC) support, AOG (Aircraft-On-Ground) support, landing gear and engine and engine wash services and a local material support desk. The current LTME site at Dubai International Airport will be kept operational.

GAMA Applauds GA Funding in FY-17 Omnibus by Congress

The General Aviation Manufacturers Association (GAMA) has praised the U.S. Congress for passing the Fiscal Year 2017 Omnibus, which providing key funding for general aviation manufacturers in safety, certification, and alternative fuels. The bill, which now heads to President Trump for his signature, will fund the U.S. government through September 30, 2017.

The bill provides $1.29 billion for aviation safety activities, including $1.5 million for six additional full time equivalent (FTE) positions to support the certification of new technologies. The measure also directs the Federal Aviation Administration (FAA) to work with industry to achieve the goal of improving the effectiveness and efficiency of product certification, including fuller utilization of organization designation authorization (ODA), something for which GAMA has strongly advocated.

Additionally, the measure emphasizes the importance for FAA to continue to "strengthen international aviation safety cooperation and improve the flow of aviation products globally through strategic engagement with the European Aviation Safety Agency (EASA), Transport Canada Civil Aviation (TCCA), and National Civil Aviation Agency of Brazil (ANAC)." These efforts should leverage the respective safety competencies of bilateral safety partners to streamline validations of products and reduce burdensome and duplicative work by regulatory specialists.

The bill also provides $7 million for NextGen – Alternative Fuels for General Aviation, $1.2 million more than the request. This funding will ensure that the necessary aircraft and engine testing is undertaken to support required FAA approvals and authorizations for the transition of the piston aircraft fleet to an unleaded aviation fuel.

"We appreciate the strong support shown by Congress in this omnibus measure for general aviation, especially in the critical areas of safety, certification, and the transition to an unleaded avgas and in raising strong concerns about the attempt to remove the U.S. air traffic control system from the FAA," GAMA president and CEO Pete Bunce said.

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USM Market Hot But Volatile

by Charlotte Adams

As airline competition rises, the pressure is on to cut costs – hence the growing interest in alternatives to new parts, such as used serviceable material (USM).

The USM market is expanding, as new players enter, existing players increase their business, component support contracts drive interest, and Asian carriers become more receptive. Airframers like Boeing have also launched programs that leverage USM. Airlines, MROs and original equipment manufacturers (OEMs) are all players in this market.

USM is a growing part of MTU Maintenance's business: "We are experiencing double-digit growth in this area each year," said Patrick Holzkamp, head of purchasing engines and used parts. The unit uses and sells USM materials.

Savings are "more than 50 percent overall, plus a quality improvement if the parts are overhauled in our shops," declared Manuel Huensch, senior manager of corporate purchasing with Lufthansa Technik (LHT).

On average a USM part can be 60-80 percent of the price of a new part, according to Rudy Bryce, general manager for the GE Aviation Materials and TrueChoice Transitions program. However, USM may not fit the objectives of every shop visit, he added. "So an understanding of the type of workscope, what modules are being exposed, and what time-on-wing and residual value targets are being set are critical to understanding the potential demand."

But prices fluctuate, depending on factors such as where the part is in its lifecycle. Early in the lifecycle, high-demand USM parts can be marketed at 85 percent of the OEM catalog list price, said Vincent Benoit, Air France Industries (AFI) director of components and asset management. And, if the OEM has supply chain issues, USM can sell for more than the catalog list price.

LHT actually prefers used material over new material if the part is overhauled in the MRO's shops or within its network. "This ensures the quality our customer expects and reduces costs," Huensch said. LHT employs used parts in nearly every area – engines, components, landing gear, and airframe "but never incident-related material," he clearly stated.

Benoit said that USM can be cost-efficient in cases such as the replacement of high-scrap-rate engine parts, the replacement verses the repair of rotable components, or when creating a pool or maintenance base kit. It can also serve to decrease pool access costs to airline customers.

But the market is volatile. "The challenge is … for asset owners to recover their investment," Benoit said, adding "the market now is facing a higher retirement rate, overflowing a shrinking market on legacy applications." Investing in the right parts at the right time is critical, Bryce agreed. "Get this wrong, and it is very easy to build up inventory on non-performing parts."

Engines

In the last few years there has been above-average fleet growth, and production rates in 2016 were not high enough to cover demand, MTU's Holzkamp asseted. This situation, together with low oil prices, has made older aircraft attractive to operate. 'Park rates' for commercial aircraft engines have declined to their lowest rate since 2001, he added, citing data from the Ascend aviation consultancy. The upshot is a strong demand for MRO for these older aircraft, more cost-intensive shop visits for mature engines as they are being flown longer, and a parallel demand for cost-effective alternatives in replacing life-limited parts (LLPs) and other parts. One of the options is USM, obtained through tear-downs.

For airliners in the over-100-seat class, about 800 engines were retired in 2015 and 2016, well down from 2013 (1,300) and 2014 (1,100), according to Ascend. The engine types most affected (until March 2016) were the CFM56-2/5A/C, JT8D, JT8D-200, CF6-50, CFM56-3, and CF6-80C. The slow retirement rate increases the demand for cheaper material and, in turn, tear-down. At the same time, half-time engines can become scarce, if the demand is higher than supply. For the next decade, retirements will remain cyclical with a probable peak at around 1,800 airliner engine retirements, predicted Holzkamp, noting that for older models, such as the CFM56-3, there is more supply than demand. For other engine types, the supply and demand ratio depends largely on the types of parts in question. For slow moving 'C-parts', there is currently more supply than demand. But, given market volatility, things could change quickly, he warned.

The 737CLs, 747s, A320CEOs and A340s also have seen a large increase in surplus availability, driven by fleet retirements and renewal programs, according to Carl Glover, AAR's vice president of parts supply for the Americas. USM is a key part of AAR's parts and aftermarket parts and services offering.

MTU Maintenance "deal[s] in everything – from sought-after LLPs such as for the CF6-80 right down to the smallest brackets," said Holzkamp. "'A-parts', or fast- moving parts, such as LLPs with remaining flight cycles that cover a minimum of one complete engine run can be very popular – in particular, LLP parts from large installed fleets such as the CFM56-5B/7B and V2500." But MTU Maintenance also deals in [slower moving] 'C-parts" because each small saving and used part can add up to create big savings for our customers."

Candidates for USM sourcing are older and retiring airplanes and engines that are typically 12 or more years old, said Jimmy James, managing director of American Airlines Tech Ops procurement. These include airframes such as the 757, 767, 737 and 777.

Air France Industries KLM Engineering & Maintenance (AFI KLM E&M) employs used engine parts and rotable components from mature fleets such as the A320, A330/340, 737NG, 747, 777, ATR, and Ejet, and from the CFM56-5B/-7B, CF6-80, and GE90, added Benoit. AFI KLM subsidiary, AFI KLM E&M Teardown Management, handles the purchase of aircraft and engines and liaises with parts traders. USM uptake is for fleets that are operational and post-warranty, Glover noted. Nevertheless operators use the market to benefit through initial provisioning tasks and additional stock carriage requirements, where they have not outsourced inventory carriage.

Components

Trends in component MRO (CMRO) are also driving the use of USM, as startup and low-cost carriers cut costs by turning over CMRO and even component carriage to third-party repair specialists and OEMs via long-term, power-by-the-hour (PBH)-type contracts.

Benoit explained that USM availability has allowed new MROs to enter the component market with aggressive pricing, allowing operators to secure better deals in exchange for longer commitments. In addition, the emergence of long-term pool and repair deals increases the level of surplus, as more inventories are consolidated into pools. He sees USM as "a nice short-term solution, easier to implement than PMA parts."

Traditionally, airlines held their own rotables stock, said Dan Watson, chief commercial officer of the AJW Group. But today more carriers recognize the cost of not having an optimized inventory, increasing their interest in PBH-style programs.

Component repair and structured support agreements are a key part of AAR's lineup, as well, and are focused on reducing operators' operational support costs. Glover explained: "Typically they are structured to leverage the use of USM inventories … through aggregating inventory carriage, repair spend, and asset availability." The growth in this outsourcing model, as well as general fleet growth, increases the market demand for spares.

The expansion of component PBH programs and pooling "opens up the number of people that are active in this market and that are actively investing in it," Watson added. AJW offers component PBH programs, pooling agreements, partout and engine shop visit management, and ad hoc parts sales and support, among other services.

Traceability

Another key point with USM is a part's paper trail. American Airlines, for example, dedicates resources to the USM receiving and inspection process. The carrier requires both serviceability and traceability documentation in order to accept used parts, explained Robert Harper, one of the airline's quality assurance managers.

Serviceability documentation – such as an FAA 8130 tag or an EASA Form 1 tag – speaks to the airworthiness of a part, providing information such as what work has been done on a part and who did it. This side of the USM equation is highly controlled by government aviation authorities.

Traceability documentation concerns a part's 'pedigree,' Harper said. This shows a part's history – who has owned or operated it. American has its own certification standards that must be met for parts to be acceptable: "One of our fears is accepting a part without good traceability." A part without traceability raises questions regarding ownership and who may have been previously maintained it.

American is also 'pretty selective' about where the chain of traceability leads to, he added. The carrier has been pro-active in informing suppliers of its requirements and repair specifications. It can't just "grab stuff off the shelf." The material has to meet American's approved repair specification or it has be made compliant to the spec by further repairs/overhauls or inspections performed by the airline's shops or by one of its audited and approved repair stations. The airline regards this requirement as a 'safeguard,' but some suppliers may see it as an extra step that adds costs.

These requirements place some limitations on both the carrier and its potential suppliers. If a distributor stocks parts that have been repaired to a generic spec, it may be easier for the supplier to turn inventory because multiple airlines might be able to accept it. If the distributor stocks parts repaired to a unique spec belonging to one airline, perhaps other airlines wouldn't accept it, Harper said adding that American's quality control process ultimately helps the airline avoid surprises.

While getting the traceability documentation can sometimes be a challenge, it's much less so than it was back in the 1980s. Back in the day, the FAA was asked to regulate the used material arena, Harper recalled, but the agency did not have the authority to do so and supported industry efforts to develop voluntary criteria instead. So American works with organizations such as the Aviation Suppliers Association and used material suppliers to make sure that they understand the carrier's requirements and quality system. AVM

Mayalsian Resorts World aircraft that was delivered by Flying Colours and designed for a leisure format with all first class style seating. (Photo: Flying Colours)

Aircraft Conversions:

Everything old is new again.

by Dale Smith

With a business model built largely on delivering the lowest cost, the world's air cargo operators are relying on the inherent savings and efficiencies that come with converting retired airliners into hard-working 'freight dogs.'

Welcome to the Access Generation powered by the Internet and the global explosion of e-commerce. With the press of a finger you can order anything from a bouquet of roses to a shipping container full of rose bushes and have them on your doorstep the next morning.

Much of that on-demand deliverability is due to the world's rapidly growing fleet of air cargo aircraft. And it's only going to get bigger. In fact, according to a Boeing report the air cargo industry will grow at 4.2 percent over the next 20-years.

In terms of the number of additional airplanes, Boeing's report states that a mix of 930 new and 1,440 converted freighters will be needed to meet market demand by 2035. That's nearly a 70 percent increase in the size of the global freighter feet.

The forecast breaks that down into a fleet comprised of 550 new large production freighters, 380 new production medium wide bodies, 400 wide-body conversions and 1,040 medium converted freighters. (Interestingly, the Boeing forecasts didn't mention the smaller regional-type aircraft that will be needed to fill the very short haul feeder routes. Probably because they don't make those types any longer.)

But no matter how you slice it up, 1,440 of any airframe mix is a lot of passenger-to-freighter (P2F) conversions and that means this segment of the market is looking pretty good right now.

"The conversion market is very good right now and all of our lines are full for the rest of this year," stated Mike Andrews, director of conversion programs, PEMCO World Air Services. "We've been in the conversion business for over 20 years and have done over 350 of them. Right now we only do 737-300 and -400 conversions and we've converted a total of 130 so far."

"We probably cover 60- or 70-percent of the smaller narrow-body conversions today," he said. "The 737 is a very good 'feeder'

Pemco World Air Services (PEMCO) has redelivered its first B737-300 passenger-to-freighter converted aircraft to Guangdong Long Hao Aviation Group. It features nine pallet positions, up to 43,100 pounds of payload, 4,600 cubic feet of total volume, and a max range exceeding 2,000 miles. (Photo: PEMCO)

freighter. The -300 will carry about 43,000 pounds of cargo and the -400 will carry up to 46,000 pounds – both have about a 2,500 nautical mile (nm) range."

Gary Warner, president of Precision Aircraft Solutions, said that his company is also experiencing an "up" market right now. Like PEMCO, Precision Aircraft Solutions performs P2F conversion on only one airframe type – in their case it's the venerable Boeing 757-200 series.

Warner also stated that much of the growth in conversions around the world could be linked to the growth of e-commerce and the rapid delivery demands of the e-tailers' Access Generation customers.

"ATSG and Atlas have been buying and converting 767s to fill the needs of e-commerce giant Amazon," he said. "And in the narrow-body segment, China is seeing an incredible boom in demand for freighters. Chinese e-commerce giants like Alibaba and JD.com are currently driving the need for volume freighters like the 757."

"To date, we have converted 73 B757-200 PCF (Precision Converted Freighters) and we currently have another seven in work," he said. "The 757-200PCF has reached maturity and remains in high demand across the globe. As a heavy-lifter it bridges the gap between the largest narrow-body and smallest wide-body freighters."

Of course like everything in aviation, there's a dark cloud lurking behind the silver lining that the current P2F business is experiencing – namely, the dwindling supply of good, low-time airliners to convert.

P2F conversions: Only the best need apply

"When it comes to a conversion, we look for an airframe with relatively fewer cycles than normal," Andrews said. "With a 737 having a 'lifespan' of some 70,000 cycles, we're look for a sweet spot of around 35,000. That gives the airplane a good life as a freighter."

As for the 757-200, Warner said that the typical conversion candidate is 15-years old with less than 30,000 cycles. That would typically give a 757-200PCF upwards of a 15-year useful life as a freighter before the aircraft reaches its Limit of Validity (LOV) for flight hours/or cycles.

And no matter the airframe type, as you may well expect, the number of cherry airframes is getting fewer and farther every day.

"Operators of older aircraft like legacy 727s and early 737s and 757s variants are realizing that the window of opportunity to convert ideal feed stock for the 737-300, -400 and 757-200 is closing," Warner said. "If they choose not to capitalize on today's available opportunities, they could be forced to operate their older aircraft until next-generation freighters like the A320/321 become available."

"Of course, everything has a sweet spot," Andrews stated. "As the airlines are still actively using their 737-300s and -400s while they await the new 737MAX, but when those airframes come off the line, they become available for conversion. That can be good for our business."

But, sooner or later – and with the rapid expansion of e-commerce around the globe – it will be sooner, air freight operations are going to need to transition to the next-generation of conversion-grade freighters. And as Warner explained it, Precision Aircraft Solutions and, no doubt, other P2F conversion companies are already working on their preparations for that day.

"We expect demand for the 757-200 to decline over the next five- to seven-years in favor of the next-generation narrow-body freighters such as the A321," he said.

So the time is pretty much right for the P2F conversion providers to get working on which airframe(s) they will bring to market.

"We talk to customers, review aircraft types and get an understanding of the general operating costs – including all the maintenance costs – of a particular aircraft type," Warner said. "The big difference now is we are are also looking at the materials the

(Above) Last year PEMCO redelivered a 737-400 Combi aircraft to First Air, Canada's Arctic and remote region air carrier (Photo: PEMCO); (right) A newly completed 757-200PCF awaits redelivery. (Photo: Precision Aircraft Services)

OEM's are using in the fuselages, the structural design concepts of each aircraft, and the various subsystems."

"These newer aircraft have more integrated systems than the older versions. I'm not talking about fly-by-wire, I'm talking in general about the various computer systems on these airplanes," he said. "There is definitely a transition from a structural/maintenance aspect of a conversion project to it now being very much a structural/maintenance/systems conversion."

The right airplane is just the beginning.

Once upon a time, the typical P2F conversion was little more than ripping out the interior, painting over the windows and cutting a hole in the fuselage for the cargo door. Not today. These are highly sophisticated aircraft that require equally involved approvals in the form of, in a U.S. carrier's case, a FAA Supplemental Type Certificate (STC).

Warner explained that in Precision Aircraft Solutions' experience from start to finish it's about a 36-month process to do all the engineering, outfit the first airplane and earn the approvals. But it all starts with figuring out how a conversion program will come together for a particular aircraft model.

"There are two ways to get the engineering information you need," he said. "One is to use OEM data under contract and the other is to do first-principle, reverse-engineering on an actual aircraft. Both are equally legal, but they are obviously very different ways to go."

"We have chosen to go the first-principle, reverse-engineering method. So the first thing is we need a launch aircraft," Warner

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One of the first tasks in Precision's B757-200PCF main cargo door installation is the lower sill removal and replacement. Precision manufactures its own main cargo door. (Photo: Precision Aircraft Services)

said. "We also contract with one of our MRO 'partners' to do the work. It's important that they have a hanger they can dedicate to the aircraft. It's going to be on the ground for about two-years as it goes through all the survey, design, installation and STC approvals work."

"Once the aircraft is in the MRO's hanger, the first step of the process is to remove the passenger interior, then the survey and measure the interior space," he said. "We also perform the same steps on other aircraft to develop a very sound level of geometrical data on the type."

"We use that as the basis for the conversion's structural design and then move into a more detailed understanding of the external load factors on the airframe," Warner added. "We then use that to develop our finite element model of the aircraft and design concepts for the systems changes. It's all an effort to de-risk the program."

Warner explained that along with all the work preparing the first article aircraft for the P2F conversion STC, nine-times-out-of-10 the aircraft's owner is going to have a heavy check performed by the MRO. So when the aircraft is re-delivered at the end of the STC/conversion process the close it all out, sign the logbook and return the aircraft to service with everything completed.

"We can also go so far as to put the aircraft on a low-utilization maintenance program, which will give the operator a little more time on the airframe," he said. "It takes into account the differences between the aircraft operating as a passenger airliner and now as a lower-utilization freight carrier."

Once the STC and other appropriate international approvals, (depending on where the aircraft will operate) are in hand, it takes PEMCO and Precision Aircraft Solutions about 90-days to perform a typical conversion.

"That includes installing our proprietary hydraulic cargo door, reinforcing the floor structure where needed and installing the cargo loading system," Andrews said. "We have all the required hardware and materials pre-kitted up and with that it's a pretty straight forward process."

P2VIP conversions are taking off too.

While passenger-to-freighter conversions make up by far the lion's share of the market, there's a growing trend for converting commercial aircraft into upper-end business and VIP jets. Flying Colours Corp., has grown to be a leader in this segment by

working their magic to turn "retired" Bombardier (Canadair) Regional Jets (CRJs) into what they've branded as their CRJ ExecLiner Conversion series.

"The current market for executive conversion programs remains buoyant," stated Flying Colours Executive Vice President, Sean Gillespie. "From our perspective, by far and away the most popular aircraft we see being converted is the Bombardier CRJ200. We have worked on the CRJ700 and 900 also, but the 200 is the most popular."

While the CRJ-family are the current favorites for the company's conversions, Gillespie said that other types including the Embraer 135 and Donnier 328 are prime candidates for a conversion program.

And, much like the P2F conversion market, Gillespie says that Asia is currently the most active region for P2VIP conversions. "We recently delivered two ExecLiners to ResortsWorld of Malaysia and we're also working on an ongoing program of CRJ200 conversions for the Chinese company Sparkle Roll," he said. "When those eight aircraft are converted they will represent a mix of shuttle and executive VIP conversions."

"Right now we are also seeing an increase in requests from the North American market, which to some extent reflects the current sales landscape," Gillespie said. "A reconfigured ExecLiner can often fulfill the needs of an owner at a lower budget and a shorter delivery time."

Gillespie said that like any executive completion, each ExecLiner starts with an inspection of the aircraft. "For us the key factor when considering an airliner for conversion is the number of hours the aircraft has flown," he explained. "A CRJ with low engine time, low hours in the air, and a good pedigree in terms of maintenance, really can offer a good alternative to a pre-owned business jet."

"From there we create the maintenance schedule to manage any required upgrades or overhauls to the airframe and systems. We also begin the engineering process to design the interior conversion to meet the owner's needs," Gillespie said.

A CRJ200 converted to VIP format using Carbon Fibre in the monuments by Flying Colours. (Photo: Flying Colours)

"We then go through the installation, completion and delivery process on the aircraft," he added. "The whole process can take anywhere from four to 10 months, depending on the overall condition of the aircraft and complexity of the interior and any modifications we have to make."

While a "standard" ExecLiner features a top-end cabin completion, Gillespie said that their customers have come up with some pretty exotic requests. "We had a client who was keen on having a pivoting bed, which required some unique engineering," he said. "Even on a pretty standard interior, the design engineering can be challenging, but that's what we do. We have many years of experience in solving these unique challenges." AVM

STATE OF THE INDUSTRY

by Andrew Drwiega

Industry Leaders Discuss Key Issues Facing Aviation MRO

The annual *Aviation Maintenance magazine* State of the Industry Leadership Survey has always attracted great interest from the MRO industry. We contacted a wide range of industry leaders, from airline MROs to independents, industry associations, airplane manufacturers and engine OEMs.

We received replies from chairmen and chief executives, vice presidents and directors. All have been candid with their answers.

We asked them the following questions

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*

Q: *What is your main concern regarding the direction and*

development of the international MRO business? is there any particular issue that needs to be addressed?
Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*
Q: *What is your company's strategy for the ongoing education and development of existing employees?*

Many of the responders answered all of the questions, while some answered those that they felt were most relevant to their own business. Answers with not applicable were omitted.

We hope that you find this survey enlightening and useful to your own business activities.

Dany Kleiman Group Vice President, MRO Services, AAR

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*
A: We increased our capacity to support wide body work with the opening of our Rockford, IL, facility. We are expanding our support of E-JETS and also anticipate additional work on cargo aircraft and some wide-body aircraft platforms that we have not typically serviced previously. AAR recently announced its foray into the ATR aircraft market, acquiring inventory from ASL Aviation Holdings' subsidiary ACLAS Global to support a new PBH contract for ASL Group's airlines, including component support and repair for about 100 passenger and cargo aircraft, including ATR aircraft.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
A: Predictive processes based on data analytics is something we have been investigating for some time. Predictive processes will help AAR deliver high quality maintenance checks based on customer requirements for timeframes.
Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*
A: We are not currently investigating, but plan to do so in the future.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*
A: Employees fresh out of aircraft mechanic schools are valuable but do require additional education by us. An A&P license is a license to train. AAR is working with educational institutions to have them present General Familiarization on the type of airframes we work on. In Oklahoma, for instance, we hire students from Spartan College of Aeronautics and Technology in Tulsa, which has lead the charge on this and it has paid off, both for the student and for AAR Aircraft Services in Oklahoma City.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*
A: We offer ongoing education through an online Learning Management System (LMS). Much of this is required. In addition, we offer tuition reimbursement for those wanting to continue their education with advanced degrees, licensures, certifications and credentials.

Sarah MacLeod Executive Director, Aeronautical Repair Station Association (ARSA)

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*
A: Hello regulatory reform. When President Trump first introduced his "2-for-1" policy, ARSA saw opportunity in the Aviation Rule-making Advisory Committee (ARAC) as a venue for the industry to get hands-on with the process. The February Executive Order directing agencies to create 'Regulatory Reform Task Forces' put the opportunity in writing; the FAA delegated to ARAC the task force's responsibility to review existing rules and recommend repeal, modification or replacement. ARSA's primary goal is to ensure the definition of "rule" remains as expansive as possible: Let's put every-thing on the block and see what cuts. As we clean house in the United States, we can push for simplification with other countries by cutting down the barriers to acceptance between NAAs.
Q: *What is your main concern regarding the direction and development of the international MRO business? is there any particular issue that needs to be addressed?*
A: It's time to really focus on aligning bilateral agreements. There has not been coordination among and between design/production and maintenance interests among and between different countries, so

there is no alignment of standards when technical and maintenance implementation procedures are developed. In ARSA's opinion, there should be no TIP produced without a MAG/MIP and the two should be built in concert. The association has been fighting to correct parts documentation is-sues in the U.S.-EU MAG since late 2015; rather than relying on the equivalence of the two systems for parts production, the regulators got caught up by the "magic forms" (EASA Form 1 and the FAA Form 8130-3) on the maintenance side. As a result, ARSA ended up needing to provide its own solution (Form E100) just to keep U.S. repair stations performing maintenance under a dual release.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*

A: It certainly is taking up a lot of attention. From a regulatory standpoint, the biggest limitation is the bias towards new rules to cope with new technologies. Just because we have a "shiny thing" doesn't mean current regulations can't handle it. Part 21 and the applicable airworthiness standards provide a system of compliance for product and parts designers regardless of what methods they choose to produce a specific article. Repair stations can produce parts in support of a repair or alteration as long as the method is acceptable – not "approved," but "acceptable" – and the work re-turns the product to its original or properly altered condition. We've got the rules, the challenge is to reasonably enforce them and let businesses take advantage of improving technology.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*

A: Regulators need to think about their own data generation, streamline processes and put information gathered to use as quickly as possible. It's the same challenge businesses face: Disseminate the wealth of information produced and put it to real, productive use. The FAA's Aviation Data Ex-change program is something ARSA has supported as a mechanism to manage service difficulty reports and perhaps as a blueprint for other agencies. In theory, AVDEX would be a mechanism for complying with reporting responsibilities while giving broad access to what's actually happening in the field. We need to continue building opportunities to be smart with the information that agency's make us produce, just like operators and maintainers are being smart about flight data or maintenance records.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*

A: This does not actually apply to us directly, but training methodologies must be adaptable to the different methods of learning. As the technologies become more accessible, the pricing will reflect the expansion, making the use more viable for small businesses.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*

A: ARSA has long heard anecdotal horror stories about the 'time to profitability' for new technicians, and put the question to its members. According to 29 responses to a poll conducted via ARSA.org in April, it takes 15 months to turn a new non-certificated technician into a "productive, profitable employee." New A&P mechanics fare a little better, but still cost their employers more than nine months of on-boarding and basic on-the-job training. The specifics may vary, but the fact is that no-body shows up ready on their first day. There will always be some orientation required, but surely we need not waste a year's worth of a young career.

Our friends in the part 147 community are pushing hard to overhaul the aviation maintenance training school rule to focus on competency and allow schools the flexibility to teach needed skills. The industry can lend its weight to that effort by making clear that reality described in our poll numbers.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*

A: ARSA continues to invest in its training program, not just to train its own people – though we all benefit from it – but to turn three decades of compliance expertise into public good. Having built an online library of more than 50 hour-long sessions on topics ranging from aircraft parts to part 145, we're now forming that core of material into a curriculum of regulatory expertise. When it's ready, we'll be able to give managers, technicians and even executives a roadmap to applied understanding of aviation regulation.

We invite the aviation community to follow along at ARSA.org. It is not only the jumping-off point for training sessions, but also a record of the association's broad efforts across the issues discussed in this survey and more…

Anne Brachet
European Vice President, Air France KLM Engineering & Maintenance

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*

A: The MRO market continues to show sustained growth also in the upcoming years, but the nature of growth is changing rapidly now and shifting towards the new generation aircraft such as 787, A350, 737MAX and A320Neo. It shows how important AFI KLM E&M's ambition to have early presence on these new platforms has been. And the continued positive business development and major successes in sales with Xiamen Airlines, Thai Airways or AirAsia show that we are a serious player in this new market. At the same time we see the competitive landscape changing rapidly. You could say that the competitors of today play in a different league than the ones of the past. Therefore, based on the strengths of its airline/MRO profile, AFI KLM E&M continues to improve itself on the things that they are already doing today like safety, operational excellence, cost and competitiveness while at the same time it focuses on increasing added value to its products by innovation and incorporation of new digital opportunities.

You've got A350 reasons to trust us.

Airlines know what airlines need. That's why we're the best choice for the support of your A350 from day one. We're ready for all the maintenance, repair and overhaul services it will need – even before its entry into service. We have the technology and the equipment, but what's more, we know how to keep airlines' most valuable assets where they belong – in the air. And thanks to our decades of experience, we can integrate new aircraft types quickly and cost-effectively into existing fleets. That makes us the ideal partner for the A350 anywhere in the world.

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Q: *What is your main concern regarding the direction and development of the international MRO business? Is there any particular issue that needs to be addressed?*
A: It breaks down into several distinct approaches and convictions. The OEM and OAM are important current and future players in our market. Due to the nature of our relations, finding a balanced symbiosis is key, so we continue our strategy of forging partnerships with them, e.g. the A350 and the Boeing 787, to get access to licenses, including for the Leap engine. Furthermore AFI KLM E&M continues expanding its worldwide MRO network, especially in Asia. Such local facilities are important to expand market presence and market share in local oriented markets and are also key in providing cost effective services for our customers. The extension of our engine part repair capabilities, whether through partnerships such as the joint venture with Safran, is part of this same rationale for optimizing our costs.

As AFI KLM E&M puts its customers central in its approach, the excellence and integrated nature of operations are prime concerns and AFI KLM E&M is looking for finding a further hassle free way for its customer interactions and always deliver the products they really look for.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*
A: 3D printing is broadly used today in our facilities to help our engineers especially to quickly prototype tooling and then support our employee innovative program. Of course we are also looking to additive manufacturing as a promising technology to help to manufacture 'on demand' at our facilities and thus reduce our inventory costs. This is valid mainly for slow movers inventory. We are pioneering in this area and have some cabin parts carried out by 3D printing that are currently flying on our aircraft.

For OEM parts, we are discussing with some of them to pave the future of the supply chain. Three challenges at least are at stake: approval of machines and process, trace of parts printed locally and license process between OEM and the maintenance site.

In the long run, we can also imagine to have a pool of machines, located in different parts of the world, able to print structural parts (metallic) and to significantly improve the supply chain experience of airlines.

But 3D printing is just a small portion of new technologies we are investigating or developing: aircraft automated inspections by drones, augmented and virtual reality for maintenance tasks and for training, cobots to support human skills an efforts, and more generally IoT technologies are the core of our MRO Lab program that is running in a fertile collaboration between our engineers, our partners and our skilled professional. Technology is a commodity; our best assets are our know-how and the close knowledge of our customer's needs in order to selects the more promising use cases.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
A: With our PROGNOS portfolio of solutions, we are developing the maintenance services of the future driven by Big Data - the gathering and analysis of the wealth of technical data generated by aircraft fleets. The expected outcome is to predict failures before they happen, which is a critical issue for airline operations.

Developed as part of our "MRO Lab" R&D program, this suite of exclusive solutions relies on processing and using the data generated by aircraft systems so that alerts can be flagged up when under certain parameters are reached. AFI KLM E&M is setting itself apart from other industry players thanks to its MRO/Airline profile. This confers a particular status thanks to which we can cover the entire spectrum of maintenance data, and that includes all aircraft and all constituent parts of those aircraft. As such, we can also combine the use of maintenance data coming from the shops and data from aircraft condition usage, enabling us to refine and further improve the value of the generated information and associated mathematical formula to be applied.

AFI KLM E&M can either further develop market solutions or fully develop specific solutions. Two solutions are already industrialized to be offered in operational format for airlines. The first one is the Prognos Engine Health Monitoring (EHM) suite, which can carry out analysis of engine data and predict faults. The second one, dubbed Prognos Aircraft, consists of a critical system performance monitoring and alerts, first developed for A380.

Operators derive significant value from these solutions. As soon as you can detect weak signals upstream of an impending failure, we can, in conjunction with the client, optimally plan the maintenance work in light of their operational constraints. With Prognos, fleets are longer and more efficient available. Eventually, the amount of unscheduled maintenance falls dramatically, which has virtuous effects on airline Total Cost of Ownership (TCO)."

In the medium term, AFI KLM E&M plans to further broaden the scope of its Research & Development work in predictive maintenance areas. The Prognos for aircraft solution, which started focus on the Airbus super-jumbo, has been adapted yet to cover all of its systems according to prioritization based on Air France and KLM operator's experience on Delays & Cancelations, and is currently developed for the latest Boeing 787s and Airbus A350s. It will be applied soon to most of the other large commercial aircraft families including our legacy aircraft.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*
A: Leading the field for web-based digital training solutions and materials, AFI KLM E&M has now gone even further with the 787 by developing ground-breaking systems targeting the digitization and virtualization of training resources.

On its way to developing these ultra-modern solutions, AFI KLM E&M designed a virtual aircraft system. The fruit of a partnership with HOP! Training by ICARE, an AIR FRANCE KLM group subsidiary, which developed this system for CRJ family aircraft, the virtual aircraft reproduces the entire aircraft and its systems in a dynamic 3D environment. We have reproduced and animated a KLM Boeing 787 to achieve this solution. The visualization system allows us to virtually access the aircraft, its cockpit, its technical compartments, open the engine and APU and it's possible to trigger different pre-conceived maintenance scenarios to enable the technicians to interact with the aircraft's systems in real time to remedy a problem.

Used during EASA Part 147 type training and approved by Aviation Authorities, the system offers genuine added-value in terms of simplicity for instructors and trainees alike, as it allows them to simultaneously combine practice and theory segments, removing the need to access the physical aircraft. As a result, the practical training course lasts no more than five days, and technicians in the qualification stage now have the opportunity to implement their theoretical knowledge directly and practically via a perfect reproduction of the aircraft, its systems, and their behavior.

Virtual reality is also at the heart of the system developed for engine run-up training of Engine technicians and mechanics. Rather than having to wait for a Full Flight Simulator to become available, personnel can now visualize a 787 cockpit in an immersive 3D environment and carry out the necessary tests.

These cutting-edge solutions are used for in-house training of AFI KLM E&M personnel and also destined to be proposed to customers. The 787 is a formidable opportunity to modernize and propel our training systems into the 2.0 era, this trend is part of a wider determination to develop a digital offering even further, based on cooperative usage and online training to maximize the effectiveness and coverage of our content for the benefit of our clients.

Charles Picasso Chief Executive Officer, ATP (Aircraft Technical Publishers)

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*
A: MROs and maintenance providers have to constantly juggle the flood of ever-changing and interdependent information—from mission-critical technical and regulatory content to compliance information. Our mission is to make life easier for them through more intelligent content and information management. When I took the helm as CEO in 2015, we started by interconnecting all of this related data and embedding this 'smart content' into their workflows to help them seamlessly manage all of their maintenance-related processes on a unified cloud platform. For years, technicians have been envisioning a day where they could simply enter their tail number and see only the relevant information—including maintenance pubs, airworthiness directives, service bulletins, compliance tracking etc.— specific to an aircraft. Going forward, we see a tremendous opportunity to deliver on that vision with an aircraft centric approach that give users all of this information at their fingertips to do their jobs faster and more accurately than ever before.

Q: *What is your main concern regarding the direction and development of the international MRO business? is there any particular issue that needs to be addressed?*
A: Global MRO spending is forecasted to increase 26 percent from 2016 to 2026— going from about $67bn to almost $100bn. And a 2015 MRO survey showed that the most prominent new technologies by 2020 will be aircraft health monitoring systems and predictive maintenance. Meanwhile Airbus forecasted that they'll need more than 33,000 new aircraft globally by 2035, mostly due to the rising demand in Asia-Pacific, which will struggle to hire and train enough maintenance professionals. We're focused on leveraging IT to help MROs and airlines to address these challenges, among others. For example, our diagnostics and reliability solutions employ a diagnostic reasoning engine, combined with a best practice database, to enable an inexperienced technician—or even any service or support staff— to consistently perform on par with experts with decades of experience under their belts.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*
A: I think it will grow in importance since engineers can speed design and production, using lighter and more complex structures that would be difficult to achieve otherwise. In an ever-ending quest to make aircraft lighter, more efficient and safer, we're seeing companies like General Electric using 3D printing for the CFM56 engine. Within the next five years, gigantic 3D printers could be used to create significant aircraft components, such as the wings or rudders. As the variety and sophistication of aircraft continues to grow, there'll be an increase need for documentation, regulations and compliance tracking to make sure that all of these interdependent pieces of the puzzle fit together seamlessly while maintaining the safety standards of the industry and the asset value of the aircraft.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
A: At our core, we're a data-driven company. We believe that we can help expand industry value overall by interconnecting data, workflows, and processes in order to help all constituents operate more efficiently and effectively. Our Aviation Hub captures an immense amount of information that could be mined and useful to OEM or MROs and there are a lot of potential applications that we're looking into. Today, our diagnostics and reliability solutions leverage all kinds of maintenance data that helps to uncover hidden trends and identify defects and performance issues, but that's just at the tip of the iceberg in terms of potential big data applications in the future.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*
A: Virtual reality technology is interesting and I can see how it could be transformative in boosting the effectiveness and efficiency of not only pilot training, but also of maintenance professionals. For example, it could be used to accelerate the training of new technicians who might some day be able to virtually take apart and put together an engine using a VR headset. It could also be used to provide virtual maintenance instructions with the mechanic having the ability to virtually see how the parts fit together alongside instructions for performing the work.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*
A: Training is certainly relevant to our customers. As I mentioned, the industry will struggle to keep up with the demand for qualified technicians, especially as more experienced workers continue to retire. One way we help is by capturing their collective field expertise and best practices in order to accelerate the development of new technicians. By leveraging technology, we can enable to them to perform at an expert level by guiding them through process of identifying the root cause of problems and going step by step towards resolving it.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*

A: We serve many constituencies— from maintenance professionals and owner/operators to pilots and schools— so part of our mission is to help support them in these efforts. Our services support the education efforts of these constituencies by allowing them to capture the knowledge of their subject matter experts so that new employees can benefit from this information.

Kenny Singletary Aftermarket Program Manager, BAE Systems

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*

A: BAE Systems is looking into line replaceable unit (LRU) exchanges and LRU overhaul, in addition to repair, asset pool programs, and expanded asset management programs based on price per flight hour for entry into service for A320Neos and 737 MAX aircraft.

Q: *What is your main concern regarding the direction and development of the international MRO business?*

A: Will the international MRO business still want to work with OEM LRU aftermarket businesses in the future? Is there any particular issue that needs to be addressed? There is a concern that third party MROs may attempt to develop parts manufacturer approval repair procedures that could jeopardize the life and operational performance on the engine control products BAE Systems develops, produced and services. As well, the use and purchases of used/surplus materials in LRU repairs and asset management, as historically most airline customers have purchased new.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*

A: Additive manufacturing is exploding across the industry. Many of the aerospace & defense primes have established centers of excellence to understand the technology and to increase the amount of additively produced hardware. BAE Systems has established a multi-site group whose focus is to bring AM technology into the product portfolio. The AM industry produced $5.2bn in 2015 and was less than one percent of the total goods manufactured in the world. GE has introduced a number of parts in their next generation aircraft engines and have saved several hundred pounds of weight per engine. Limitations with this technology are like anything that is new: not enough products in safety critical applications to fully understand long term data with additively produced hardware. Designing for additive manufacturing is a work in progress, as well.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*

A: Our Engine Systems product support teams already utilize some big data to measure field performance on our engine control products, i.e. our Full Authority Digital Engine Controls (FADEC).

From a broader prospective, unfortunately, we do not currently have access to the aircraft data that would be necessary to have an effect on our business. Over time, we suspect that the airlines will see that a partnership and sharing of the data will allow us to collaborate with the data. Only then will we all benefit and be able to use the aircraft data to find problems with the hardware before it occurs, as well as use that data in the shop to determine the root cause of the problem.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*

A: BAE Systems has invested internally in augmented reality which advances human visualization and understanding. The technology can be used on the manufacturing floor for any touch labor operation where the VR technology can show what steps are next while performing an operation. This technology can also be used as a training and development aid for engineering.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*

A: Given the complexity of the work we do, few individuals fresh out of education are fully qualified for the work that we do. However, through BAE Systems' on the job training, mentoring and formal development programs, we are able to help new hires bridge what they learned in school into practical skills that we can use.

We partner with universities to help inform their curriculums. In addition, we believe that robust co-op and internship programs have a major impact on helping new graduates be job-ready.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*

A: Ongoing education is encouraged and financial assistance is provided by BAE Systems for employees to further their educations. BAE Systems has an 'on line' training program that allows the employee to register for training programs and classes. BAE Systems offers company-provided training (on the job and external), tuition reimbursement programs to enable employees to advance their degrees, and experiential learning programs (mentoring, job rotations, etc) which advance the education and development of existing employees.

"...few individuals fresh out of education are fully qualified for the work that we do. However, through BAE Systems' on the job training, mentoring and formal development programs, we are able to help new hires bridge what they learned in school into practical skills that we can use.


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Todd Duncan Chairman, Duncan Aviation

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*
A: Duncan Aviation has invested heavily in future business opportunities for all areas of our business.

For airframe, we continue to work with the most popular OEMs and maintain authorized service center status where it makes sense to do so, partnering with the OEMs on the care of our mutual customers.

In engine, we consistently evaluate the launch locations for our engine rapid response teams, who provide in-field service for unscheduled events and AOG services. We currently have 14 launch offices. We also invested heavily with Honeywell for our HTF7000 authorization and TFE731 Heavy authorization, which allows us to perform hot sections and overhauls on the TFE731 engine. To support this, we will be building an engine test cell at our Lincoln engine shop location this summer.

We have also invested heavily in STCs for various ADS-B mandate solutions. Duncan Aviation has access to or holds 37 FAA-approved solutions for ADS-B, which allows the company to perform upgrades on more than 100 aircraft models. In addition, Duncan Aviation is the only Rockwell Collins-authorized facility that can perform repairs and upgrades to the TDR-94 and TDR-94D transponders required to comply with the ADS-B mandate.

We have also invested in many other STCs. We hold or have access to FANS solutions for 24 aircraft models. We have also invested in STCs for connectivity, including Gogo Business Aviation 4G solutions, as well as STCs for Cabin Management System (CMS) installations.

Q: *What is your main concern regarding the direction and development of the international MRO business? Is there any particular issue that needs to be addressed?*
A: Duncan Aviation has a European Customer Advisory Board that consists of members representing both operators and MRO facilities in Europe. In round table discussions with the members, it became apparent that there are numerous burdensome inconsistencies between the FAA and EASA regarding MRO rules and regulations. As follow-up to the meeting, we submitted a letter to both organizations with recommendations for improvements that would better serve our global customers without compromising safety.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*
A: 3D printing, or additive manufacturing, allows aircraft manufacturers to reduce costs to produce components and shorten manufacturing times. At Duncan Aviation, use of this technology is growing slowly. We need to have very robust processes and controls given the safety and reliability concerns that come with any new technology. Currently, we are only using it in non aircraft application. We could see it being used in interior parts applications in the future.

Right now, we have several 3D printers in use, mostly for making connector covers for components and plugs for landing gear. We design and print our own connector covers as a way of reducing customer costs while allowing us to print what we need when we need it. Our landing gear plugs reduce the amount of time it takes to mask a landing gear for painting to around one hour rather than 7-8 hours. Instead of taping around every item that doesn't need to be painted, we can custom-design and print plugs that snap onto the gear. The plugs can be cleaned and reused, reducing our use of masking tape.

Q: *What are its limitations?*
A: For aircraft, 3D printing is great for prototype printing, but it is limited by the type of material available. Print size is also a limitation.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
A: Several things come to mind when thinking about big data and its use. First of all, our volume allows us to leverage scale and strategically invest in technology. We have a very sophisticated work order system that captures critical information about every task we complete. This includes data that we are required to capture and data that we choose to capture. Collectively, this data helps us better serve our customers in terms of setting fact-based expectations, identifying options, anticipating parts requirements and maximizing efficiency. Additionally, we are developing a knowledge-based system that captures and leverages the expertise and 'tribal knowledge' that is so valuable in consistently producing quality products and services. At Duncan Aviation, more than 400 of our team members have 20 or more years of service with us; we want to make sure that knowledge does not walk out the front door when they retire.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*
A: Duncan Aviation has been using Virtual Reality (VR) technology to enhance training for years. Most often, it's through the use of flight simulators at technical training schools. VR helps to reinforce the learning and increases efficiency by providing virtual lessons to our maintenance technicians and pilots.

TRAINING / EDUCATION

Q: *What is your company's strategy for the ongoing education and development of existing employees?*
A: Duncan Aviation invests significant resources in our team members' training and development. This comes in many forms, including new team member on-boarding, technical training schools, leadership programs, and internal hands-on learning. Our training strategy aligns the business needs of the company with effective training solutions. The result is improved performance. Duncan Aviation also supports team members through tuition reimbursement. Team members can use this benefit to help with the costs of finishing a degree or earning their private pilot license. We have the best people in the industry working here. Investing in education and development shows our team members that we value them. It also ensures our customers continue to receive the highest quality of work from us.

Zilvinas Lapinskas CEO, FL TECHNICS

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*
A: Geography-wise, the Asian market remains as the one with the largest potential. Local fleets keep expanding by hundreds of airplanes each year while local MRO industry is developing with a slower pace. This gives opportunities for established MROs, particularly from Europe, which bring European practices to the region.

Product-wise, we plan further developing all our products with a particular focus on base maintenance, line maintenance, spare parts supply, as well as Engine repair and support management. Following the launch of an MRO hangar in Jakarta in 2016, we are able to provide these products to the region's carriers thus supplementing Training and Engineering support that we have been providing for Asian Pacific customers from quite some time already.

Q: *What is your main concern regarding the direction and development of the international MRO business? is there any particular issue that needs to be addressed?*
A: As the pressure from airlines and OEM grows, MRO companies are forced to explore new ways of cutting prices. Unfortunately, in some regions and cases this may lead to certain quality and safety-related risks. This concerns not only maintenance processes, but spare parts supply as well. Some suppliers might be substituting products which may have a significant impact on airline and MRO operations.

Thus while cost optimization and exploration of more efficient maintenance is very important for the industry, it's vital to stick with aviation's main rule – safety first.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*
A: Additive manufacturing promises a lot of advantages, but it's still a rather long way to make such technologies truly efficient and safe. Three key issues which are still to be overcome are: standardization of materials, software, processes, etc.; improvement of system's user friendliness; and rapid prototyping change to rapid manufacture/ automation of manufacture

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
A: Bid data's main goal is to create additional value to customers. Equipped with large data volumes, maintenance teams can monitor aircraft components in real-time thus timely detecting any faults or predicted in advance. Bid data can allow the replacement of parts before they fail, preventing aircraft groundings and leading to better efficiency in the maintenance, overhaul and repair process. Eventually, this might reduce the number of AOGs and reduce check costs. At FL Technics, we are monitoring the development of such systems and certainly looking forward to implementing such solutions.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*
A: FL Technics is looking to invest at virtual reality solutions for training purposes. Currently, we are already estimating investments into VR technologies, since wearable devices and virtual reality (VR) applications will be the future of Part-147 organizations. VR courses, online training coupled with on-job-training will be essential advantages for any training organization to win the competition.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*
A: Those universities or training organizations which provide both theoretical and practical training – their students are highly appreciated by aviation employers. However, we understand that only few organizations have capabilities to provide practical experience. Thus we cooperate with various local educational institutions, as well as provide our own practical training courses for newcomers in order to ensure the flow of qualified new team members.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*
A: We are proud of having an in-house Part-147 organization that conducts continuous training and qualification training for existing staff. Training is provided by in-house instructors and in our own facilities thus ensuring the employees receive the training in accordance with our requirements and in line with the company's goals and values.

Derek Zimmerman President, Product Support, Gulfstream

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*
A: We will continue to grow and extend our MRO capabilities through investments in technicians, facilities, equipment and technology. We will also further expand our Field and Airborne Support Teams (FAST)

with additional technicians and specialized mobile repair vehicles in more locations around the world.

Q: *What is your main concern regarding the direction and development of the international MRO business? is there any particular issue that needs to be addressed?*
A: I would like to see continued effort by the various government and regulatory entities to harmonize requirements for operators and maintenance providers. As an industry, we need to recognize that in order for this to be most effective, we can and must participate in this process, align our interests and support existing advocacy groups (such as the General Aviation Manufacturers Association (GAMA), the National Business Aviation Association (NBAA), the Aircraft Owners and Pilots Association (AOPA) and others).

We are also focused on providing a great working environment that allows us to continue to attract, develop, retain and reward highly skilled and motivated technicians (and other support personnel). We recognize that the marketplace for talent is highly competitive and worldwide demand is growing, but believe the stability and strength of our brand and scope of our operations can create meaningful career opportunities for both current and future employees.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*
A: Specifically to MRO, we see significant opportunities and advantages in using this technology to quickly create specialized or unique tooling for spares fabrication. More widespread use in creating spares will emerge as the technology becomes more accepted and the certification criteria continue to evolve.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
A: We are already realizing benefits from the greater availability and access to aircraft maintenance and operational data.

First, our ability to listen and respond to an aircraft in real time started with PlaneConnect on the Gulfstream G450 and G550, then took a significant step forward when we introduced the Aircraft Health & Trend Monitoring System (AHTMS), also known as PlaneConnect HTM, on the Gulfstream G650 (and it will also be available upon entry into service for the G500 and G600). This system allows operators and key personnel to both receive and evaluate thousands of different aircraft parameters throughout all phases of flight.

Second, we have enhanced our Computerized Maintenance Program (CMP) with the addition of MyCMP Diagnostics (this is currently available for the G650ER, G650 and G550 and will be available on the G500 and G600 at launch). This online expert system consolidates and integrates Fault Isolation Manuals (FIMs) from different component manufacturers and captures real-world troubleshooting and removal/installation activity. This allows us to take the cumulative experience of our field reps, tech ops, technicians and operators to both share and improve troubleshooting guidance.

Finally, I would like to highlight the importance of Flight Operational Quality Assurance (FOQA), or Flight Data Monitoring (FDM), to continue to enhance the overall safety of our entire industry. We strongly recommend and encourage all of our operators to incorporate data analysis, constructive dialogue and continuous improvement in their aircraft operation.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*
A: We have been using virtual reality (VR) systems for several years in both the design and marketing of our aircraft. We've found that this technology works best in a controlled environment where the user benefits from a fully immersive experience. We're also using VR in our training partnership with FlightSafety International to familiarize operators with the inner workings of aircraft and aircraft systems.

I'm probably even more excited about augmented reality (AR) systems and the ability to be aware of and engaged in real-world activities while leveraging a supplemental stream of real- time information and communication.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*
A: We are fortunate to have close working relationships with a number of high schools, technical schools and colleges as well as local and state government officials. We've found them to be incredibly supportive of developing and deploying content to help prepare prospective employees for successful careers in aviation. We also place great emphasis on recruiting military personnel transitioning from active duty to civilian careers. Veterans comprise nearly 30 percent of our U.S. workforce.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*
A: We recognize that we have an opportunity and obligation to continue to develop our workforce and we do this through a combination of classroom and in-situ training. We can provide classroom training through Gulfstream University and FlightSafety International and supplement with on-the-job (OJT) training events in our training labs. This approach allows new employees to learn concepts and then apply those lessons in a safe and supervised environment.

Neil Book
President and Chief Executive Officer, JSSI

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*
A: Innovation is a priority at JSSI. In addition to our maintenance programs, which cover virtually every make and model of turboprop, helicopter, business jet and regional jet, we've created new and exciting business opportunities with JSSI Parts, Jet Engine Leasing, AMP and JSSI Advisory Services. These new products and services expand our footprint and allow us to offer more robust service levels to customers.

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Q: *What is your main concern regarding the direction and development of the international MRO business? Is there any particular issue that needs to be addressed?*
A: At JSSI, we have customers around the world who depend on us for guidance and support 24/7, whether it is for an unexpected AOG situation or the need to plan for the next inspection or overhaul. Our focus is on building relationships with MRO facilities globally, who offer the highest quality service and most efficient turn times.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*
A: This technology is certainly reshaping our world. Additive manufacturing will ultimately have a profound impact on the business aviation sector by bringing parts to market faster and less expensively. However, limitations remain with regulatory hurdles and the necessity for quality controls.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
A: JSSI collects data points on nearly 2,000 aircraft enrolled on JSSI programs. By leveraging all our data, we effectively forecast both the timing and cost of maintenance events with real precision. We have been able to streamline the process of developing maintenance programs for new platforms in a fraction of the time that it took just a few short years ago.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*
A: Real-world experience is important to JSSI and to our customers but that doesn't mean we only look to engage with experienced industry professionals. We implemented an active internship program years ago with universities that have strong aviation and aerospace technology programs. In fact, many of these interns have become long-term employees with JSSI. I believe most of the schools we work with do a good job with their curriculum but as an industry we just need to get better at attracting more talented young people into these programs.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*
A: Our employees are truly JSSI's greatest asset. As a company, we work tirelessly to ensure we provide a workplace that fosters personal growth and encourages ongoing education. Additionally, to ensure our team remains at the very top of their game, we provide frequent in-depth technical training sessions for our worldwide customer service and technical teams from our dedicated training facility in McKinney, Texas.

"Additive manufacturing will ultimately have a profound impact on the business aviation sector by bringing parts to market faster and less expensively. However, limitations remain with regulatory hurdles and the necessity for quality controls."

Dr Johannes Bußmann, Chief Executive Officer, Lufthansa Technik

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*
A: The ongoing dynamic development of the MRO market creates challenges but also offers opportunities.

Both possibilities mean a need for change for MRO suppliers, especially because they are closely connected to a growing cost pressure. Therefore we are permanently further improving our structure and existing portfolio, but we are also increasing our efforts to think out of the box and to go new ways. We are determining the potential of new ideas for the MRO business, initiating innovative projects, integrating new advanced technologies and revolutionizing work processes. Big data use and MRO 4.0 are major fields which we are focusing on.

Within these areas, for example we are looking at: additive manufacturing; digitization of MRO in general; aircraft health monitoring & predictive analytics; robotics & automation; next generation of aircraft and engine technology; artificial intelligence & machine learning; and drones.

Q: *What is your main concern regarding the direction and development of the international MRO business? Is there any particular issue that needs to be addressed?*
A: One large area which is still raising many questions is big data. The possibility of the new technologies to permanently supervise an aircraft, an engine or a component creates many possibilities to improve MRO business but keeps also potential risks. The question of data ownership hasn't been solved, yet, for example. Who can do what with the collected data? What about data safety? How can we avoid that sensitive data will be used by the wrong people?

And how can a reliable and high quality of data analysis and implemented MRO actions be guaranteed and supervised? The pure raw data collection is just a starting point. The complex work comes with the transformation of these data into real MRO measures. And there are many other questions which still have to be solved in the future.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*
A: We more and more use AM for tooling and prototyping. We also start using AM for repairing and replacing parts. Once OEMs will 3D-print parts in their serial production, we will be ready to repair those parts with AM in our facilities. We believe that AM will be competitive to conventional manufacturing for the aerospace

industry within the next five years. Today we miss an industry format for the data triple, CAD-Model, material information and process parameters, which contains all information to manufacture a part additively being essential for industrialization of AM. Also experts combining aerospace knowledge with AM-knowledge are still rare.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*

A: Lufthansa Technik is harnessing its vast data pools with teams of highly experienced engineers and data scientists to identify a variety of measures improving our services and offer new services.

For this we partner with other companies. For instance FLYdocs is our strategic partner for records management software. Here we are developing new digital services that will be of high value for operators and lessors globally. Another service we are preparing to roll out is Condition Analytics. This new and highly intelligent platform allows airlines to predict precisely when components should be replaced and recommends measures to be taken to avoid failures before they actually happen.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*

A: We are using VR in our VIP Business for designing special cabin layouts. One example is the Mercedes Benz Style VIP cabin. For training or operations purposes we don't see effective use cases, yet. However, we have first implementation projects in place using augmented reality supporting our mechanics. This will be improve and expand for our Mobile Aircraft Repair Services.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*

A: As a highly attractive employer brand, Lufthansa Technik continues to have the option of choosing from a large pool of applicants. We are therefore less exposed to the deficits of school education than other companies. Moreover, we can purposefully mitigate any individual deficits that may exist through our comprehensive training programs and promote trainees accordingly.

In collaboration with the city of Hamburg, we are furthermore involved in the area of training preparation. As part of the vocational training preparation program, selected pupils with recognized deficits are prepared through internships and targeted support to ensure their subsequent suitability for commencing dual-study vocational training.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*

A: Every year, Lufthansa Technik invests a high single-digit million figure in training and further education for its employees. For example, the ongoing development of aircraft technology regularly demands new type training. Moreover, lifelong learning has been a compulsory requirement in the area of aircraft maintenance for decades now. Comprehensive training based on the latest scientific findings is also a regular element of Human Factors Training, which aims to exclude the possibility of human error in aircraft maintenance to the greatest extent possible.

Leo Koppers Senior Vice President MRO Programs, MTU Maintenance

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*

A: The global MRO market is very healthy. Recent figures from Oliver Wyman foresee the global MRO market value increasing to over $100bn by 2026, up from $72.1bn predicted for 2017. At MTU Maintenance, we will grow with this market, continuing to serve customers with the customized engine solutions for which we are known. The CFM56, V2500, CF34 and GE90 engine families are extremely important to us in this regard. Over the next five years, many of these engines will start to mature. As they do so, MRO costs increase due to need for heavier shop visits and material replacement. Our mature engine's program is perfectly suited to this market environment. In fact, with the market entry of A320Neos and 737 MAXs many engines will be retired, creating an increased supply of spare engines and used serviceable material. More material in the market means that the options within this program will be even more flexible and cost effective for our customers. We're looking forward to supporting operators through this phase of the engine's lifecycle – through for instance customized builds, green-time lease in or out and teardown and re-marketing of parts.

As far as next generation engines are concerned, we achieved MRO readiness for the PW1100G-JM over a year ago and are currently only one of two shops currently certified to carry out MRO work. Initial visits have been invaluable in improving repair processes in collaboration with the OEM. They also build on the range of engineering and in-depth expertise within MTU Aero Engines as a next-generation engine manufacturer.

Q: *What is your main concern regarding the direction and development of the international MRO business? is there any particular issue that needs to be addressed?*

A: Generally speaking, there will be increased OEM coverage for next generation engines and independent providers will need to intensify their cooperation with OEMs in order to access to both engine MRO and potentially IP protected repair licenses, as well as MRO volume. MTU Maintenance has adapted its strategy to this market situation. Firstly, we benefit from MTU Aero Engine's risk and revenue share partnerships with OEMs and are part of OEM aftermarket networks for the PW1100G-JM, GEnx and GP7200. Secondly we are increasing our strategic partnerships, for instance with Lufthansa Technik. The two companies also committed to a joint venture to serve the PW1100G-JM engine in 2016.

Additionally, MTU Maintenance is present in growing markets. It is no secret that the biggest growth sector for commercial MRO in the

coming years will be Asia. According to Cavok figures for instance, shop visits in China will jump from 722 in 2017 to 2,230 in 2027. That's a CAGR of 11.9 percent compared to the global average 3.2 percent. We are present here through MTU Maintenance Zhuhai, a joint venture with China Southern Airlines. Our partnerships with airlines help us understand and serve operator needs in the fastest way possible and generates base load volume. MTU Maintenance Zhuhai celebrated its 15th anniversary in 2016 and enjoys a stellar reputation in the region as China's largest maintenance shop and market leader. In fact, this location completed its 1,000th CFM56 engine shop visit and its 2,000th shop visit overall in 2016.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*
A: The MTU Maintenance industrial engineering department concentrates solely on improving our repairs, processes and technologies. They are currently exploring many technological advancements and potential future applications – for instance automation for grinding processes. This team is eagerly researching additive manufacturing technology, for instance in blade tip restoration.

On a broader company level, MTU Aero Engines already uses additive manufacturing to produce boroscope bosses for the PW1100G-JM that powers the A320neo. Another example is a new seal carrier that was designed for a demonstrator engine based on Pratt & Whitney's PW1500G. All of these have the potential to increase efficiency and therefore, reduce costs.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
A: Big data is the phrase in everyone's mouths in the MRO industry currently. Generally, Big Data helps better evaluate the behavior of certain fleets by being able to identify specific patterns which can only be detected due to the larger amount of data that are being gathered on newer engine types. The largest way that big data will affect the aftermarket is that it will take MRO management and condition analytics into the predictive sphere, meaning that not only can negative trends be caught early and rectified – as is the case today – but MRO providers will be able to analyze larger patterns, better predict performance in the field and, as a result, better plan shop visits, parts logistics and manage fleets. All of these factors will result in parts savings and shorter turn times. At MTU Maintenance, we work with data on engine parameters directly from operations – on a smaller and more specific basis and are also exploring the possibilities this opens up for predictive maintenance.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*
A: MTU Maintenance collaborates with a number of research institutions, partners and companies to stay on the cutting edge of technology. We assess any potential trends and developments through our industrial engineering team, but are not currently using virtual reality training technology at this time.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*
A: We have great school and university programs across the company and at all of our global locations. These programs help us create and maintain contact to young talent and include visits, work experience, research and informational materials as well as the opportunity to write bachelor or master theses within our company.

Generally speaking, we have quite specific needs regarding maintenance personnel. We look for people with the correct qualifications, or provide training for them to attain the appropriate certification – for instance we offer engine mechanic, surface coating and logistics training programs.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*
A: We offer a number of various educational schemes and training within the company which mean that we are able to train staff to our high standards, but also that employees have access to any career development options they might be interested in. These can include masters programs, dual study programs or courses through our campus learning center. The latter provides access to an extensive range of courses in all areas of professional life at MTU – from leadership seminars and courses in project management to technical engine courses and additional and specific engine qualifications.

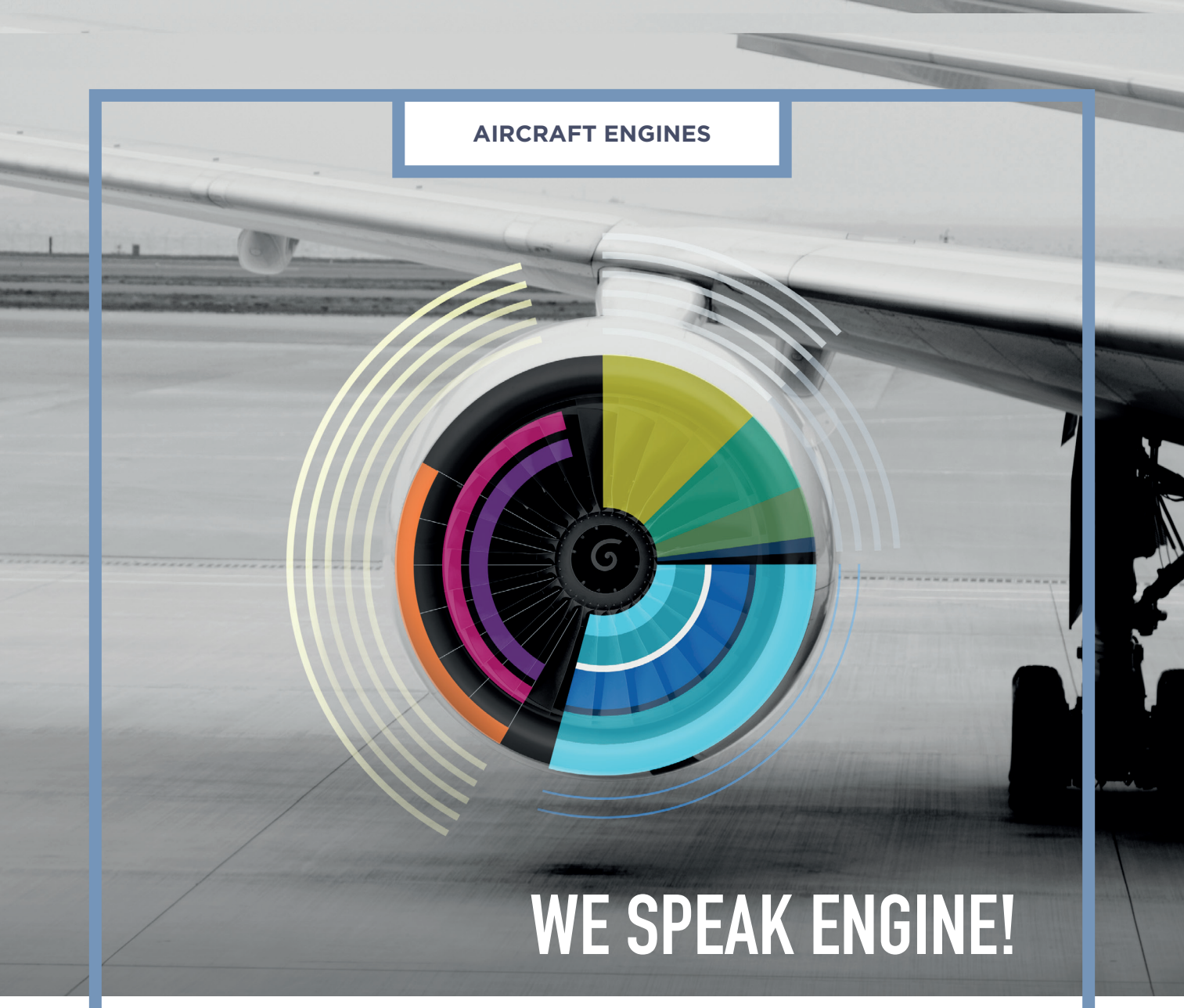
Joe Sylvestro
Vice President, Aftermarket Operations, Pratt & Whitney

INTERNAL

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*
A: One area where we are growing our support of customers is with our new EngineWise services platform, announced in April. Pratt & Whitney's EngineWise brand is all about sharing our engine expertise and fleet intelligence with Pratt & Whitney customers so they can optimize engine performance and keeps their operations running smoothly. Essentially, EngineWise better represents what we offer, and how we're evolving to improve the predictability, reliability and health of our customers' fleets.

Another big focus for us is building our GTF MRO network to support the growing number of GTF engines entering service. Now the network includes some of the industry's top MRO companies to provide the highest quality maintenance support for GTF engines. Today, GTF MRO network members include Pratt & Whitney, MTU, JAEC and Lufthansa Technik. But over time, as the volume of overhauls increases, the network is expected to expand to include airlines and other MRO shops.

Big data has also been a large focus for us for many years. We're using state-of-the art data analytics and real-time intelligence to proactively monitor the health of our engines and predict and prevent engine disruptions before they occur.



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SAFRAN

Q: *What is your main concern regarding the direction and development of the international MRO business? Is there any particular issue that needs to be addressed?*

A: With 10,500 engines in service across 400 operators, flying in 120 countries all over the world, having a successful international MRO business is very important to Pratt & Whitney. To support our global customers and engine fleets, we have 17 high-tech, high-volume Pratt & Whitney facilities, as well as a network of top MRO collaborators and suppliers, to provide the best service possible for our customers. Pratt & Whitney is in the process of re-tooling the service centers where necessary to ensure readiness for the new product lines. Working closely with operators, sharing intelligence and developing the best solutions together with operators is what our new EngineWise service brand platform is all about.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*

A: Pratt & Whitney has used additive manufacturing for decades with rapid prototyping of plastics to enhance manufacturing and speed production - from design, to prototyping, to finished product. Over the last 10 years, we have transitioned to powder bed technologies for metals and have used additive manufacturing to accelerate the engine development process and are manufacturing flight parts for Pratt & Whitney engines using this technology.

We are encouraged by additive manufacturing technologies and its many benefits. It enables new manufacturing in terms of design, speed, flexibility and affordability, making it complimentary to conventional methods. We are pursuing additive manufacturing production of components with a positive business case.

We fully expect the use of additive manufacturing to continue to grow. It is an important next step for companies to pursue and compete globally.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*

A: For decades, Pratt & Whitney has been investing in data analytics to proactively monitor the health of engines on-wing, predict future maintenance visits and prevent engine disruptions before they occur.

In order to provide operators with differentiated engine services and support while improving overall engine performance, Pratt & Whitney's deeper push into analytics has focused on a three pillar framework focused on:

- customer: how we optimize the customer experience and enhanced service value,
- predictive: integrating our expertise and technologies to develop & evolve our end-to-end predictive capabilities, and;
- connectivity: driving improved enterprise performance, capability and responsiveness through cradle-to-grave connectivity.

Through data analytics, we can create customized, intelligent workscopes, provide early warning detection focused on preventative maintenance and improve visibility into the overall health of the fleet. No two operators are the same – operators have different aircraft/engines, geographic routes, operational needs and environmental conditions. Collecting this fleet data enables us to maximize the customer's specific engine performance and engine time on-wing, while maintaining predictable MRO spend.

Additionally, we have not only invested in robust technology platforms, we've also put emphasis on hiring the right people for our team to ensure we can provide the best possible outcomes for our customers. We are collaborating with subject matter experts cross-functionally within Pratt & Whitney and externally.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*

A: Pratt & Whitney is currently investing in virtual reality tools, as an example, to enhance our customer training technologies. In fact, the Pratt & Whitney Customer Training in East Hartford, Conn., in conjunction with the United Technologies Research Center, is using virtual reality technology in its training programs so participants can virtually walk inside our GTF engine to examine parts and view a running engine in motion.

These tools not only support immersion training, but through virtual reality, we are able to provide a more comprehensive, effective customer training experience overall. The participant can see, for example, how an engine's particular valve works and visualize how air flow moves through the engine to cool components.

The technology is being introduced into the classroom at the Customer Training Center on a piloted basis to gain additional feedback from students on how to build new curriculum around it. We are working to implement a virtual reality component that supplements the training we currently have in place.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*

A: Pratt & Whitney has several skills development programs in place with community colleges and technical schools throughout the U.S. Because we anticipate the need to hire approximately 25,000 employees worldwide over the next 10 years to meet customer commitments and accommodate retirements, normal attrition, and business growth, training programs are incredibly important and will help support our company's growth.

As an example, in our Aftermarket business, we announced an expanded relationship with Columbus Technical College with a dedicated training facility to provide new and existing employees at our Columbus, Georgia facility with robust training programs. These programs are focused on aerospace mechanics and advanced manufacturing technologies, crucial skills that will help our company move forward.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*

A: At United Technologies Corporation, lifelong learning is the cornerstone of our culture. The world is constantly changing, and it is critical to learn and evolve to meet those challenges and remain competitive. As a company, UTC's future success is dependent on the development and advancement of all of our employees – and the Employee Scholar Program is key to unlocking that.

The program was created to encourage and promote the education and development of our employees. Not just so they could develop skills necessary for their current jobs, but also for the jobs of tomorrow. The Employee Scholar Program is one of the most comprehensive company-sponsored employee education programs in the world. Since 1996, more than 38,500 degrees have been earned by employees in more than 60 countries.

Employees are empowered to expand their knowledge in their current field, or learn new skills for a different career path. In a globally competitive world, we have to make sure our employees are as well-trained and educated as possible. We can't do that if we don't' provide our employees the tools and resources to get that education or develop those skills.

Tom Palmer Director of Services, Rolls-Royce

Q: *What are the main areas of opportunity within MRO that your company will expand into or develop further over the next five years?*
A: We face a challenge – how do we continue to raise standards for customers while managing a growing, diverse, fleet? It is clear that important new solutions are emerging which combine advanced technology with our own engine knowledge and expertise.

The game-changer in technology terms is the incredible promise held by digital analytics, creating an IntelligentEngine that is both connected, contextualised and cognitive and interacts with vast set of data from a number of providers. Related to it is a physical and digital support infrastructure that is focused on service delivery.

Today we at Rolls-Royce can feel we have already taken the power of digital a long way with engine health monitoring systems that analyze billions of data points every flight. But in fact that services portfolio addresses just 4 percent of an operator's direct operating costs on a typical flight. When we fully deploy digital capability, we can see ways to extend our services so that we can support operators with an additional 65 percent of their cost.

It involves the deployment of knowledge more widely and more collaboratively – to understand fuel usage, aircraft routes and flight paths, air traffic control and the weather right through to managing an operator's engine inventory and helping them plan that inventory right through to the point of engine disposal, either to another operator or to retirement.

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
A: Most airlines can see that the digital revolution gives them enormous opportunities, improving connectivity, responsiveness and performance and they know it can also reduce infrastructure costs. But they want support – from a partner that has deep industry knowledge and is committed to using data intelligently to really affect their day to day operations.

Our strategy is to work collaboratively to combine our own knowledge as an OEM with others who are the best in their field. We have already announced a digital collaboration with Microsoft, experts in data management, and Singapore Airlines, leaders in service innovation.

We have been pioneers in the use of EHM to support our CareServices such as TotalCare, and by continuing to collaborate and innovate with the best in the industry we will continue to be the services pioneer of the future.

Kriya Shortt Senior Vice President, Customer Service, Textron Aviation

EXTERNAL

Q: *What are the main areas of opportunity within MRO that your* company will expand into or develop further over the next five years?
A: At Textron Aviation, we remain focused on being flexible in how we support our customers, and we continue to collaborate with our customers on solutions that best fit their needs. In order to remain agile to the needs of our customers, we are working to identify and strengthen our core processes to maximize our service offerings and drive efficiencies. We are also streamlining component repair and overhaul capabilities to provide cost-effective options to part replacement.

Q: *What is your main concern regarding the direction and development of the international MRO business? is there any particular issue that needs to be addressed?*
A: Over the last several years, we have invested significantly within Europe and today operate six factory-direct service centers and six line maintenance stations strategically positioned throughout the region. We also have established a centralized parts distribution center serving our European customer base, as well as a fleet of rapid response aircraft able to transport parts and technicians to customers in the event of an AOG.

With changing regulations impacting how our customers maintain their aircraft, we are focused on remaining agile by offering services to support them. For example, as new EASA regulations have emerged around Part NCC and CAMO management, we have developed programs make compliance simple for our customers.

Q: *How quickly is additive manufacturing growing in importance? What are its limitations?*
A: Additive manufacturing is quickly growing in importance due to the speed, efficiency and weight reduction it brings to the manufacturing process. Its place in the aircraft manufacturing is largely dependent upon FAA and other regulatory agency approvals.

INTERNAL

Q: *The use of big data is beginning to transform the MRO business. What is your organization's strategy regarding its implementation and the effect it will have on your business?*
A: Textron Aviation's service organization uses data in a variety of ways. Historical data allows our service centers to forecast maintenance durations and be better prepared for issues that may arise during standard inspections. By leveraging historical data from Maintenance Transaction Reports (MTRs) and Maintenance Task Findings, maintenance intervals within the aircraft's maintenance

schedule can be extended, bundled or eliminated altogether. Data thresholds are very important for determining the life expectancy of aircraft parts and dictating the maintenance cycle of those parts needed to maximize useful life.

We also use aircraft diagnostic systems to capture faults in real time, which is critical to understanding general aircraft operational and reliability trends. For unscheduled maintenance events, Textron Aviation uses its expanded satellite-based diagnostics systems to gather aircraft diagnostics and provide troubleshooting techniques to pinpoint issues, discover operational trends, and determine component reliability performance.

Q: *Is your organization already or looking to invest in virtual reality technology for training or as part of operations activities?*
A: Textron Aviation has investigated a number of virtual reality innovations related to structural repairs, aircraft design, troubleshooting, and technical publications. For example, we use virtual reality to determine whether new aircraft designs allow for proper access for maintenance personnel to perform tasks or remove parts – well before the first aircraft is built. We also are now starting to integrate virtual reality into our technical manuals, providing technicians with 3D views of assemblies that can be expanded for ease of operation. These features in-work will give maintenance personnel the opportunity to plan jobs and recognize which parts of the aircraft will be affected by each task.

TRAINING / EDUCATION

Q: *Are prospective new employees who are fresh out of education suitably qualified in the areas that you require? If not, how could educational establishments improve or update their courses and qualifications?*

"With changing regulations impacting how our customers maintain their aircraft, we are focused on remaining agile by offering services to support them. For example, as new EASA regulations have emerged around Part NCC and CAMO management, we have developed programs make compliance simple for our customers."

A: We have developed relationships with the best schools in the industry and have worked closely with those schools on preparing students to enter the workforce. New employees joining Textron Aviation have endless opportunities available to them throughout the organization. With our focus on developing employees for a robust career with the company, it is increasingly important for prospective employees to have strong written and oral communication skills to effectively communicate with leaders and customers.

Q: *What is your company's strategy for the ongoing education and development of existing employees?*
A: Textron Aviation provides a broad platform of training opportunities. From technical training to leadership training, we are keenly focused on developing a growth path for employees that could extend throughout the business. As part of the broader Textron organization, employees also benefit from additional resources and expertise unavailable at other companies. We work very closely with our sister company, TRU Simulation + Training, on maintenance training to ensure our technicians are equipped with the most up-to-date knowledge and skills to maintain our aircraft. AVM


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Big Data Takes Off But Flight is Just Beginning

by Charlotte Adams

Aircraft sensors and onboard equipment gather large amounts of data. In addition to data storeable in a database, 'big data' includes volumes of unstructured data like engineering drawings, simulation files, engine telemetry, and old maintenance write-ups.

Big data technology is used to broadcast, aggregate, index and process a very large amount of data from many sources and with heterogeneous formats, explained Rodolpe Parisot, AFI KLM E&M's chief digital officer.

The volume and diversity challenges traditional computing. Yet modern algorithms, aided by digitization and the Internet of Things (IoT), can uncover patterns in what would otherwise be a meaningless jumble.

"Sufficiently sized data sets enable the generation of a statistical baseline for the detection of trends or exceedances," explained Uwe Zachau, head of industrial engineering with MTU Maintenance.

"The real 'art' is in the data analysis and producing the predictive models from this large pool of inputs": Uwe Zachau, head of industrial engineering, MTU Maintenance.

Nevertheless big data is just getting off the ground: "We believe the majority of monitoring programs are in the diagnostic phase though the aim of all providers is, of course, to enter the predictive sphere as soon as possible."

Big data's largest effect on the aftermarket will be "tak[ing] MRO management and condition analytics into the predictive sphere," Zachau said. Thus MRO providers will not only be able to detect and rectify negative trends early on -- as is the case today -- but they also "be able to analyze larger patterns, better predict performance in the field, and, as a result, better plan shop visits, parts logistics, and fleet management."

The most valuable engine MRO market data is the data that is collected "directly from operations" - combined with maintenance records - "as this provides a context for any anomalies or patterns [that are] discovered," added Zachau. "The real 'art' is in the data analysis and producing the predictive models from this large pool of inputs."

Infrastructure investment is necessary, yet the larger issue at the moment is amassing the data to feed the databases and create enough data points to be able to establish patterns across engines, regions, and operations.

Data analytics helps to create customized, intelligent workscopes, said Lynn Fraga, senior director, aftermarket programs, for Pratt & Whitney (P&W). While these techniques improve visibility into the overall health of the fleet, however, "no two operators are the same [and] operators have different aircraft and engines, geographic routes,

operational needs, and environmental conditions. Collecting fleet data helps maximize the customer's specific engine performance and time-on-wing while maintaining predictable MRO spend, Fraga said.

According to Parisot, AFI KLM E&M considers digital transformation and big data as a strategic move in its portfolio of services. The Franco-Dutch MRO sees these market trends as so powerful that it is transforming itself into "a fully data-driven organization," able to deliver the best digital services to its customers.

Data Volumes

Aircraft sensors and onboard equipment gather up to a terabyte (1 TB) of data during a flight, revealled Ryan Chapin, chief product portfolio manager for GE Aviation's Digital organization. This data characterizes key measurements that are important to operations, maintenance, training, and equipment optimization. GE engines on the latest-generation aircraft produce on the order of 25 megabytes (MB) per flight hour per engine. All of the 'snapshot data' currently available is captured.

Traditionally, an aircraft transmitted single-snapshot engine reports in different flight modes; about 10 kilobytes (KB) per snapshot report, said Zachau. "Newer developments use continuous data from the whole flight, including snapshots each second. Although this data is still below one gigabyte (GB), it is already exceeding current in-flight data transmission capabilities and is therefore downloaded via wireless quick access recorders after arrival, he said.

Airplanes like the 787 and A350 "collect 10,000 times more data than 1990s or early 2000s-era aircraft," explained Joel Reuter, vice president of public affairs for Rolls-Royce North America. "That is because more parameters are being measured at higher frequencies, using broader transmission pipelines." He predicts that data from the next generation of airplanes entering service will increase by another order of magnitude.

P&W's Geared Turbofan (GTF) family incorporates 40 percent more health and performance monitoring sensors than the V2500, Fraga explained. Data flows from the airplane to the airline and then to Pratt & Whitney. The data then is normalized for more accurate trending and anomaly detection. But in both GTF and non-GTF applications data also can be sent to P&W in flight. With the GTF's increase in sensors and expanded data capture through the full-flight profile, P&W continues to develop new reporting, trending, and monitoring capabilities, Fraga affirmed.

The GTF also expands field data capture for engine health management to nearly four million pieces of data per engine per revenue service flight, Fraga says. The new powerplant family also provides "deeper integration of sensor data within the FADEC [full-authority digital engine control] for an increase in fidelity."

Caveats

There is a growing list of sensors or components that send data over the available bus infrastructures such as ARINC 429 and ARINC 717, said Jan Stoevesand, head of analytics and data intelligence, information management, for Lufthansa Technik (LHT). Modern equipment can record 4,000 or more data points in parallel. But the sheer amount of collected data often is used as a synonym for the potential to generate insights, he noted. "Our experiences in the last two years of data analytics lead us to the conclusion that 'it is not the amount of data, it is the right amount of right data'" that makes a difference.

The same is true with aircraft sensors, Stoevesand said. Their rising numbers do not automatically improve the quality of the analytics results. The key factor, rather, will be to pick the right set of sensors and to collect the data when it is needed at the frequency that it is needed.

> "Airplanes like the 787 and A350 collect 10,000 times more data than 1990s or early 2000s-era aircraft. That is because more parameters are being measured at higher frequencies, using broader transmission pipelines."
>
> – Joel Reuter, Vice President of Public Affairs, Rolls-Royce North America

Boeing

Boeing's Airplane Health Management (AHM) uses analytics to evaluate two million conditions each day to determine when alerts should be generated across 4,000 airplanes, explained John Maggiore, managing director for maintenance and leasing solutions for the Digital Aviation unit.

AHM is "the remote monitoring of airplane data to understand its current or future serviceabilities," Maggiore said. Data can include real-time and post-flight collections, mechanic write-ups, and shop findings. AHM enables pro-active maintenance management and maintenance scheduling to avoid schedule disruptions. "It's all about 'no surprises,'" he stated.

AHM predictive alerts, for example, indicated that a 777integrated drive generator would fail in the near future, Maggiore recalled. A scheduled inspection found and corrected the issue before it created an in-service delay or cancellation and saved up to $300,000 in repair costs.

Qantas, an early adapter of AHM, used prognostic alerts on its 747-400 fleet. In 2010 the airline also adopted AHM for its 737NG fleet. The carrier used AHM's predictive alerts on the narrow-body fleet to address and fix issues during regularly scheduled maintenance – before they turned into costly delays and cancellations, Maggiore said. Qantas, for example, was able to reduce pneumatics systems-related pilot reports and delay events significantly on its 737NG fleet, with logbook activity dropping over a four-year period by more than 80 percent, thanks to AHM.

Boeing also provides an Optimized Maintenance Program (OMP). These customized programs reduce scheduled maintenance labor and material cost by more than 20 percent and associated ground time by more than 30 percent on average, while maintaining or improving fleet on-time performance and reducing in-service maintenance activities, Maggiore stated. OMP uses techniques such as text analytics, parametric modeling, and diagnostic analysis to optimize maintenance program scope, contents, and intervals.

One large European 737 operator used OMP to reduce scheduled C-checks from six to four, slashing the carrier's scheduled maintenance cost by 47 percent, according to Boeing.

A 777 operator reaped OMP benefits, as well, after program implementation and for three years post-OMP. Its delay rate

P&W's Geared Turbofan (GTF) family (such as the PW1100G-JM pictured) incorporates 40 percent more health and performance monitoring sensors than the V2500. *(PW Image)*

GE Aviation Apps Powered by Predix

Water Wash Optimizer

This provides fleet-wide and engine-level views of engine operating parameters before and after the procedure. Customers can "see the amount of exhaust gas temperature recovery achieved from the procedure," said Jayesh Shanbhag, executive director, digital strategy, for GE Aviation's Services organization. "The app also indicates time-on-wing gained, based on an engine's average deterioration rate, and it provides a fuel savings scenario planner to customize wash procedures for maximum fuel savings."

Flight Phase Analyzer

This uses continuous engine data to provide analysis for taxi, takeoff, climb, and cruise phases of flight.

Engine Health Validator

This expedites delivery and reduces the cost of leased engines that are maintained in the OEM configuration by cutting the time and expense required to verify the condition of leased engines. Reporting includes a history of engine operational performance and aids in time-on-wing estimation.

decreased from 0.69 before OMP to 0.27 after OMP. And the carrier reduced scheduled maintenance-related delays by 55 percent and scheduled maintenance non-routine findings by 14 percent, Boeing revealed.

"Digital Twins"

According to GE's Chapin, the "key ingredients to success in the industrial Internet" – central to modern aircraft data analysis - include focus on data, domain-specific analytics, and a cloud-based platform designed for scale and reuse."

Domain-specific analytics combines physics and data science expertise to build "digital twins" – the digital model of a jet engine, for example. The virtual image of an engine might enable its overhaul interval to be increased. GE Aviation uses its 3-year-old Predix, cloud-based platform and operating system to create new twin models and applications.

GE Aviation also is driving toward a concept of wide-ranging data exchange. It recently launched the Configuration Data Exchange initiative for the aviation industry "to drive asset productivity and maintenance optimization across the aviation ecosystem," Chapin said. The data pipeline will enable two-way digital exchange of aircraft configuration data and the exchange of operations, maintenance, and configuration data between participants, such as airlines, MROs, lessors, OEMs, and parts brokers. The pipeline will be agnostic to the various information technology systems of record, the company says.

Rolls-Royce also cites digital twin techniques, "whereby in-service data (as flown) is being combined with simulation data (as designed), and even coordinate measuring machine data (as manufactured), to gain more accurate understanding of the actual condition and performance of engines," Reuter said. The company is also interested in the prospects of automated analytics presented by machine learning and other forms of artificial intelligence, he added.

Rolls-Royce also stresses the increasing width and depth of the data that it collects and analyzes. "Today we are able to connect the end-to-end system," said Reuter. The company combines design, simulation, test, and manufacturing data with operational, and maintenance data, along with inputs such as fuel consumption, pilot behaviors, and context data, such as weather and traffic controls, in order to increase customers' control of and insight into their operations.

P&W cites its ADEM (Advanced Diagnostics and Engine Management) and eFAST (enhanced flight data acquisition storage and transmission) programs. These help the OEM reduce the operator maintenance burden, such as borescoping, and connect trend analytics to remote on-wing-/near-wing maintenance, Fraga says.

ADEM uses a suite of Web-enabled tools and captures flight conditions, temperatures, pressures, low/high rotor speeds, fuel flow, and vibration parameters at takeoff and cruise. For GTF engines ADEM will be expanded to capture these parameters at engine start, climb, and during thrust reverser usage. eFAST, P&W's next-gen engine health offering, includes a highly secured acquisition, storage, and transmission infrastructure that can record aircraft/engine full-flight data, generating reports and offloading data and reports to a remote ground station.

MROs

But MROs like LHT and AFI KLM E&M have by no means yielded the field to the OEMs. LHT has decided to build its technology stack around the Hadoop ecosystem, Stoevesand confirmed. "This gave us the flexibility to choose from a large variety of tools and … to quickly scale to our rising demands."

But a technology stack is not a market differentiator anymore, he said. Lufthansa Technik's key advantage is having the data scientists and engineers who "jointly develop use cases on top of that infrastructure," he added. "They developed algorithms that are able to predict the wear of expendables or … the decrease of precision of certain components long before a component failure."

LHT also builds 'digital images' of the aircraft it works on, collected via the combination of data from internal and external systems, customer and public data, and structured and unstructured data. This enables the creation of "models that can predict the condition of the aircraft or even specific components within the aircraft," Stoevesand confirmed. Among the data sources are aircraft sensors, maintenance data, airline ops data, logbook data, weather, and environmental information, he says.

AFI KLM E&M has developed Prognos, a suite aimed at predictive maintenance and engine health monitoring, which is applicable to Airbus, Boeing, GE, CFMi, and Rolls-Royce products, among others.

Prognos is proving its value. "Every single component removed following a Prognos recommendation has been confirmed faulty at the test bench," Parisot cocluded, addint that many no-go potential faults have been anticipated and avoided, thanks to this predictive maintenance tool. AM


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Battery Maintenance Review

by Mark Robins

Taking care of aviation batteries is a necessary, but vital, requirement for aircraft operators.

Aircraft batteries, like car batteries, are an essential yet oft overlooked piece of equipment in an aircraft. They are needed to start the engine or APU, to provide electrical power and as a back up if a malfunction occurs.

Like any other piece of equipment, aviation batteries require scheduled checks and maintenance in order to ensure their safe and reliable operation, especially in emergency conditions on board an aircraft.

"Maintenance checks permit any problems to be identified and rectified," said Jean-Marc Thevenoud, market manager at Saft Aviation in France. "The maintenance interval is the period for which correct operation is ensured with a low probability of failure and that allows high levels of Mean Time Between Unscheduled Removals (MTBUR) and Mean Time Between Failures (MTBF) to be achieved.

Factors that influence battery maintenance interval times include the charging system, type of starting, battery operating temperature, flight duration, number of starts, ground operation and battery technology.

Overall Maintenance

Aviation battery maintenance depends on the type of aircraft and its usage. All maintenance, including charging and discharging, should be done specifically in accordance with the instructions contained in the component maintenance manual (CMM), or if a CMM doesn't exist, the operating and maintenance manual (OMM).

Janak M. Rajpara, director of engineering/QA at Teledyne Battery Products, Redlands, Calif., said basic aviation battery maintenance should involve:

- Ensuring minimum battery to cable connection resistance
- Checking for physical wear at connectors, cables, and battery pins
- Visually checking for chemical corrosion

"One needs to wirebrush the ring and battery terminals," he added. "They can corrode or oxidize over time. They need to be kept clean. The battery-to-cable connection can get hot if loose or dirty."

Again, charging processes and load testing are described in the battery's CMMs. "The charging methods are described by the type of charge: constant voltage (or potential), constant current and float," said Rajpara. "Each method provides specific treatment to the battery. It is essential that recommended chargers be used for the needed maintenance. The use of inadequate charging will damage the battery or shorten its service life."

This aviation battery is installed in a Kitfox plane. EarthX Lithium Batteries image

Aviation battery.
Teledyne Battery Products

Teledyne Battery Products (Gill Batteries) recommends load testing to ensure airworthiness of the batteries in use. "Basic load testing is accomplished by the use of the fixed discharge rate as determined by battery type," Rajpara explained. "After the battery has been load tested, it must be recharged per the CMM before returning to service. On occasion, one may need to conduct an additional load test, particularly if the battery has been heavily discharged."

Battery Types

A lead acid battery cell contains an anode made from lead oxide and a cathode of elemental lead immersed in an electrolyte solution of sulfuric acid. A valve-regulated lead-acid (VRLA) battery does not require constant maintenance but is not 'maintenance free.'

"[There is] no way to complement the water losses that occur during operation, but a VRLA battery requires periodic control if its life has to be extended beyond the period following the first installation on board an aircraft—one to two years depending on the manufacturer," said Laurent Bressoud, product support, Saft Aviation, Levallois-Perret, France. "This control is performed off-wing with a periodicity of about six months which is similar to what is required for Ni-Cd batteries."

Nickel-cadmium (Ni-Cd) cells have an anode made of cadmium hydroxide and a cathode of nickel hydroxide that are immersed in an electrolyte made up of potassium, sodium and lithium hydroxides. According to Bressourd, Ni-Cd batteries experience, "Capacity decay with time with no sudden change in the decay slope," he said. "Even if a non- predictable single cell failure occurs, cell internal short-circuit for instance, the cell fails in short circuit mode and the battery can continue to operate with a slightly lower voltage until it can be put off-wing for repair."

Rajpara recommended that the following factors must be understood with Ni-Cd batteries:

- Top charge
- Proper electrolyte levels
- Cell balancing
- Need for deep cycle
- Overhaul
- Monitoring temperature sensors

Lithium Ion (Li-ion) batteries are relatively maintenance free during storage according to one supplier. "A lithium battery has a self-discharge rate of less than 2 percent per month, so the battery could sit on a self for over a year," said Reg Nicoson, chief technology officer, EarthX Lithium Batteries. "But when it is installed and there is an electrical drain from equipment on-board the airplane, all bets are off. When installed in an aircraft, a battery maintainer should be used during long periods of non-use (greater than one-month periods)."

More Maintenance Tips

A battery's capacity, that is, its ability to deliver the rated current for a minimum time while the overall battery voltage and that of each individual cell remains above minimum set voltages should be checked annually. "This is especially important for electrically dependent aircraft (with electronic ignition and electric fuel pumps)," Nicoson added. "In general, a battery should be replaced when its capacity is 80 percent of the nameplate rating. For example, if a battery is rated at 15Ah, it should be replaced when the measured Ah degrades to less than 12Ah. A battery that will not hold a charge is a battery that is defective/damaged or at the end of its life. In any case, the battery must be removed from service as soon as possible. This is especially important with a lithium battery."

Rajpara recommended these additional basic battery maintenance tips: follow specific electrolyte fill levels: too much electrolyte will cause spillage and corrosion problems; periodically check the battery voltage; conduct capacity tests at the appropriate temperature; and use clean / distilled water for periods needing water additions.

Thevenoud stressed that good aviation battery maintenance starts with having well-designed and well-equipped battery shops equipped with well-trained technicians. "Saft has developed dedicated class trainings for Ni-Cd and Li-ion batteries in France, United States or at customer sites," he said. "Saft has also a network of Saft authorized battery shops all over the world that are audited by Saft on regular basis." AVM

By Jason Dickstein

European Acceptance of Parts from the United States – A Primer

Did you know that FAA-PMA parts are approved by EASA? Under the European system, they are not merely accepted - they are actually approved under the terms of a 2007 EASA decision. And that EASA approval happens automatically the moment that they are approved by the issue of the FAA PMA (without the requirement for a separate application).

There are a lot more PMA parts than many people realize. An FAA PMA is the normal approval mechanism for any company that wants to produce and sell civil aircraft parts to the marketplace but that does not possess a production certificate for a complete aircraft, engine or propeller. Major companies like Honeywell produce aircraft parts under PMA; so it is important to ensure that parts produced under this approval mechanism can be accepted in order to ensure that aircraft can keep flying with safe (approved) replacement parts.

The European Union (EU) regulations require that EASA issue certificates for the design of parts and of their installation into products subject to those EU regulations. This created a problem because when EASA was formed, several significant EU member states had long-standing agreements to accept FAA-PMA parts from the United States. This made sense for supporting European air carriers who were already using such parts.

In order to deal with this legally - while at the same time forbearing from unnecessarily inhibiting trade – EASA issued a decision that automatically approves certain FAA-PMA parts. This decision was known as EASA Decision No. 2007/003/C and it can be summarized as follows:

1) The EU needs to approve parts before they can be installed on aircraft, and this approval needs to cover design and installation eligibility
2) Member states have concluded bilateral agreements with the United States for the acceptance of FAA-PMA parts
3) As long as EU-member states continue to have bilateral agreements with the United States for the acceptance of FAA-PMA parts, it is most efficient to approve those parts in advance
4) Therefore, the 2007 decision preemptively approves all FAA-PMA parts that meet at least one out of three criteria

An FAA-PMA part only needs to meet one out of these three criteria to be considered 'approved' under the 2007 decision.

The first category of EASA-approved parts is FAA-PMA parts that are not 'critical components.' These are considered approved by EASA. No further action is required.

A 'critical component' is a part identified as critical by the design approval holder, or otherwise by the exporting authority. The design approval holder for a PMA is the PMA holder, so the PMA holder will be the one to know whether the part is critical. Typically, critical copmponents are identified as such because they have some sort of "hard time" feature described in the Airworthiness Limitations of the instructions for continued airworthiness (ICAs). "Hard times" can include a replacement time, inspection interval, or related procedure that is specified in the Airworthiness Limitations of the manufacturer's ICAs.

The definition of critical component that is found in the 2007 Decision includes a caveat that the exporting authority (the United States in the case of a FA-PMA made in the US) may also designate something as critical. A mechanism for this arises when an airworthiness directive is issued against the part number, and it imposes some sort of airworthiness limitation.

Most PMA parts do not have these sort of hard times associated with them, so most PMA parts are not critical components. For these parts, EASA requests that the statement "This PMA part is not a critical component" be written in the Remarks Block of the FAA Form 8130-3.

The second category of FAA-PMA parts that are automatically considered to be approved by EASA are those for which the design data comes from a licensing agreement from the holder of the FAA design approval (type certificate or supplemental type certificate). Such parts can be identified in the FAA's PMA database, because they will indicate that the design approval basis is a licensing agreement.

Some European importers have reached out to us in the past because of concerns about how to accept licensed non-critical parts. Because the first category addresses non-critical parts, this second category is often thought of as being limited to

critical parts; however the specific language of the EASA Decision (and of the later EU-US Technical Implementation Procedures that have repeated this language in section 2.8) does not limit this category to critical parts. Therefore, licensed non-critical parts fit into both this category and also into category one. They can be accepted into the EU under either category, at the discretion of the contracting parties.

EASA requests that the statement "Produced under licensing agreement from the FAA design approval holder" be written in in the Remarks Block of the FAA Form 8130-3 for licensed parts.

The third category is for non-licensed critical FAA-PMA parts. These are only automatically approved by EASA if the PMA holder can show that the part has received an explicit approval by means of a design change or STC from EASA. This is normally accomplished when the PMA holder applies for an EASA STC through the local FAA Aircraft Certification Office, and in response EASA issues an STC to validate the PMA design.

EASA will also accept design approvals granted prior to 28 September 2003, from any of the National Aviation Authorities of the Members States of the European Union.

One feature of a FAA-PMA which makes it different from a Technical Standard Order Authorization (TSOA) is that a FAA-PMA has an inherent installation eligibility. On the PMA supplement, there is a designation of one or more types on which the PMA is eligible, and a statement about the part number(s) that the FAA-PMA part replaces. In the United States, this statement support the installers obligation to make a finding of eligibility under 14 CFR 43.13 (the installer's obligation to ensure that the part will return the product to a condition at least equal to original or properly altered condition).

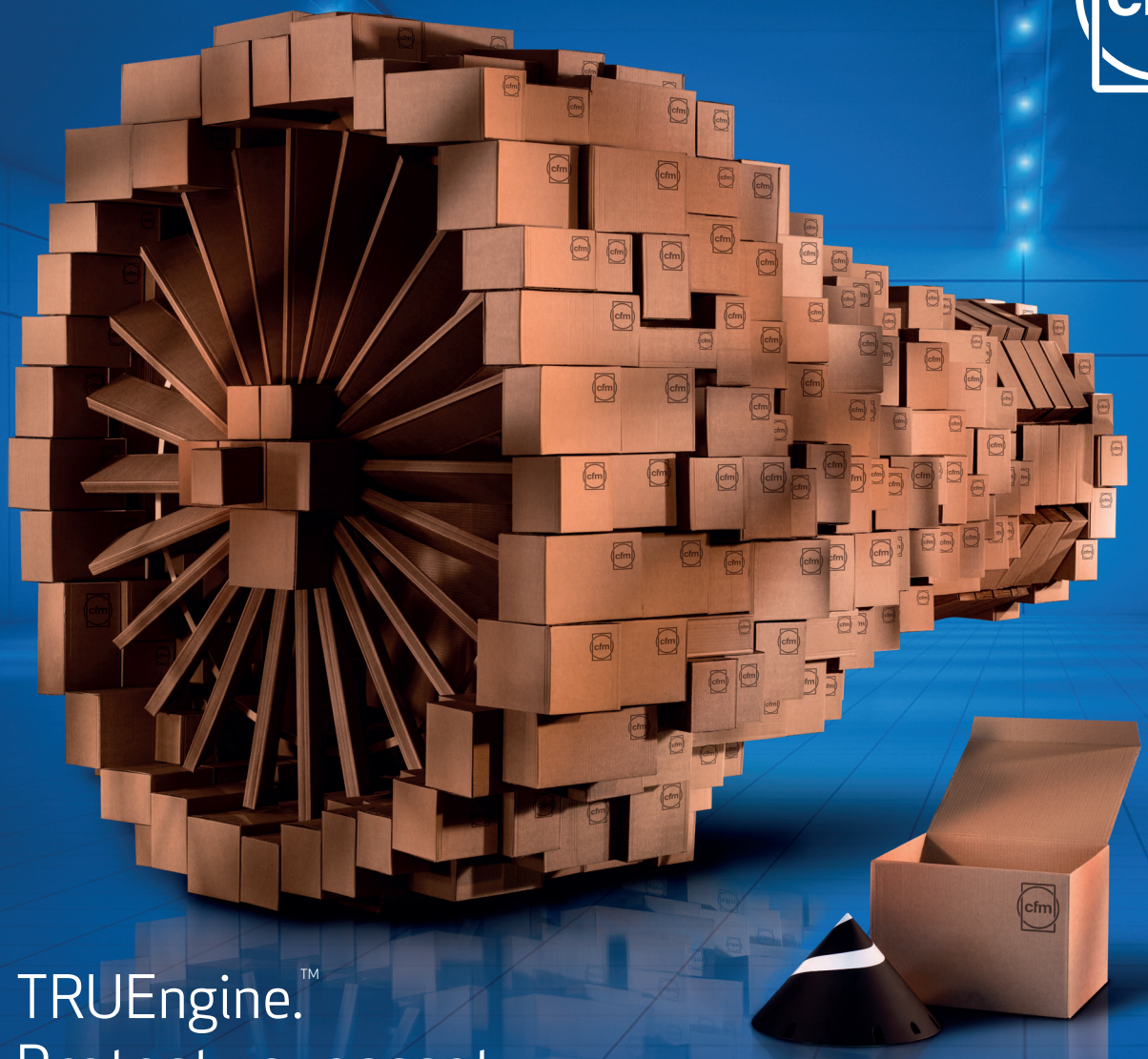
In Europe, there is a similar obligation for eligibility. The manufacturer certifies eligibility (EASA 21.A.307) and the installer ensures eligibility before installing (EASA 145.A.42(b)). So how does the EU handle PMA eligibility?

Under the 2007 Decision, EASA issued a blanket approval to the PMA part. That approval was not limited, so it is consistent with the scope described in the PMA (design, production and eligibility).

Under the Technical Implementation Procedures (TIP), EASA has gotten more specific in its approach to acceptance of PMA eligibility. The TIP explains that PMA approvals are directly accepted for installation on products "without further showing."

In addition, EASA has stated that it will accept repair data from the United States on non-critical components when it comes in the form of a PMA (TIP Section 3.3.2.2). The TIP explains that the data is considered to be EASA-approved following its approval/acceptance by the FAA; and the process does not require application to EASA, nor does it require any compliance finding to the EASA certification basis. Where the installation of an FAA-PMA represents a major repair, the FAA data is accepted when it is presented in the form of an 8110-3 (a common form used for the approval of design data underlying a PMA part) or when it is substantiated in an FAA letter (such as the letter granting PMA). AVM

Want to learn more? Then please register for the 2016 MARPA Conference, which will take place October 25-26, 2017 at the B Resort and Spa in Orlando, Fla.



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