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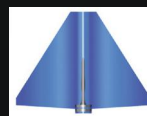


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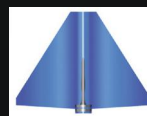


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PMA parts are positively affecting the aviation industry's supply chain, efficiencies and cost control.

Aviation Component Solutions image



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**AVIATION
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+44 (0)20 3892 3050
+1 (920) 214 0140

EDITORIAL

Editor-in-Chief

Joy Finnegan
jfinnegan@aerospace-techmedia.com

Contributing Editors

James Careless	Mazzy Beasley
Mark Robins	Ian Harbison
Jason Dickstein	Mario Pierobon
Jeff Guzzetti	James T. McKenna

ADVERTISING/ BUSINESS

Publisher/Owner

Adrian Broadbent
abroadbent@aerospace-techmedia.com

US/Canada Sales Director (A-I)

Greg Szatko
GSzatko@avm-mag.com

US/Canada Sales Director (J-Z)

Daniel Goodwin
dgoodwin@avm-mag.com

International Sales Director

Kyra Willis
kwillis@avm-mag.com

DESIGN/PRODUCTION

CPUK Print Publishing

www.cp-uk.co.uk

CLIENT SERVICES

Finance Director

Maria Hernanz Reyes
maria@aerospace-techmedia.com

PRINTER

CPUK Print Publishing

www.cp-uk.co.uk

MAILING

Spatial Global Limited

Derby, UK



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TECH
MEDIA LTD**

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An Even More Important Part of the Future

BY JOY FINNEGAN
EDITOR-IN-CHIEF

Take a look around an airline ramp today and you'll see something the aviation industry wasn't expecting a decade ago. Lots of airplanes that weren't supposed to still be here.

They were supposed to have been replaced by newer, quieter and more fuel-efficient aircraft. Instead, production delays, supply-chain problems and enormous manufacturer backlogs have turned yesterday's retirement candidates into some of today's most valuable assets. And somebody has to keep them flying.

For years, the aviation industry's basic assumption was straightforward. Airlines would progressively replace older 737NGs, A320neos and aging widebodies with MAXs, A320neos, 787s and A350s. That would gradually reduce the maintenance burden associated with older aircraft. Unfortunately, that isn't happening nearly as quickly as desired. There are other challenges to be sure. But this one is creating bottleneck upon bottleneck in MRO.

"Aircraft are not being delivered on schedule, engines are not staying on wing as long as expected, spare parts are hard to secure, repair turnaround times have skyrocketed, and maintenance capacity is constrained," said Stuart Fox, IATA's director flight and operations at a conference this summer, not to mention continued supply chain issues, worker shortages and lack of capacity.

IATA says the average global fleet age has now reached a record 15.2 years. The aircraft backlog exceeds 18,000, while airlines are short more than 5,000 newer aircraft they had expected to have by now. The aircraft that airlines expected to retire are becoming indispensable. The maintenance implications are many and varied. An airline expecting new aircraft deliveries may have been saying, "We're not putting another major investment into this airplane..." but is now faced with keeping it going for three, five or more years. These are diametrically opposed philosophies, and the realization has required some major shifts in thinking and planning.

Instead of delaying whatever is possible, additional heavy checks, structural inspections and repairs, landing gear overhauls, engine shop visits, wiring inspections, corrosion inspection and control and many other types of work are becoming necessary.

Oliver Wyman's latest forecast explicitly says airlines will continue extending the service lives of aging fleets and maximizing aircraft flying hours because production is lagging demand. Ten years ago, their forecast predicted that accelerated deliveries would create a huge technology shift and that retirements of older aircraft would remain brisk. Instead, here we are in 2026 talking about keeping those airplanes flying.

Older airplanes aren't inherently unsafe, of course. Aircraft can continue operating safely as long as they comply with the applicable maintenance, inspection and airworthiness requirements. But they do require more maintenance and more parts, while MRO companies are already operating at capacity and certified spare parts can be difficult to find. The aging fleet

is also less fuel efficient causing billions in additional fuel expense — IATA says \$4.2 billion in additional fuel expense in 2025 alone. The aging has slowed aviation's historical fuel-efficiency improvement movement.

All of that is complicated by another aging issue: technicians. We've talked and talked about the shortage of mechanics. It is a strange phenomenon — impactful but not quite dire. The technicians who know older aircraft best are often the industry's most experienced technicians. As those technicians retire, MROs aren't simply losing labor. They're losing institutional knowledge at exactly the moment the industry needs that knowledge to keep older aircraft operating longer.

Oliver Wyman's 2026 Survey says: "Operators and MROs/OEMs report finding it similarly challenging to secure required mechanics and technicians. While operators historically recruited experienced technicians from MROs, the supply of qualified technicians, especially at large airframe MROs, is limited. Operators are thus increasingly recruiting technicians directly from schools — which could impact productivity in the near term, as these newer technicians will have a steeper learning curve."

When thousands of aircraft that were expected to become teardown candidates stay in service, they continue consuming spare parts while simultaneously not becoming a source of used spare parts in the used serviceable materials (USM) market.

The aviation maintenance industry has been handed an extraordinary challenge. The world's airlines have enormous demand for capacity. The manufacturers cannot provide new aircraft quickly enough. Therefore, a significant portion of that capacity has to come from aircraft already in service. So, a thankless task has fallen to you. The MRO industry is buying the manufacturers time.

Airlines can tolerate delayed deliveries because maintenance organizations keep existing aircraft airworthy. Airlines can postpone retirements because technicians keep aging structures, engines, landing gear, avionics and components functioning.

The aviation industry has spent years talking about the aircraft of the future — more efficient engines, increasingly digital cockpits and eventually new propulsion technologies. But for the next several years, one of aviation's biggest challenges will be much less glamorous. The industry will need to keep the airplanes we already have flying longer than anyone expected.

The Boeing and Airbus duopoly will eventually work through their enormous backlogs. Until then, however, the industry's capacity problem is an aircraft maintenance problem. And that makes the people keeping aging airplanes flying an even more important part of aviation's future. **AM**



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GE Aerospace Signs Avionics Systems Service Support Agreement with FL Technics Indonesia



GE Aerospace has signed an agreement with FL Technics Indonesia to provide avionics systems service support for Boeing 737 and Airbus A320 aircraft at FL Technics Indonesia's facility in Jakarta and Bali.

The agreement supports FL Technics Indonesia's continued expansion of its MRO capabilities and service offerings for

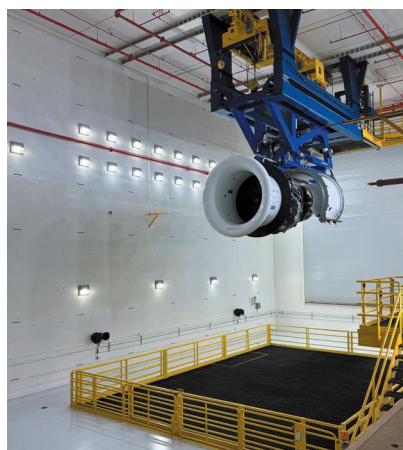
airline customers in Indonesia, while reinforcing GE Aerospace's commitment to the region's evolving aviation maintenance needs

through avionics expertise and responsive service solutions.

"Avionics plays a critical role in aviation, which is why it's an area we're always working to keep at the highest standard, with the best resources and expertise behind it," said Martynas Grigas, chairman of FL Technics Indonesia. "This partnership with GE Aerospace lets us build on that even further, bringing an added layer of expertise directly into our Jakarta and Bali operations. It's part of how we keep improving our service with high-quality, reliable maintenance solutions as our airline customers' operational needs evolve."

Matt Burns, general manager of avionics for GE Aerospace, added, "We are proud to work with FL Technics Indonesia as it expands its capabilities in a dynamic and growing aviation market. This agreement reflects GE Aerospace's commitment to supporting customers in Indonesia and across the region with avionics expertise that support safe, reliable and efficient operations."

MTU Maintenance Fort Worth Celebrates Grand Opening and Inducts First LEAP-1B Engine



MTU Maintenance has officially opened its modernized Fort Worth facility and inducted its first CFM International LEAP 1B engine. The engine belongs to Brazilian airline GOL Linhas Aéreas (GOL), marking both the start of operations for the site and a new chapter in a long-standing customer partnership.

The grand opening was celebrated with employees, executives, customers and local representatives on site, underscoring the strategic importance of MTU's growing presence in North America.

GOL, the launch customer, has partnered with MTU for over 20 years, starting with the CFM56 engine, predecessor to CFM LEAP engine. "We are proud to continue our long-standing partnership with MTU as we celebrate this milestone today," says Albert Pérez, GOL's chief operating officer. "MTU's technical expertise and tailored support are crucial to our operations. We rely on their services to

ensure the highest reliability and performance for our fleet."

GOL operates over 60 Boeing 737 MAX aircraft powered by CFM LEAP-1B engines. The Brazilian low-cost carrier was the first South American operator of this engine type.

MTU is expanding its network and capacity globally, with Fort Worth as a Premier MRO provider and key location for North America. In addition to the CFM LEAP engine program, GE Aerospace GENx services will be introduced to the site in due course.

"As one of the world's leading engine MRO providers, we are systematically expanding our global footprint," said Dr. Johannes Bussmann, CEO of MTU Aero Engines. "The opening of our Fort Worth facility demonstrates our commitment to growth, to our customers and to strengthening transatlantic partnerships. The site will be a cornerstone of our strategy to support next-generation engine programs at scale."

MTU is investing \$120 million to upgrade the 43,000-square-meter facility, which it has been expanding since relocating to the site in 2023 to enable full disassembly, assembly and test capabilities. "We are extremely proud of all our team has achieved in a short space of time and look forward to seeing our facility, the team and our customer base grow significantly in the coming years," adds Gernot Sell, managing director, MTU Maintenance Fort Worth. The company's commitment to the region is reflected in its workforce development: staffing is expected to grow to more than 1,200 once the site is fully ramped up. An on-site training academy is already in operation, supporting the development of highly-skilled aviation professionals and ensuring long-term expertise for advanced engine programs.

MTU Maintenance carries out over 1,400 shop visits for a portfolio of over 30 engine types annually. The company's global workforce of more than 7,000 engine experts serve more than 1,400 customers across its entire service portfolio, including asset management and leasing, on-site services and piece part repairs. In addition to Fort Worth, LEAP MRO support is also provided at MTU Maintenance Zhuhai and MTU Maintenance Hannover.

HAECO and ANA Sign New Landing Gear Overhaul Agreement



HAECO secured a new landing gear agreement with All Nippon Airways (ANA) through 2030. The agreement covers landing gear overhaul services for ANA's Boeing 777-300ER and 777F fleets, to be

provided at HAECO's dedicated landing gear facility in Xiamen.

The collaboration between HAECO and ANA began in 1997 and spans more than three decades. Over the years, the partnership has expanded to include a wide range of airframe services, including base and line maintenance support across Hong Kong and the Chinese Mainland. In June 2025, the two companies celebrated ANA's 500th aircraft input at Xiamen Gaoqi International Airport,

marking another milestone in their long-standing relationship.

"This agreement marks an important milestone in our partnership with ANA, as we expand our support to include landing gear overhaul services," said George Edmunds, group director components and engine services at HAECO. "ANA is highly regarded for its uncompromising standards of safety and operational excellence, and we are proud to be entrusted with this critical element of fleet support for our partner. We look forward to building on our successful collaboration in the years ahead."

Tsuyoshi Yazaki, vice president supply-chain operations of ANA said, "HAECO has been a trusted airframe services partner to ANA for many years, consistently demonstrating strong technical capabilities and a commitment to service excellence. As we continue to optimize the performance and reliability of our Boeing 777 fleet in the region, we are pleased to extend our partnership with HAECO and rely on their proven capabilities in landing gear overhaul services."

HAECO and Rolls-Royce Launch Trent 1000 Modular Replacement Service



HAECO launched a specialized modular replacement service for Rolls-Royce Trent 1000 engines at its London Heathrow facility. The company says this strategic initiative, developed in collaboration with Rolls-Royce, is a key component

of its "front porch of the overhaul shop" strategy, delivering flexible, rapid-response maintenance solutions directly at the point of operation.

HAECO Global Engine Support, a dedicated engine services operating company under HAECO Group, is now one of four locations worldwide authorized to perform major modular replacements for the Trent 1000, specifically the Module 32 (intermediate pressure compressor) and Module 41 (high pressure

compressor). The replacement utilizes the efficient horizontal strip method, a process that significantly reduces turnaround times, extends engine time on wing, and helps optimize global MRO capacity for Rolls-Royce customers.

"Introducing this capability at our London site represents a major milestone in our partnership with Rolls-Royce and our commitment to supporting the Trent 1000 fleet availability," said George Edmunds, group director of components and engine services at HAECO. "We are delivering a certified, efficient, and safety-first solution that enables airlines to restore fleet health faster and return aircraft to service with confidence."

Rachel Walker, senior vice president, Trent 1000, Rolls-Royce, said: "While we're busy selling engines and making new ones, our priority is getting our re-engineered components to our existing customers as quickly as possible. Our work with HAECO is helping reduce MRO choke points and we're grateful for the strength of our long-term partnership, and the inherent capability in its people, to make this happen."

ST Engineering and RTX's Collins Aerospace Deepen Collaboration on Aircraft Component Support

ST Engineering's Commercial Aerospace business and Collins Aerospace signed off three multi-year agreements that build on their long-standing working relationship to enhance component support for airline operators.

These agreements mark a new collaboration on component repairs and extend existing arrangements for spare parts procurement and lifecycle repairs. Together, they enable ST Engineering and Collins to integrate original equipment manufacturing (OEM) and MRO expertise, providing airline operators with reliable, fast-turnaround component repairs to meet aircraft dispatch needs.

The agreements cover three areas of collaboration. ST Engineering will provide repair services for Collins' fan assembly

electronics boards used on the 787. The cooperation agreement reduces Line Replaceable Unit (LRU) repair turnaround times and improves efficiency through repair-over-replacement solutions for airlines and operators. ST Engineering extended and expanded a multi-platform agreement to procure new power and controls spare



INTELLIGENCE

parts from Collins for its LRU component MRO operations. The broader scope adds more narrowbody aircraft components to ST Engineering's portfolio for enhanced OEM-standard component repair support. And lastly, ST Engineering and Collins extended their collaboration on A320 and 737 family LRU component repairs through Collins' aftermarket support program, FlightSense.

"Our long-standing relationship with Collins Aerospace brings together its OEM expertise and ST Engineering's lifecycle MRO and comprehensive asset management strengths to better support airline operators worldwide," said Poon Kok Wah, SVP and head of component services at ST Engineering. "The expanded scope of these agreements deepens our collaboration and enhances

the value of our Maintenance-By-the-Hour program, in-house component MRO capabilities for the 787, 737 MAX and A320neo and distribution and material services. Together, these capabilities provide customers with broader repair coverage, reliable component support and responsive lifecycle solutions."

"Expanding our collaboration with ST Engineering allows us to better support the aviation ecosystem with agile and high-standard MRO solutions," said Jen Latka, vice president of aftermarket, power and controls, Collins Aerospace. "These lifecycle and repair programs ensure that operators worldwide benefit from maximized component efficiency and enhanced fleet performance."

Pratt & Whitney Canada Signs Four-Year PW127M Maintenance Agreement with AirBorne Airways

Pratt & Whitney Canada signed a four-year agreement with AirBorne Airways to provide comprehensive MRO services for the PW127M engines powering its ATR 72-500 regional turboprops through 2030. AirBorne operates its fleet of ATR 72-500 aircraft on the Rural Air Services network, a vital public service that connects remote and underserved communities across East Malaysia.

"We worked closely with AirBorne to develop a maintenance solution that manages engine costs and supports high dispatch availability for these critical flights," said Anthony Rossi, vice president, customer service, Pratt & Whitney Canada. "This agreement reinforces our commitment to advancing our MRO services and meeting customers' evolving needs."

AirBorne's engines will be primarily maintained at Pratt & Whitney Canada's Singapore facility, a key hub for customer support across Asia-Pacific. Recent investments have expanded the site's turboprop MRO capabilities, strengthening the company's ability to provide more localized support to operators across the region.

"We value our relationship with Pratt & Whitney Canada and the proven quality and reliability behind its products and services," said Megat Ardan Aminuddin, CEO of AirBorne. "Having this support based in Singapore puts our engine maintenance and repairs close to home and our aircraft back in service faster. That confidence gives us the operational certainty we need to consistently serve our customers on our intra-Borneo routes where reliable air transport is a vital link for remote communities."

The PW127M is part of Pratt & Whitney Canada's PW100 engine family, which has provided regional turboprop operations for more than 40 years. PW100 engines have accumulated more than 200 million flight hours and power aircraft serving communities around the world.



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AFI KLM E&M and Malaysia Airlines Berhad Sign Long-Term Component Support Agreement to Support A350 Fleet



Air France Industries KLM Engineering & Maintenance (AFI KLM E&M) has signed a long-term agreement with Malaysia Airlines Berhad (MAB), the operator of Malaysia Aviation Group's (MAG) A350 fleet, to provide comprehensive component support for its aircraft.

The agreement builds upon the existing successful relationship between AFI KLM E&M and MAB, which includes ongoing support for the airline's Boeing 737 fleet. Under the new agreement, AFI KLM E&M will provide comprehensive component support for MAG's A350 aircraft, supporting their availability and operational performance through a solution tailored to the airline's operational requirements.

AFI KLM E&M brings extensive A350 experience through Air France's own operation of the aircraft type, combined with its experience supporting multiple A350 operators worldwide. This combination of airline operational insight and MRO expertise enables AFI KLM E&M to provide support aligned with the specific needs of Malaysia Airlines.

GE Aerospace and WZL-2 Sign F404 MRO Support Memorandum of Understanding

GE Aerospace and the Military Aviation Works (Wojskowe Zakłady Lotnicze NR 2 S.A. or WZL-2) signed a Memorandum of Understanding (MoU) to explore opportunities to develop MRO services capabilities and depot level maintenance for the F404-GE-102 engine that powers the Polish Air Force's KAI FA-50 Golden Eagle fighter jets. The MoU was announced by Jakub Gazda, CEO, WZL-2, Zbigniew Matuszczak, member of the management board and technical director, WZL-2, and Scott Keating, GE Aerospace's Defense & Systems executive regional general manager for Europe, at the 34th International Defence

Industry Exhibition (MSPO) in Kielce, Poland.

"Establishing engine support within Poland is critically important to ensure readiness and availability for our military customer," said Keating. "We look forward to working with WZL-2, a well-respected engine MRO provider in Poland, to determine how we can best serve Poland's needs on the F404 engines to offer this capability in country."

"Our partnership with GE Aerospace offers us the opportunity to develop our expertise in servicing F404-GE-102 engines. We want to ensure that increasingly advanced maintenance

capabilities for equipment used by the Polish Armed Forces are developed and maintained domestically," said Gazda, adding: "This is yet another example of WZL-2's consistent development of capabilities that strengthen the security and operational independence of the Polish Armed Forces."

Under the MoU, GE Aerospace and WZL-2 will assess requirements necessary for F404-GE-102 engine maintenance.

The Polish Air Force ordered 48 KAI FA-50 light combat aircraft in 2022. The first 12 were delivered in the FA-50GF (Gap Filler) configuration in 2023, while the remaining 36 are to be delivered in the FA-50PL configuration. This MoU will cover all 48 F404-GE-102 engines on order as well as spare engines.

More than 4,000 F404 engines have been delivered and have accumulated more than 13 million engine flight hours, including 300 engines that power the T-50, TA-50, and FA-50 Golden Eagle produced in the Republic of Korea.



SR Technics Appoints Antoine Hanna as VP BD for Middle East, Africa and Türkiye



SR Technics, a world-leading engine MRO service provider, announces the appointment of Antoine Hanna as vice president business development for the Middle East, Africa and Türkiye region, effective October 1, 2026.

He brings nearly 20 years of aviation industry experience and has been with SR Technics since 2007. Most recently serving as business development director in the region, he has played a key role in driving regional growth, strengthening customer relationships, and expanding SR Technics' presence across key markets.

"Antoine's deep market and technical knowledge, customer focus, and proven commercial leadership make him ideally positioned to support our continued growth in the region. Having worked closely with him for many years, I am confident he will further strengthen our customer partnerships and regional presence," says Bo Lump, senior vice president business development at SR Technics.

"I am honored to take on this new role and look forward to further strengthening our relationships with customers and partners across the region. Together with our teams, we will continue to deliver value-driven solutions and support the long-term success of our customers," said Hanna.

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NATIONWIDE COVERAGE

Honeywell Aerospace to Provide Garuda Indonesia with APU Maintenance Support



Honeywell Aerospace has signed a three-year agreement with PT Garuda Indonesia (Persero) to provide repair and maintenance services for Honeywell Aerospace's 131-9B, 331-350 and 331-500 auxiliary power unit (APU) models across Garuda Indonesia's aircraft

fleet. This agreement builds on Honeywell Aerospace and Garuda Indonesia's long-standing partnership, while establishing a multi-year framework for APU repair support for Garuda Indonesia.

The arrangement provides Garuda Indonesia with greater repair-cost predictability and defined service expectations, supporting the airline with more effective maintenance planning over the three-year term.

"Consistent, predictable maintenance support is critical in helping airlines plan maintenance effectively and keep their fleets operating reliably," said Eric Ai, president, Asia Pacific, Honeywell Aerospace. "This agreement enables Honeywell Aerospace to provide that support to Garuda Indonesia through a clear

multi-year framework and represents an important next step in our long-standing relationship focused on supporting the airline's operational needs."

Auxiliary power units provide electrical power and conditioned air while aircraft are on the ground, supporting aircraft and cabin systems during boarding and turnaround. As an original-equipment and lifecycle-service partner, Honeywell Aerospace supports airlines from the systems installed on their aircraft through ongoing repair, overhaul and upgrades. This includes a global network of 26 repair and overhaul facilities, including facilities in Asia Pacific, and more than 100 commercial air transport channel partner locations.

Mukhtaris Aris, director of maintenance of Garuda Indonesia said, "As we continue our transformation journey, we remain focused on strengthening our operational capabilities including optimizing APU reliability as a part of our effort in maintaining aircraft readiness.

"Through the strategic partnership with Honeywell Aerospace, we are aiming to deliver a seamless journey for our passengers through operational excellence by ensuring our aircraft readiness and operational reliability."

The agreement reinforces Honeywell Aerospace's aftermarket support for airline maintenance and lifecycle services in Indonesia and across Asia Pacific.

ATA 27 Flight controls

B737 NG B737 MAX Flaps (FSEU)



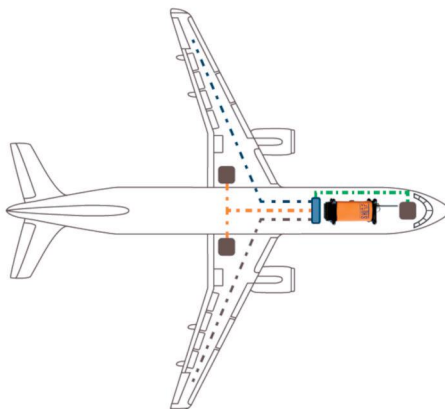
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Gulfstream Demonstrates Sustainability Leadership in Mesa

Gulfstream Aerospace Corp. today announced the completion of a solar panel installation at its Mesa Service Center in Arizona. The facility also just received U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Gold certification. Together, these achievements represent a significant step forward in Gulfstream's long-term commitment to a more sustainable future.

The new solar panels support 100% of the 225,000-square-foot/20,908-square-meter service center's electricity at peak production. With this installation, the facility operates with more than 4,000 solar panels which are expected to produce over 4 million kilowatt-hours of electricity a year, enough to meet annual demand. This is Gulfstream's sixth solar installation across its facilities and its first in Mesa.

"By continuing to invest in renewable energy technologies at our facilities, Gulfstream is making meaningful progress toward our goal of lowering our environmental footprint," said Mark Burns, president, Gulfstream. "As a sustainable aviation leader, we remain committed to advancing environmental and clean-energy initiatives that support our industry."

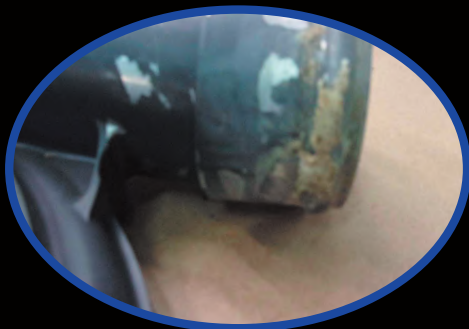
The Mesa Service Center is Gulfstream's first facility to earn LEED Gold certification. It was built to operate with enhanced environmental efficiency through recycled, regional and lower emissions materials, use of renewable energy, solutions to reduce water consumption, redirection of construction waste to recycling, and optimization

of overall energy performance. This latest achievement increases Gulfstream's total LEED- and Building Research Establishment Environmental Assessment Methodology (BREEAM)-certified footprint to more than 2.6 million square feet across 12 facilities. These green buildings help reduce environmental impact and lower overall resource consumption.

Gulfstream continues to pursue more sustainable options through advancements in aircraft innovation, efficient operations and renewable fuels. To date, the company has successfully flown more than 3.5 million nautical miles on Sustainable Aviation Fuel (SAF) blends and increased SAF consumption by nearly 25% year over year. Gulfstream's next-generation fleet delivers fuel-efficiency improvements up to 33% more than predecessor models, and the company was the first business jet original equipment manufacturer to fly on 100% SAF.



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Patriot Wing Opens \$43 Million C-5M Inspection Hangar

Leaders of the 439th Airlift Wing unveiled a new \$43 million regional isochronal inspection hangar at Westover Air Reserve Base, Mass., Sept. 10, 2026, expanding the Air Force's capacity to sustain readiness across the C-5M Super Galaxy fleet.

Military members, elected officials and community partners attended the ribbon-cutting ceremony marking the opening of the 94,000-square-foot facility. The hangar replaces a structure built more than 70 years ago for the B-36 Peacemaker and provides Patriot Wing maintainers with a modern, purpose-built environment for conducting comprehensive, time-based aircraft inspections.

"Investing in this facility is really about investing in our Airmen, our community and our mission," said Col. Christopher Holland, 439th Airlift Wing commander.

The Patriot Wing operates at one of only two Air Force installations capable of performing regional isochronal inspections on the C-5M. The program supports aircraft assigned throughout the Air Force, helping preserve the strategic airlift capability needed to project, connect, maneuver and sustain the Joint Force.

"We open a really large door," Holland said. "The future of mobility for the United States will pass through it every few weeks."

During an isochronal inspection, maintainers disassemble and examine major portions of an aircraft, look for damage and complete a prescribed series of maintenance checks. Each

inspection generally takes two to three weeks.

Col. Jordan Murphy, 439th Maintenance Group commander, said maintenance requirements have increased as the C-5 fleet has aged. Although the new hangar is not expected to shorten the prescribed inspection process, it will increase capacity and improve the precision, consistency and quality of the work.

Once operations are fully established, Patriot Wing maintainers expect to complete approximately 17 to 19 inspections annually.

"This is a world-class facility supporting the entire C-5M enterprise," Murphy said.

The hangar expands available workspace and incorporates equipment designed to improve maintenance safety and workflow. Its features include an overhead crane capable of lifting 2,000 pounds, built-in aircraft power, an advanced fall-prevention system, integrated sheet-metal work areas and upgraded workstations.

The new facility provides infrastructure designed for the size and maintenance requirements of the C-5M while supporting Air Force efforts to balance immediate readiness with long-term modernization.

"For years, our maintainers accomplished world-class work in what is now a 70-year-old hangar," Holland said. "Now, with this \$43 million high-bay facility, our maintenance professionals have a modern facility with which they will meticulously care for each and

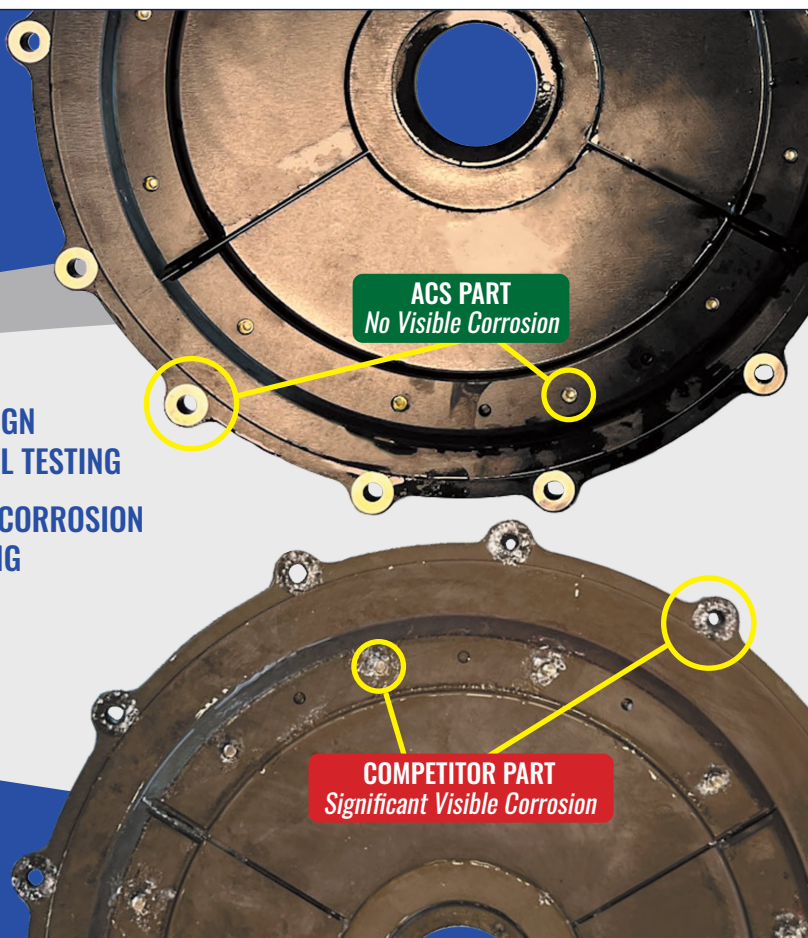
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every aircraft that passes through it."

The project developed over nearly 20 years through the efforts of successive wing leaders, maintenance professionals, civil engineers, congressional partners and community advocates.

Murphy, who has been involved with the project for more than a decade, credited Patriot Wing maintainers, civil engineers, the U.S. Army Corps of Engineers, construction teams and other partners with bringing the facility to completion.

U.S. Rep. Richard E. Neal has supported the project since its earliest stages. During the ceremony, Neal discussed the congressional process required to authorize and fund the facility and

the installation's long-standing importance to national defense.

"This is a terrific moment for Chicopee, a terrific moment for Western and Central Massachusetts, but it's also a terrific moment for the United States of America," Neal said.

The facility also demonstrates the Air Force Reserve's role as an operational force advantage. By conducting inspections on C-5Ms assigned throughout the Total Force, Patriot Wing Airmen provide experienced, accessible and integrated maintenance capability beyond their locally assigned mission.

"This facility belongs to you," Holland told the maintainers. "Your work keeps America's global reach ready, responsive and unmatched."

The ceremony occurred one day before the 25th anniversary of the Sept. 11, 2001, terrorist attacks and during the year marking the nation's 250th anniversary. Neal recognized the service of military members, law enforcement officers, firefighters and emergency medical personnel and reflected on the military's role in defending the nation.

For the Airmen performing the inspections, the new facility's mission remains focused on returning safe, reliable aircraft to service.

"These inspections keep our aircraft mission-ready," said Senior Airman Theodore Davis, crew chief, 439th Maintenance Squadron crew chief. "We make sure what's broken is fixed so the aircraft can go back out and accomplish whatever mission the Air Force calls for."

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Brian Rohloff Begins Tenure as Textron Aviation President & CEO



Brian Rohloff assumed the role of president and CEO at Textron Aviation at the end of summer. Rohloff most recently served as the leader of the company's broad global customer support organization, with additional roles that span manufacturing, parts, sales and finance, giving him a broad perspective on the people, products and customer relationships that define Textron Aviation. The company

says his experience across the business has helped shape his understanding of how decisions made throughout the company affect the employees who build and support its products and the customers who depend on them.

Rohloff's connection to the company's aviation heritage began long before his career. He grew up just east of Textron Aviation's east campus in Wichita, and has said he remembers waking to the sound of Beechcraft aircraft engine run-ups from the nearby campus. He later joined Cessna Aircraft Company and went on to work alongside teams responsible for building, delivering and supporting aircraft around the world.

"The future of Textron Aviation is incredibly strong," Rohloff said. "We have the best people in the industry. It is their

craftsmanship, innovation and commitment to customers that have built the Beechcraft and Cessna brands into what they are today, and that same dedication continues to set us apart."

Rohloff's career has taken him from finance and manufacturing leadership to sales and global customer support, giving him experience across the lifecycle of the company's products and customer relationships. Among his formative assignments was helping start the Citation CJ4 production line in 2009, a role he says deepened his appreciation for the expertise required to bring an aircraft from the production line to the customer.

"As a leader, I strive to be connected, curious and accountable," Rohloff said. "Accountability starts with me and making sure I deliver what I say I am going to deliver. When we understand the mission and what is expected of us, we can deliver greater value to our customers."

As he begins his tenure, Rohloff says his immediate focus is staying connected to the people closest to the work and the customers who rely on Textron Aviation and its Cessna and Beechcraft brands.

"I want people to know they can expect me to be accessible, engaged and committed to listening," Rohloff said. "Our success has always started with great people, strong customer relationships and a dedication to doing things the right way. Those principles will continue to guide me as we build on the company's strong foundation together."

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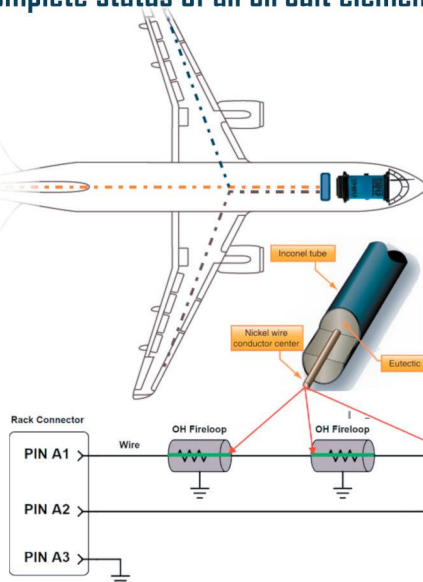
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West Star Aviation's New Live Technician Tracking Map Gives Operators Real-Time Visibility into AOG Technician Locations and Technical Expertise Nationwide



West Star Aviation has launched a new Live AOG Technician Map, which the company says gives business aviation operators

West Star Aviation provides 24/7/365 mobile maintenance support for operators requiring service away from their home base. The new tool makes it easier for operators to understand the scale of West Star's mobile support organization and the breadth of expertise available across the country.

West Star says the launch of the Live AOG Technician Map further reflects its continued investment in its AOG capabilities. Supporting the AOG network is a dedicated control center staffed by 12 controllers, providing around-the-clock coordination and dispatch support to help ensure rapid response when customers need immediate maintenance assistance.

As AOG activity continues to grow, West Star has expanded its technician staffing and strengthened the resources available to support grounded aircraft. That additional depth enhances the company's ability to respond quickly and efficiently while giving customers greater confidence that expert support is available when and where it is needed.

West Star's AOG operation is designed to minimize downtime and help return aircraft to service quickly and safely.

The Live AOG Technician Map is available now on West Star Aviation's website.

greater visibility into its nationwide Aircraft On Ground (AOG) support network and the technical expertise available to assist when aircraft are unexpectedly grounded.

The interactive map displays current technician locations across the United States and allows users to click on individual points for additional information, including each technician's call sign, technical skill set, and assigned region. This feature offers operators a real-time view of West Star Aviation's Aircraft On Ground network and reinforces the depth of resources available to support customers when time is critical.

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StandardAero Teams with GMR Aero Technic to Support Operators in India

StandardAero has signed a Supplier Service Agreement with GMR Aero Technic, India's largest third-party MRO service provider. The agreement is initially focused on leveraging the capabilities of both companies to provide enhanced on-wing support services to operators in India for narrowbody engine platforms including the CFM56-7B and LEAP-1A and LEAP-1B.

India is a major market for the new generation LEAP-1A and LEAP-1B engines, which power the Airbus A320neo and Boeing 737 MAX families respectively. Operators in country have approximately 1,000 powerplants in service and a further 3,200 on order. The CFM56-7B, which powers the Boeing 737NG family, also remains in widespread use in the country, with more than 100 engines still in service.



engines still in service.

StandardAero has a long history of supporting Indian operators, providing customers across the

nation with reliable engine MRO services for the LEAP-1B narrowbody turbofan, AE 3007A regional turbofan and the PW127 regional turboprop, among others.

"StandardAero is pleased to build on our existing MRO capabilities for operators across India through this new agreement with GMR Aero Technic," said Rebecca Lane, StandardAero senior vice president of global sales. "India represents one of the fastest-growing commercial aviation markets, and StandardAero is committed to ensuring that operators across the country receive the support they need to meet the nation's ambitious regional connectivity objectives. Coming less than a year after our agreement with GMF AeroAsia in Indonesia, this new partnership with GMR Aero Technic highlights StandardAero's commitment to providing operators with local support on a global scale."

Commenting on the announcement for GMR Aero Technic, Ashok Gopinath, president and accountable manager, said: "Our partnership with StandardAero marks an important milestone in GMR Aero Technic's journey towards developing advanced engine support capabilities for the APAC region. By combining StandardAero's global expertise in engine aftermarket services with our infrastructure and regional presence, we aim to create a responsive on-wing support network that delivers greater value to airlines and operators. This collaboration further strengthens our



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vision of positioning India as a leading hub for aircraft MRO and specialized aviation services."

StandardAero supports the LEAP-1A and LEAP-1B engine family from its 810,000-square-foot facility in San Antonio as a CFM LEAP Premier MRO provider, having signed the first non-airline CFM Branded Service Agreement (CBSA) in the Americas for the LEAP-1A and LEAP-1B in March 2023. StandardAero has been providing LEAP quick-turn shop visit (QTSV) services to operators since March 2024, and completed correlation of its first test cell for the LEAP in November 2024, paving the way for performance restoration shop visit (PRSV) inductions.

In addition to establishing MRO capability for the LEAP-1A and LEAP-1B at its San Antonio facility, StandardAero is also industrializing new engine component repairs for the LEAP family through its Component Repair Services (CRS) network of locations, and its Repair Development Center of Excellence. To

date, StandardAero CRS has industrialized nearly 500 component repairs for the LEAP-1A and LEAP-1B. StandardAero also continues to grow its team of LEAP technicians through its in-house Aviation Mechanic Training Program, located at its Training Academy in San Antonio.

StandardAero also holds a CFM International General Support License Agreement (GSLA) for the CFM56-5B and CFM56-7B since 2009, and today serves the global operator base with engine overhaul and test capabilities from two locations across North America: Winnipeg, MB, Canada and DFW International Airport, TX, USA. The company provides an extensive range of additional services for the CFM56 family, including exchange engines, used serviceable material (USM), component repair and overhaul, and EHM data analysis.

TransNusa Expands Skywise Collab to Launch Indonesia's First Integrated Flight and Technical Operations

Skywise has expanded its collaboration with TransNusa, signing an agreement to adopt Skywise Core X2 and Skywise Fleet Performance+ (S.FP+) which will bridge flight operations and technical operations under an integrated ecosystem.

This milestone marks the first S.FP+ and Skywise Core X2 agreements in Indonesia, reinforcing the region's commitment to creating a modern, unified digital operational environment.

TransNusa is already an active user of Skywise solutions, including N-Flight Planning (N-FP), Skywise's highly configurable, scalable, and flexible cloud-based solution that transforms complex flight planning into an intuitive, manageable, and efficient process; Mission+ FLIGHT, the electronic Flight Folder (eFF) module of Mission+, containing the briefing package for the pilot, with the main documents to prepare, execute and report on the flight; and Mission+ MAPS, the charting module of Mission+, for en-route and terminal charts, also proposing an Airport Moving Map (AMM) and weather information.

As a next step in their digital journey, TransNusa has recognized a unique opportunity to select additional Skywise solutions, Skywise Core and S.FP+.

TransNusa has selected the Skywise Core X2 solution - the package leveraging the Skywise data platform that turns insights into action across all divisions and functions. This will enable TransNusa to build digital twins of their operational



workflows, develop custom applications using low-code/no-code tools, and break down organizational silos to optimize day-to-day flight and

maintenance operations.

TransNusa specifically requested S.FP+, an integrated digital solution designed to establish a robust foundation for data-driven fleet management, for enhanced fleet health monitoring and real-time operational visibility. The solution will support the digitalization of the airline's technical operations, maximize the availability of their aircraft, and streamline the collaboration across Technical Operations teams.

Based on aircraft data generated in-flight and integrated with maintenance information, S.FP+ will provide TransNusa's Maintenance Control Centre team with instant visibility into aircraft system status, enabling them to detect anomalies early, uncover technical trends, and make informed maintenance decisions to ensure maximum fleet reliability and availability. As TransNusa continues to expand its operations, this agreement allows the airline to evolve from traditional spreadsheet-based reporting into a unified, real-time data ecosystem.

TransNusa selected Skywise to deepen its digital capabilities based on a deep foundation of trust, proven synergy, and ecosystem integration. Skywise delivers a fully integrated portfolio of solutions that simplifies TransNusa's workflows, enhances data consistency across the organization, and accelerates the airline's digital journey.

"By bridging the gap between Flight Operations and Technical Operations, this ecosystem breaks down traditional silos and equips TransNusa with a single, actionable source of truth. We are thrilled to support TransNusa in this journey, and we deeply value their trust as this seamless integration not only maximizes fleet reliability today, but establishes the digital future of the airline," stated Alessandro Luzi, head of region APAC at Skywise.

"This partnership between TransNusa and Skywise is the way forward and is consistent with our pledge to offer safe and comfortable travel with excellent flying experiences to our passengers," said Datuk Bernand Francis, group CEO of TransNusa. He added that with real time aircraft data at hand, it will enable TransNusa to make early preparations thereby reducing maintenance ground time and flight delays.

Beyond Aero image.



By James Careless

Preparing MROs for Electric and Hydrogen Aircraft

The move into electric and hydrogen-powered aircraft is going to present MROs with an unprecedented set of engineering and operational challenges.

To map out a survival strategy for MROs, Aviation Maintenance convened a virtual roundtable on what lies ahead. Our panelists are Roei Ganzarski, CEO of Alitheon, previously served as CEO of magniX, whose electric propulsion systems have powered multiple electric-aircraft programs and Universal Hydrogen's hydrogen-electric Dash 8 demonstrator. He was also executive chairman of Eviation, developer of the clean-sheet Alice all-electric commuter aircraft, and later served as an adviser to Universal Hydrogen. And Beyond Aero's Luiz Oliveira (chief engineer), Anaïs Cateni-Caudéran (head of marketing and communication), and Benjamin Le Drogo (head of sales): Beyond Aero is an aerospace company actively designing and developing a purpose-built hydrogen-electric business aircraft. Alitheon develops optical-AI technology for item-level authentication and supply-chain traceability.

Aviation Maintenance: What new maintenance, repair and overhaul (MRO) business opportunities do you see emerging first as hybrid, electric, and hydrogen aircraft enter service?

Roei Ganzarski: Start with the uncomfortable part: scheduled heavy engine overhaul revenue shrinks drastically. Electric

propulsion has a fraction of the moving parts of a turbine — no hot section, no fuel control, no oil system, and no borescope inspection cycles. Anyone whose financial model depends solely on traditional engine overhaul profit pools needs a different plan. The opportunity is that the money doesn't vanish; it moves.

First to arrive are shop qualifications and approvals. High-voltage DC, arc flash procedures, battery handling, and hydrogen safety do not sit in a standard A&P curriculum. Repair station ratings have to exist before the first revenue flight, making training and certification sellable products years ahead of the fleets.

Energy on the ramp is another major frontier. Charging is the new fueling business, and whoever owns ground energy at secondary airports owns access to the network. MROs and FBOs are the natural owners because they already hold the ramp, the permits, and the handling relationships.

Battery swapping and pack pooling will turn the battery pack into a rotatable rather than a fixed installation to minimize turnaround time. That means logbooks, cycle history, state-of-health testing, conditioning, storage, and leased pools — the closest structural analog to engine leasing and power-by-the-hour that exists in this architecture.

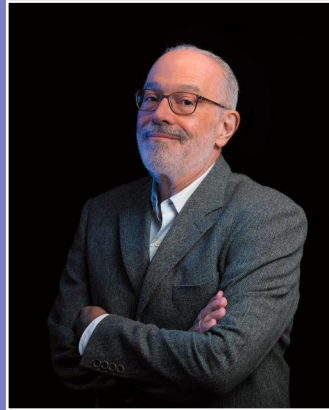
On-site hydrogen production via small-scale electrolysis inverts fuel logistics for remote networks in places like Alaska, northern Canada, or island routes. Alongside it, tank inspections, leak



Anaïs Cateni Cauderan
Beyond Aero



Benjamin Le Drogo
Beyond Aero



Luís Oliveira
Beyond Aero



Roei Ganzarski
Alitheon

detection, high-pressure handling, and fuel cell stack health monitoring create new revenue streams.

Additionally, second-life battery packs retired from flight still retain significant stationary storage capacity to buffer airport chargers, giving MROs a second customer for pulled packs. Finally, short-sector regional flights will accumulate cycles fast, driving increased demand for line maintenance, airframe, gear, brakes, tires, and non-destructive testing.

Luiz Oliveira: We expect the first opportunities to appear around specialized support services rather than traditional heavy mechanical overhaul.

For hydrogen-electric aircraft, these include specialized training for technicians working around hydrogen and high-voltage systems, alongside specialized tooling, personal protective equipment, test equipment, and calibrated equipment packages.

There will be strong demand for fuel-cell health monitoring, inspection, repair, exchange, and overhaul services. Electric motors, inverters, power electronics, and high-voltage distribution systems will require clear inspection and component exchange policies.

MROs can also capture value in hydrogen storage system inspection, remote diagnostics, and rapid component-exchange programs rather than extensive on-aircraft repairs.

Furthermore, mobile technical response teams for propulsion-related Aircraft On Ground (AOG) events, software configuration management, and hydrogen ground-handling support for operators and airports present strong growth avenues.

Because AOG response, parts availability, and fast component exchange are major pain points in business aviation today, next-generation OEMs must design an integrated support model from the outset. Early on, OEM involvement will remain high for specialized propulsion systems, while local MROs perform conventional tasks like wheels, tires, brakes, and airframe inspections.

Aviation Maintenance: What specific new skills and knowledge will future Airframe and Powerplant (A&P) mechanics need to safely complete inspections on high-voltage systems, batteries, and fuel cells?

Ganzarski: Today's A&P is trained for an airplane whose electrical system exists to run lights, radios, and fuel pumps at 28 volts DC. They are low energy, easy to de-energize, and treated as a support system. In an electric or hydrogen aircraft, the electrical system is the propulsion system. That single change reorders the entire skillset.

Mechanics must become comfortable with inverters, motor controllers, contactors, and liquid cooling loops, as thermal management becomes a flight-critical system. Diagnostics shift from physical inspection to data interpretation — reading logged parameters, cell balance, impedance trends, and thermal history. Firmware and configuration control become maintenance actions with direct airworthiness consequences, while bonding, shielding, and EMI control move from housekeeping to safety-critical mandates.

High voltage (800 to 1200 volts DC) leaves zero margin for error. Stored energy in a battery cannot simply be switched off, making standard lockout/tagout incomplete. Mechanics need arc flash awareness, PPE discipline, insulated tools, and insulation resistance testing on high-voltage harnesses.

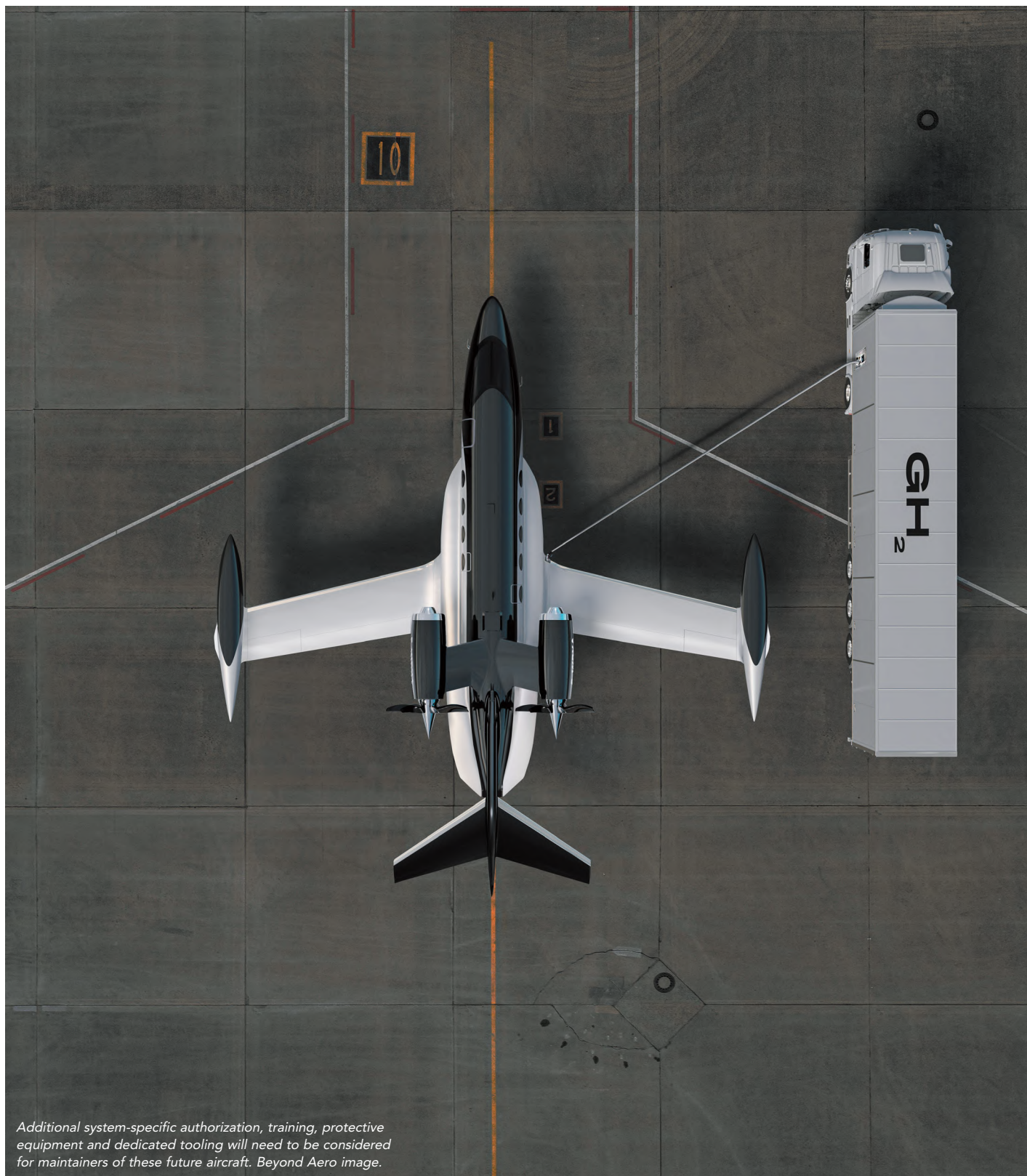
Aviation also introduces challenges automotive training ignores: dielectric strength falls with altitude, making creepage, clearance, and partial discharge behavior critical, while thermal runaway in a confined fuselage requires entirely different containment strategies.

For hydrogen, instincts built around Jet A must be unlearned.

Hydrogen is odorless, colorless, buoyant, and ignites across a wide concentration range with an almost invisible flame. Technicians need leak detection instrumentation, line purging and inerting procedures, an understanding of hydrogen embrittlement, and strict torque discipline.

For liquid hydrogen, add cryogenic handling, cold burn protection, boil-off behavior, and fuel cell stack health management. The talent for these systems exists today in automotive traction, industrial gas, rail, and space launch, but it doesn't hold an A&P certificate. The industry must deliberately create pathways for lateral entry rather than expecting traditional schools to start from scratch.

Anaïs Cateni-Cauderan: Technicians will increasingly combine traditional aircraft maintenance skills with electrical safety, energy-system knowledge, software diagnostics, and isolation procedures.



Additional system-specific authorization, training, protective equipment and dedicated tooling will need to be considered for maintainers of these future aircraft. Beyond Aero image.

For hydrogen-electric aircraft, relevant competencies must encompass high-voltage awareness, electrical shock hazard prevention, safe de-energization, and lockout/tagout procedures using insulated tools and proper PPE. Mechanics must understand systems that remain energized after aircraft shutdown, as well as fuel-cell fundamentals spanning electrical, thermal, air, water, and hydrogen interfaces.

On the hydrogen system side, technicians require skills in hydrogen detection, ventilation requirements, leak-response protocols, ignition-source control, and high-pressure depressurization precautions.

They will also need to handle power electronics, electric

motors, cabling, and cooling loops safely, while using digital diagnostic tools to interpret system-health data and manage post-maintenance software configurations.

A useful analogy comes from the automotive industry's handling of high-voltage vehicles: mechanics should not be permitted to intervene on high-voltage or hydrogen propulsion systems simply because they hold a general maintenance qualification. Additional system-specific authorization, training, protective equipment, and dedicated tooling must be strictly required.

Aviation Maintenance: How will traditional MRO facility infrastructure need to change to accommodate cryogenic

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hydrogen storage, fuel cell testing, and large-scale battery management?

Ganzarski: Hangars were designed around Jet A, a fuel that pools on the floor, stays where you put it, and needs a controllable ignition source. Neither hydrogen nor a lithium pack behaves that way, and the building envelope must change accordingly.

Because hydrogen is buoyant, it collects at the structure's highest point. Hangars require fixed gas detection at the roof line and ceiling pockets, ventilation engineered to sweep the top volume, and updated electrical classifications for fuel-present zones. Vent stacks must route to safe discharge points, purge capability must be plumbed directly into the shop, and separation distances must be reassessed.

Cryogenic liquid hydrogen demands vacuum-jacketed lines, boil-off management, cold burn protection, and oxygen deficiency monitoring. Most facilities will not retrofit this into an existing hangar, opting instead for separate outdoor or semi-enclosed areas with dedicated permitting.

Fuel cell and high-voltage test cells require heavy electrical service, water treatment for stack loops, thermal load rejection, and regenerative load banks so energy drawn during testing isn't dumped purely as waste heat.

Battery storage requires climate-controlled, fire-rated rooms with physical separation between units, suppression tailored for lithium fires, containment for suppression water, quarantine bays for

damaged packs, and state-of-charge management infrastructure.

The overriding constraint is electrical utility service. Charging, testing, storage conditioning, and on-site electrolysis all draw heavily from the same feed. Transformer lead times and grid upgrade schedules often exceed aircraft certification timelines, making utility capacity the primary bottleneck to plan around.

Benjamin Le Drogo: For Beyond Aero, it is important to clarify that our aircraft architecture is based on gaseous hydrogen (GH₂) rather than cryogenic liquid hydrogen (LH₂).

Because we do not use liquid hydrogen, Beyond Aero does not require cryogenic insulation, boil-off gas management, cold-burn protection, or thermal-equilibrium controls. Our GH₂ infrastructure requirements focus instead on high-pressure storage, piping isolation, depressurization, leak detection, ventilation, and safe venting.

For traditional MRO facilities, the required level of adaptation depends on the task. Line maintenance activities where the fuel system remains closed could continue within existing MRO hangars using proportionate adaptations.

These include high-level ceiling hydrogen detectors, enhanced ventilation with air recirculation controls, interlocks between gas alarms and ventilation systems, grounding and bonding provisions, hot-work controls, and defined entry and towing procedures.

More detailed maintenance tasks involving fuel system openings require dedicated areas with system isolation, defueling, line inerting, external vent connections, and



"For traditional MRO facilities, the required level of adaptation depends on the task. Line maintenance activities where the fuel system remains closed could continue within existing MRO hangars using proportionate adaptations," says Beyond Aero's Benjamin Le Drogo. Beyond Aero image.

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Additionally, because our primary energy source is hydrogen rather than battery packs, MROs servicing our aircraft avoid the large-scale battery handling, charging, quarantine, and thermal-runaway infrastructure required by battery-electric fleets. The goal is adapting existing MRO facilities proportionately without recreating the entire maintenance environment.

Aviation Maintenance: What new diagnostic tools and software will technicians need to use, and how will this differ from traditional mechanical troubleshooting?

Ganzarski: The mental shift is bigger than the toolbox shift. Traditional troubleshooting is sensory and physical — looking for metal in a filter, feeling for play, smelling fuel, or borescoping a turbine section. The aircraft reveals its condition physically, and the mechanic's judgment is the primary instrument.

An electric or hydrogen powertrain does not present that way. A battery pack has no wear you can see, a fuel cell stack degrades invisibly, and a motor controller fails through software, thermal history, or electrical connectors. The system reports its health through data, shifting the technician's job from physical observation to data interpretation.

The primary tools become battery management system interfaces, cell-level state-of-health and impedance analyzers, motor controller diagnostic software, thermal imaging cameras,

insulation testers, and gas detection instruments. Much of the diagnosis occurs on a tablet or laptop connected to the aircraft.

Maintenance triggers also shift from calendar intervals to trend analysis. A cell balance drifting over fifty cycles matters far more than any single static reading within limits. This is true condition-based maintenance, requiring shops to track fleet histories over time.

Firmware versions, calibration files, and software updates become airworthiness-critical items. Loading an incorrect configuration carries consequences as severe as installing a wrong part.

Furthermore, rotatables like battery packs and fuel cell stacks require data logs that travel with the physical unit across removal, storage, testing, and secondary applications. Technicians must maintain the discipline to verify diagnostic instruments, ensuring drift or software miscalibrations don't report false system health.

Oliveira: Maintenance will become overwhelmingly data-driven because electric, electronic, and software systems control a larger share of the powertrain.

Technicians will use tools that integrate traditional maintenance documentation with high-voltage insulation testing, fuel-cell performance diagnostics, hydrogen pressure checks, power electronics health monitoring, thermal tracking, and event-history logs. Remote troubleshooting connections with OEM engineering teams and digital maintenance planning platforms will become standard.

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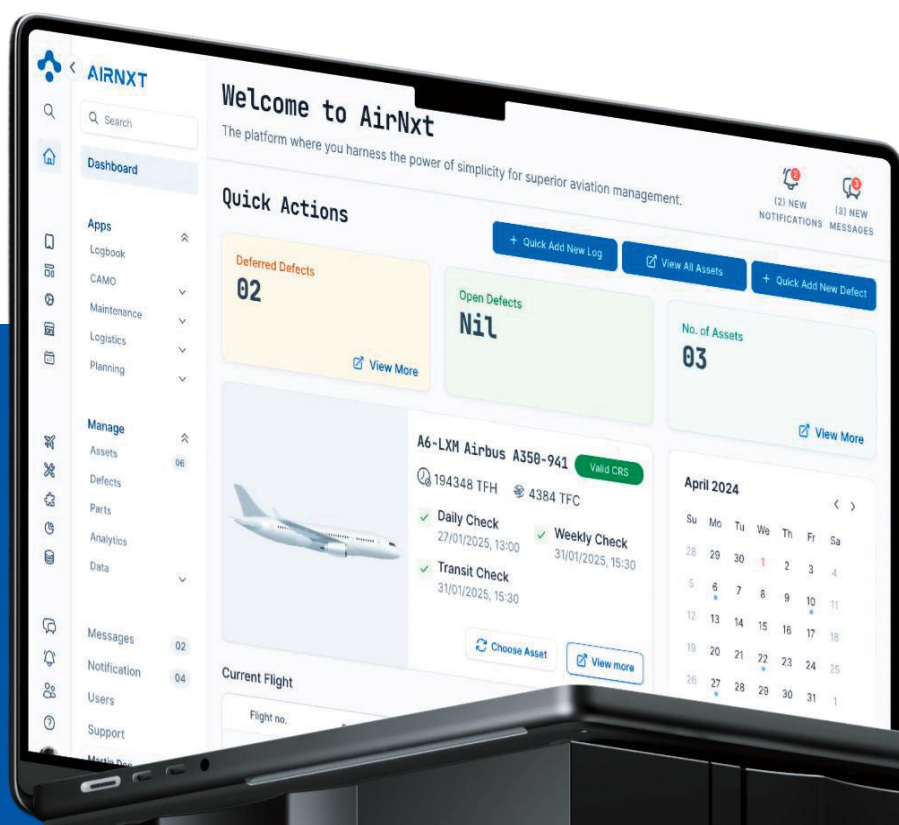
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However, more data does not automatically yield better maintenance. Excessive sensing or poorly calibrated alerting can trigger false fault codes, escalating the costly "no fault found" component removals that already burden the industry.

We place high value on predictive diagnostics and prognostic tools that help technicians isolate root causes rather than simply generating more alerts.

We also strongly advocate retaining familiar aviation maintenance conventions. Maintenance manuals should preserve established ATA-style structures and terminology, updated with digital hyperlinks between procedures, parts catalogs, and troubleshooting flows. New propulsion architectures should be easy to navigate without forcing technicians to relearn basic documentation logic.

Aviation Maintenance: How is the current industry shortage of aviation maintenance technicians impacting your strategy for training teams on these advanced, next-generation technologies?

Ganzarski: I don't agree with the premise of a labor shortage. There is no shortage of people; there is a shortage of people willing to work in aviation maintenance under the terms the industry currently offers.

The skills needed for next-generation aircraft sit in automotive traction systems, industrial electrical work, rail, industrial gas, and space launch. Those workers exist, but they choose other sectors that offer day shifts, air-conditioned working environments, competitive pay, and employer-funded training, compared to aviation's night shifts, cold hangars, and self-funded certifications.

If you fix the terms, the pipeline fills. Our strategy is to recruit people who already possess the difficult technical skills — high-voltage discipline or gas handling — and teach them the aviation regulatory and documentation layer, which is procedural and teachable. This lateral entry path is far faster than building high-voltage expertise from scratch in traditional A&P programs.

Furthermore, we are establishing job structures before fleets enter service, free from legacy shift patterns or inherited contracts. If electric and hydrogen aviation sets better workplace terms from the start, it will pull talent from both outside industries and legacy maintenance.

We should also market this sector as deep-tech rather than traditional aircraft maintenance to attract modern technical talent.

Cateni-Caudéran: The industry landscape makes simplicity and scalability critical. Our objective cannot be requiring an entirely new skillset for every routine maintenance action. We must preserve the existing technician skill base while introducing clearly defined qualifications for high-voltage, fuel-cell, and hydrogen systems.

Experienced mechanics already understand aircraft structures, flight controls, avionics, human factors, and airworthiness processes. We build on that foundation through a layered qualification model.

Under this model, conventional airframe maintenance remains accessible to existing rated technicians. Specific training modules grant authorization for high-voltage and hydrogen tasks, while deeper propulsion work is handled by specialized OEM teams or qualified network centers.

Digital diagnostics and remote engineering support allow local technicians to troubleshoot effectively without requiring specialists physically present at every station.

Training strategies must also align with workforce retention. A service center loses capability rapidly if experienced technicians leave, making workplace retention and training economics central to long-term readiness.

Aviation Maintenance: What are the biggest safety risks associated with servicing electric motors and hydrogen systems, and how should MROs prepare for them on the hangar floor?

Le Drogo: For electric propulsion, primary hazards include high-voltage shock, stored electrical energy, unexpected system energization, arc flashes, and thermal hazards in power electronics or energy storage units. For hydrogen systems, hazards center on gas leaks, flammable mixture formation, high-pressure releases, and servicing un-isolated lines.

Human factors pose an equally significant risk. New technology can induce incorrect assumptions about whether a system is isolated or safe. Conventional aviation offers many examples where technicians altered cockpit or avionics setups for maintenance without correctly restoring configurations prior to flight.

On next-generation aircraft, configuration control is paramount. Hangar floor preparation requires clearly defined safe-isolation sequences and physical verification that systems are fully de-energized, depressurized, and inert before any intervention begins.

MROs must establish hydrogen detection, adequate ventilation, control over ignition sources, and strict access restrictions for high-voltage zones.

Technicians require insulated tools, dedicated PPE, clear visual

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status indicators on the aircraft, and double-check verifications for safety-critical interventions to ensure the aircraft's state is completely unambiguous to everyone nearby.

Aviation Maintenance: Finally, what is the single most important step a traditional MRO provider should take today to make sure they are ready when these new aircraft officially enter the market?

Oliveira: The vital step for MROs today is building competency frameworks in early partnership with aircraft OEMs, rather than making heavy investments in hydrogen equipment prematurely.

MROs should focus first on identifying which existing skills remain applicable, mapping new competency needs, defining tasks that require special authorizations, and outlining future tooling requirements.

Beyond Aero is taking action by working with engineering institutions like ISAE-SUPAERO in Toulouse to anticipate the skills hydrogen-electric aviation will demand and translate them into tangible training pathways.

Market adoption will depend heavily on whether operators

believe aircraft can be supported quickly when an issue arises.

For an MRO, true readiness means building technical competence while preparing the broader operational ecosystem: trained personnel, approved procedures, parts access, digital diagnostic links, and rapid escalation pathways to the OEM. The strongest model brings the traditional MRO ecosystem into the development process early, building on decades of established maintenance experience.

Ganzarski: The single most critical, unaddressed challenge is battery cell provenance.

In traditional turbine engines, major components like discs are large, high-value, individually serialized parts produced by a small set of tightly regulated suppliers. A battery pack, by contrast, contains thousands of low-value cells drawn from commodity supply chains that aviation does not control, where gray-market and counterfeit channels thrive.

Substandard turbine parts typically degrade gradually, allowing inspection cycles to catch them. A defective battery cell undergoes thermal runaway, propagating violently to adjacent cells and causing an uncontained event in flight. No borescope or

visual inspection can detect a compromised cell in advance.

The industry cannot rely on paper certificates, serial numbers, or barcodes for traceability. As recent engine parts documentation scandals proved, paper proxies can be forged or transferred to uncertified items.

Because battery packs will be rotables swapped, leased, pooled, and transitioned into second-life storage, every handoff creates risk. MROs need physical, object-level authentication technologies that permanently bind the physical item to its digital record, ensuring verification does not depend on trusting paper documentation. **AVI**

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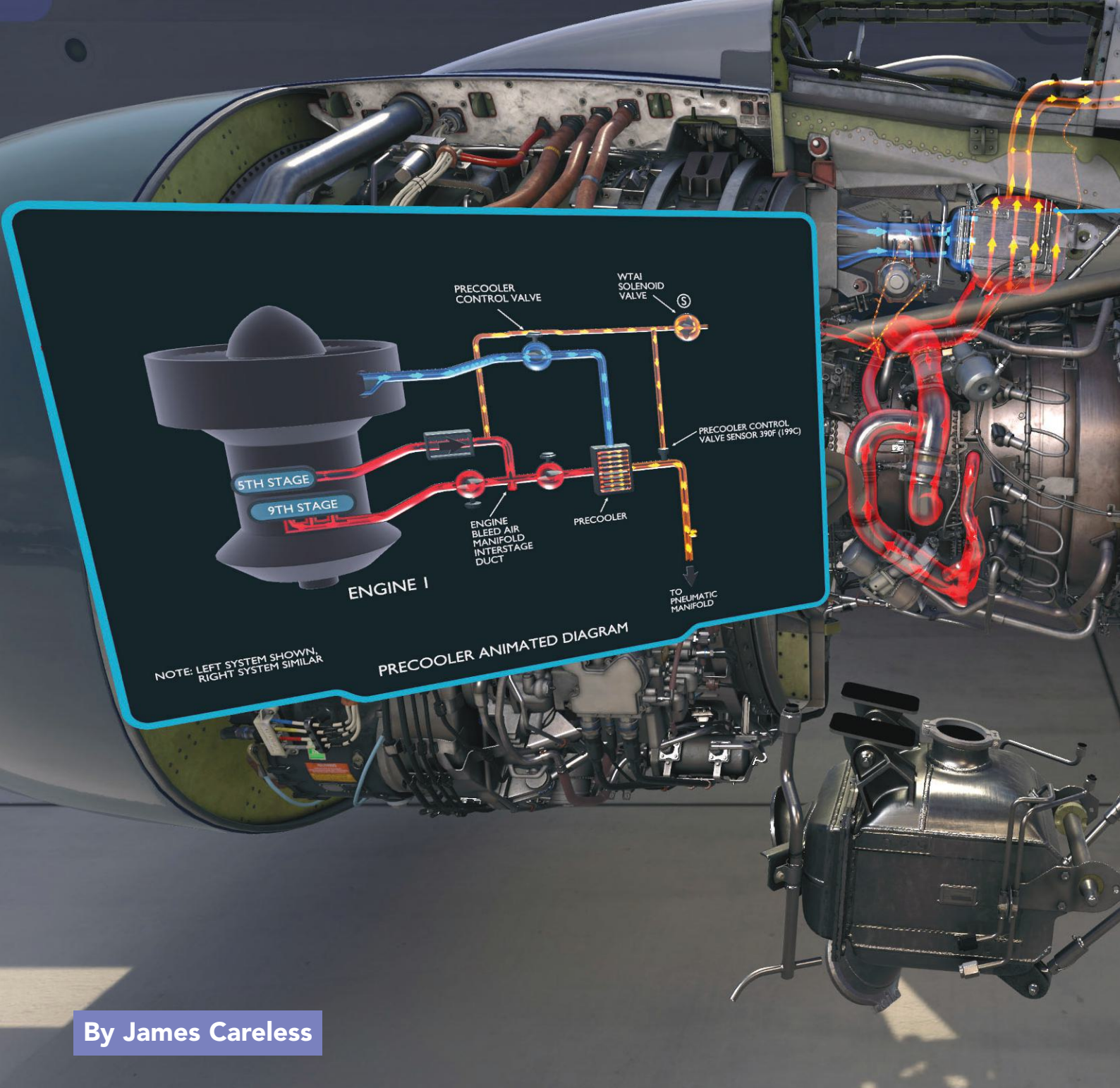
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By James Careless

The Virtual Hangar: How XR Is Transforming Aviation Maintenance Training

Extended reality (XR) technologies — including augmented reality (AR), virtual reality (VR), and mixed reality (MR) — are transforming aviation maintenance training and support.

The availability of AR, VR, and XR

technologies is presenting MROs with unprecedented opportunities to enhance technician training, safety, and operational efficiency.

But how can MROs use these virtualization technologies effectively, applying methods that are safe, reliable, and trustworthy? To find out, Aviation Maintenance convened a virtual



David Dwyer



Dr. Phillip Mangos

roundtable of experts.

Our experts are David Dwyer, Mass Virtual COO. Mass Virtual develops immersive training technologies such as the MassXR platform, which is used by defense and commercial aviation applications. And Dr. Phillip Mangos, Adaptive Immersion CEO and founder. Adaptive Immersion develops VR training for dangerous work environments.

Aviation Maintenance: Please share a brief overview of your business, including how you are currently using AR, VR, or XR on the shop floor, the main benefits and drawbacks you see, and how you are addressing those issues.

Mangos: What got me interested in this space was my personal history developing personnel selection assessments for individuals in dangerous jobs. I realized that the best way to predict someone's performance on the job is to let them actually try out

the job itself. Back in the day, we didn't have the technology to offer that safely, especially for dangerous roles before someone was hired and properly trained. Now, with high-fidelity, immersive virtual reality technology, we can.

To this end, Adaptive Immersion develops adaptive VR and XR training for the world's most dangerous missions and occupations, focusing on military and industrial safety settings. We provide operators with unlimited, variable, realistic practice that classrooms and live drills simply can't provide before their first real attempt on the job.

Specifically, we provide training for aviation-adjacent operator roles — the personnel charged with keeping aircraft operational, safe, secure, and ready to fly. This includes teams specializing in maintenance on the aircraft itself, weapon systems, and explosive ordnance disposal (EOD) personnel.

An exemplar use case is our hands-on procedural VR training for personnel face to face with ordnance threats. The system provides

hyper-realistic visuals and precise task replication so operators can do everything they would do in the real world within a safe virtual environment.

The primary benefit is a large increase in practice repetitions and variability on an accurate replica of a real aircraft, which is crucial because live aircraft impose significant restrictions on availability. More practice across varied conditions improves skill development and permanence while enhancing safety in the vulnerable first 90 days on the job when operators are at the greatest risk of injury or incidents.

One drawback we see is general pushback to training in a headset, usually rooted in a lack of familiarity with the technology. However, when people see the visual quality and psychological fidelity of the task firsthand, backed by quantitative ROI data, that pushback tends to fade.

Dwyer: Mass Virtual develops immersive training and learning technologies that help organizations shift appropriate training into high-fidelity digital environments, creating more opportunities to practice, measure performance, and build capability while reducing unnecessary dependency on operational resources with the ultimate outcome of increasing organizational operational performance.

Our MassXR platform powers immersive training programs across defense and commercial aviation, including Virtual Hangar for the U.S. Air Force. The largest benefit we see here is increased access to training, the ability to safely practice low-

frequency/high-consequence tasks, and see true measurable technician performance.

The largest challenge with AR/VR/XR is that not every task belongs in this medium. We focus on applying the right solution to the right part of the learning or maintenance workflow, rather than trying to replace every existing piece of training or support material.

Aviation Maintenance: Which specific AR, VR, or XR hardware and software platforms are you actively using, and can you share concrete examples of how technicians use them during daily maintenance tasks?

Mangos: We use a standard hardware stack built on best-in-class equipment, primarily using the Varjo XR-4 series in pure-play VR mode with some mixed reality (MR) applications. We favor the tethered version for visual fidelity and security reasons, supported by GPU-powered desktop or laptop computers. Some setups require a base station for tracking, and we use peripherals like a floor mat and fan to help orient users in physical space, along with custom training aids, props, and standard controllers to ensure a smooth experience.

On the software side, our custom VR system embeds intelligent scenario generation and visual effects to deliver customized immersive training experiences.

In terms of real-world use cases, military operators across multiple bases use our solution for mission preparation and



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Adaptive Immersion uses a custom VR system that can embed intelligent scenario generation and visual effects to deliver customized immersive training experiences, Dr. Phillip Mangos says. Adaptive Immersion image.

curriculum-based practice on the exact aircraft they maintain during live operations. Think of an F1 racing pit crew rapidly servicing a car: when aircraft land on an aircraft carrier between sorties, teams must perform rapid maintenance on the airframe, weapons, and ordnance to prepare the aircraft for the next round. Our VR trains technicians for those high-pressure turnaround environments. If an aircraft returns with an ordnance-related hazard, we can train EOD and maintenance personnel in the procedures required to render it safe before maintenance proceeds.

Dwyer: We remain hardware agnostic, but have fielded solutions with numerous COTS hardware solutions including HTC VIVE Pro 2, HTC Focus Vision, Meta Quest 3, Microsoft HoloLens, Magic Leap 2, and most recently Samsung Galaxy XR. Since we are a solutions provider, our focus is less about the specific hardware choice, and more about improving operational effectiveness by preparing and assisting technicians before and while they are on the aircraft.

Our largest footprint of deployed solutions resides within the U.S. Air Force, where we have a large footprint of VR solutions and a smaller cadre of AR solutions deployed across nearly 300

global locations, covering over 35 different platforms, training over 31,000 users annually. This effort has been largely focused on reducing the dependency of training and familiarization on actual aircraft platforms, and preparing the maintainer to be ready when they first touch the aircraft.

A large focus has been placed on developing procedures and training solutions that address low-frequency, high-consequence tasks. By deploying these solutions, we have reduced aircraft downtime by about 45%, decreased classroom training hours by 60%, and increased task efficiency by 15%. In this instance, Mass Virtual's software platform, MassXR, provides the content, distribution, learning management, assessment, and reporting capabilities behind these solutions.

Aviation Maintenance: What specific operational advantages and improvements in efficiency, accuracy, or turnaround time have you seen from using these technologies on the floor?

Dwyer: Our solutions have been fielded to our customer base, and they have conducted independent studies of the effectiveness.



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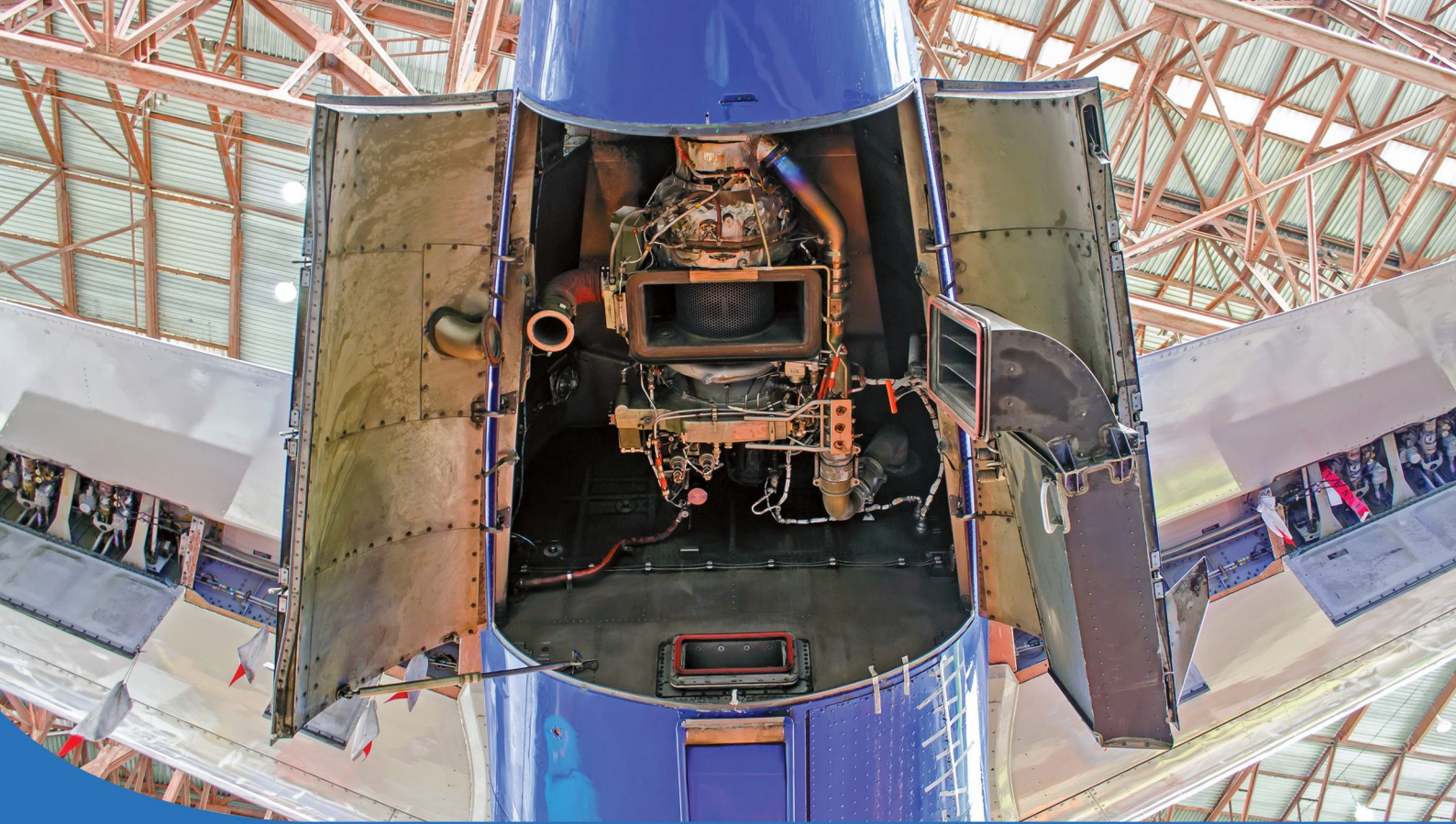
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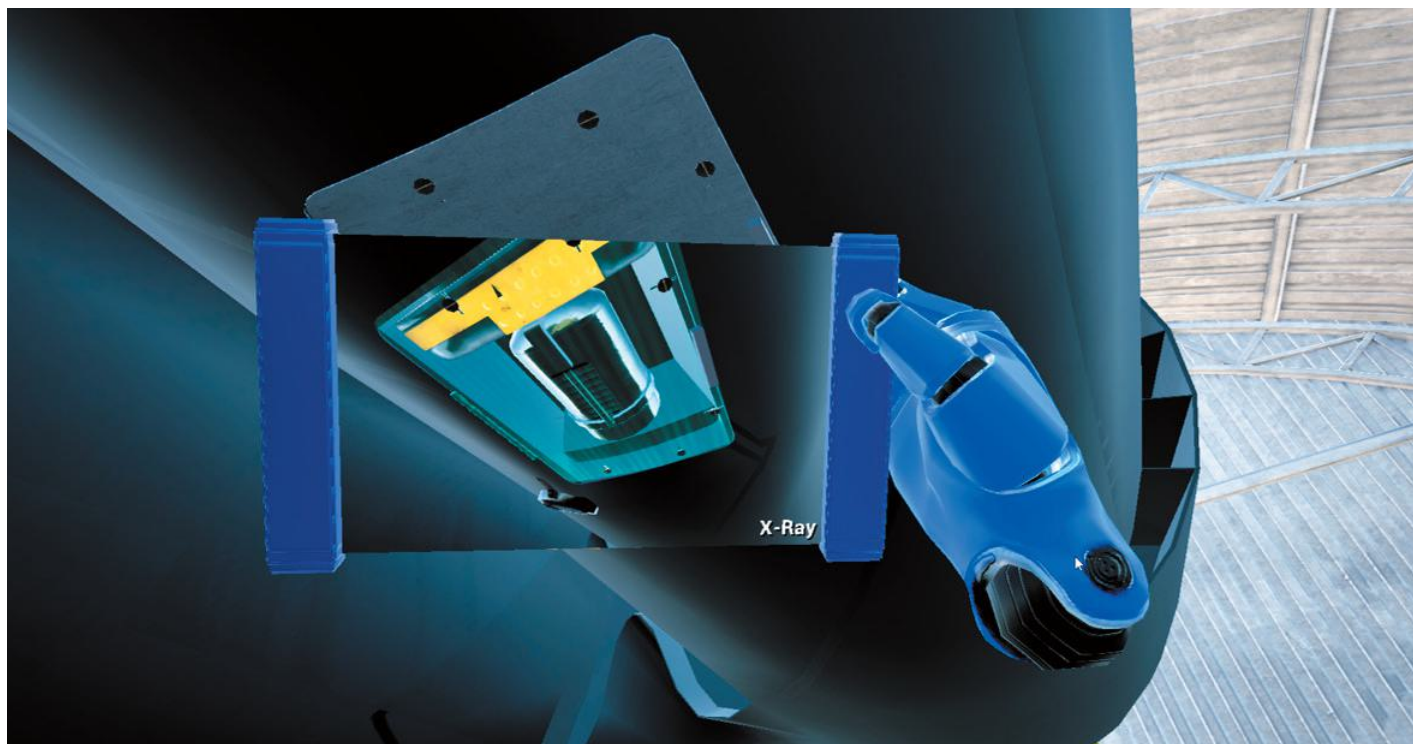
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"The most expensive classroom in aviation is a grounded aircraft," according to Adaptive Immersion's Dr. Phillip Mangos at a conference earlier this year. "Every hour of on-aircraft training competes with availability, and every experienced instructor is stretched across more students than the pipeline was built for. What we are showing on the most advanced XR hardware in the world...is a way to move the repetitions into the headset and keep the aircraft flying — without letting the procedure drift between the practice environment and the real one." Adaptive Immersion image.

One of the strongest advantages of XR is that it decouples training availability from aircraft availability. In a recent article, Little Rock Air Force Base cited an \$18.5M savings in mitigated training costs by enabling the ability to train and prepare without real aircraft using our Virtual Hangar (powered by MassXR) solutions. The 913th Airlift Group at Little Rock AFB has no aircraft assigned for this training, yet maintainers use multiple virtual aircraft platforms without needing physical flight line access.

In addition, the ability to become familiar with an airframe or procedure that you may not have experienced in the past, or one that is still in development, is where we are finding a real fit. In these instances, we provide crew coordination and maintenance training before the aircraft is even fielded or configured. The ability to train earlier in the pipeline is one of the most compelling uses of XR.

Mangos: On efficiency, we have documented significant increases in practice repetitions without operators touching a live asset, resulting in reduced reliance on limited live aircraft and classroom resources. Live training exercises are expensive, difficult to coordinate, and carry heavy logistics and personnel costs. Our VR acts as a high-fidelity supplement, allowing maintainers to get many more "reps and sets" safely.

This increased throughput directly impacts on-floor performance. In our training environments, operators show score improvements across 20 reported cognitive dimensions. All of this has been validated against real-world floor performance, demonstrating significant gains in efficiency and task accuracy, particularly for hard-to-practice maintenance procedures.

A prime example is our training for "broken arrow" scenarios — rare, high-consequence events involving crashed aircraft carrying nuclear weapons. Operators rarely get live practice for these events because training sites are so limited, but VR allows them to build readiness for these critical situations risk-free.

Aviation Maintenance: What are the biggest technical shortfalls or limitations of the current technology, and what features or capabilities still need to improve?

Dwyer: For VR, the majority of technical barriers have reduced as the technology has matured. However, the remaining gap for maintenance operations remains in the AR space.

A shortage of mission-capable AR headsets/glasses continues to be a challenge. In hangar and flight line operations, current AR hardware struggles with operating in diverse lighting conditions and battery power limitations. While these remain hurdles for true flight line execution, we continue to find great success utilizing full simulation prior to performing real-world tasks.

Mangos: One of the biggest technical shortfalls is equipment durability. Best-in-class hardware contains sensitive optical and electrical components vital for high immersion. However, maintaining "handle-with-care" hardware is a challenge for hands-on maintainers and ordnance professionals who work in rugged environments with heavy-duty tools and might toss equipment around in the course of their duties. There is a clear need to increase hardware durability for operational field use.

While visual fidelity continues to make great strides, the overarching challenge across all XR training comes down to psychological fidelity — accurately capturing the exact mental and cognitive processes used to solve problems in the real world within the simulated environment.

Psychological fidelity is not purely a hardware issue. You can have photorealistic visuals and high frame rates, but still fail to address the isolated task components most susceptible to skill decay. Building true psychological fidelity requires a strong skill assessment and measurement foundation, adaptive instructional features, and deeply probing after-action review (AAR) and debriefing capabilities.



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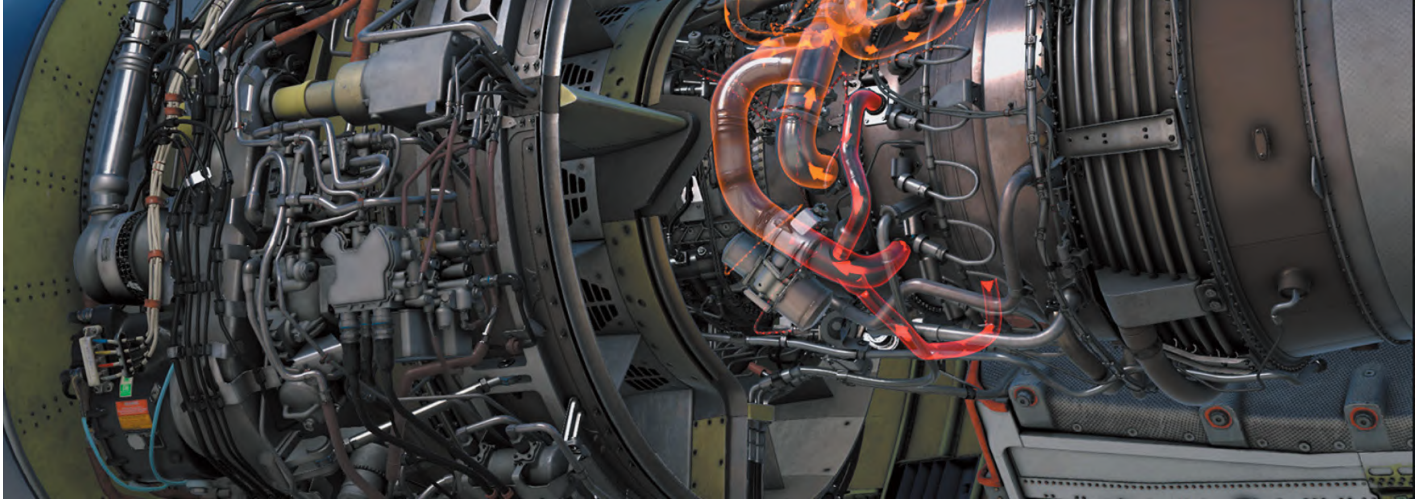
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Mass Virtual's David Dwyer says XR becomes particularly valuable when the maintainer needs to understand location, spatial awareness or interaction with a complex system or task. Reading or looking at a 2D wire diagram doesn't always give the best theory-of-operations understanding for how things work. XR fills that gap. Mass Virtual image.



Aviation Maintenance: What physical infrastructure upgrades, hardware investments, or IT changes were required to deploy these tools across your shop?

Mangos: No major physical infrastructure or IT upgrades were required. Our system is optimized to be highly compact and portable — requiring only a GPU-capable laptop or PC, tethered Varjo XR-4 headset, controllers, tracking base stations, a floor mat, and a fan. Outside of cybersecurity compliance considerations, all that is needed is a dedicated physical space with standard electrical power and climate control.

To ensure success, the focus needs to be on standardization and train-the-trainer programs so local instructors know how to install and run the system correctly.

Looking to the future, there is strong interest in moving toward wireless and cloud-based collaborative experiences, enabling operators at different geographic sites to train together in real time. Building infrastructure that supports remote, massively distributed collaboration without compromising visual or simulation fidelity will be an important evolution.

Aviation Maintenance: How have you handled reskilling and training your technicians, and how has the shop floor staff reacted to using these tools in their daily routines?

Mangos: We address reskilling through two layers. First is basic education — educating users on the benefits of VR and enforcing standard best practices to minimize disorientation or cybersickness. Second is standardization and train-the-trainer programs, ensuring local instructors can onboard users smoothly so technicians learn baseline control inputs quickly without fumbling.

When a training program is designed correctly around "psychological fidelity," transitioning to VR isn't a huge leap because it mirrors the cognitive and procedural demands of their actual job.

Because of this approach, end-user reactions have been overwhelmingly positive. We also maintain a direct user feedback loop to identify pain points and continuously improve system usability.

Dwyer: One lesson and theme we have seen over our deployments is that adoption of XR, when incorporated into existing training, has a significantly greater impact than deploying it as a standalone solution.

As evidenced in our Fort Bliss fielding, initial skepticism is easily removed when you present a high-fidelity solution that accurately replicates the real world. The technology has to solve a real problem for the maintainer. If it does not make the task more accessible, effective, or useful, simply putting a headset on will not drive adoption.

Aviation Maintenance: What are the overall pros and cons of using XR platforms in real-world MRO operations compared to traditional paper or tablet-based workflows?

Dwyer: We generally don't view XR as a replacement for every paper or tablet-based workflow. XR becomes particularly valuable when the maintainer needs to understand location, spatial awareness, or interaction with a complex system or task. Simply reading or looking at a 2D wire diagram doesn't always give the best theory-of-operations understanding for how things work. XR fills that gap.

Mangos: The main pro of immersive VR/XR is the ability to achieve high visual fidelity and rapid, accurate replication of dangerous, repetitive, or procedurally complex work in a safe environment without interrupting actual operational task flow. This full immersion drives direct, measurable skill development and clear training ROI.

The main cons are that not everyone is naturally suited for immersive VR. Some users are more prone to cybersickness,

imposing an upper time limit on headset usage before discomfort sets in.

Aviation Maintenance: Are there any lessons learned that you want to share?

Dwyer: There are two primary lessons we have learned from our deployments:

The experience has to be worth the effort: We must deliver a solution that gets beyond the friction of putting a physical device on. It has to bring efficiency or actionable information that helps technicians do their jobs better. You must see a clear operational gain to justify deploying XR.

Access is paramount: Aircraft are expensive, instructors are limited, and many maintenance procedures occur infrequently. XR provides a continuous training resource independent of physical aircraft availability. This shifts the economics of technical preparedness, allowing rehearsal to occur much earlier so that limited time spent on actual aircraft is vastly more productive.

Aviation Maintenance: What are your future plans for expanding or evolving your use of AR, VR, and XR technology over the next few years?

Dwyer: We are continuing to field VR, AR, and traditional solutions. As hardware matures, we expect the lines between these platforms to blur. VR will remain extremely effective for immersive training

and rehearsal, but the next generation of XR hardware — featuring improved hand tracking, pass-through capabilities, and smaller form factors — will bring a massive leap forward.

Over time, we expect the line between pre-task training and real-time performance support to dissolve. Advancements in hardware and AI will soon allow us to deliver contextual instructions, data, and remote expert assistance directly to the maintainer in their live work environment. Our focus remains on building a robust content and software ecosystem that evolves alongside the hardware.

Mangos: We plan to expand our XR technology into adjacent military and industrial domains involving dangerous, hands-on technical work — such as oil rigs, gas, energy, and mining.

We are expanding our software features to make the user experience both highly functional and visually seamless. A major focus is advancing our skill assessment and After-Action Review (AAR) framework, enabling maintainers to pinpoint exact procedural errors and rewind time to play back their specific actions leading up to a mistake.

Lastly, we are expanding our intelligent scenario generation capabilities, leveraging advanced artificial intelligence to create dynamically adaptive scenarios tailored to the operator's specific job requirements. **AM**



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The Power Behind the Plane: Keeping APUs Running



One of the major operational disruptions for any airline is unscheduled maintenance. When a system like the auxiliary power unit (APU) is involved, the impact can extend beyond a maintenance task to affect aircraft availability and operations. Though the APU

is mostly used for ground operations, it is needed to keep both the electrical and pneumatic systems functional during an in-flight emergency, like the loss of engine power. Being a critical system, its continued serviceability is also a key factor in maintaining safe flight operations. Its availability during maintenance operations can also reduce turnaround time for operators.

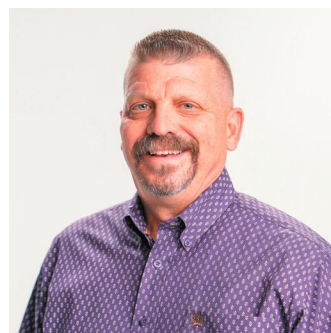
Hence, airlines aim to maintain APU reliability to maximize on-wing time and reduce aircraft downtime. Even though this seems like a maintenance issue, the challenge goes far beyond just keeping the APU serviceable for operators.

In-Shop APU Maintenance

An APU is unlikely to require major repairs because of a single in-service failure. In-shop maintenance typically arises from a gradual decline in operational performance over time, alongside



Ray Boyd
Honeywell Aerospace



Jason Evans
MK Test Systems

recurring faults, which can make continued operation impractical and uneconomical.

"One of the key indicators is an elevated exhaust gas temperature (EGT), which is a known predictor of maintenance needs," says Ray Boyd, general manager, narrowbody APU product line, Honeywell Aerospace.

However, elevated EGT is just one of many reasons an APU might

be removed for maintenance. As APU deterioration is not always straightforward, other system parameters, such as increased oil consumption, leaks and contamination, the presence of foreign object debris (FOD), damage to internal drive shafts, abrupt changes in start performance, and unusual vibrations, can also signal the need for a shop visit. A single abnormal indication is not sufficient reason for removal.

"Vibration, abrasion, contamination and mechanical damage can all contribute to insulation degradation, resulting in increased leakage current in APUs," says MK Test managing director, Jason Evans. "If left undetected and not addressed immediately, these can eventually lead to functional failure."

This is why early detection is important. If deterioration is diagnosed before functional failure, maintenance teams can determine the best corrective actions to avoid an unplanned disruption to operations and maintenance.

The Cost of an Unscheduled APU Removal

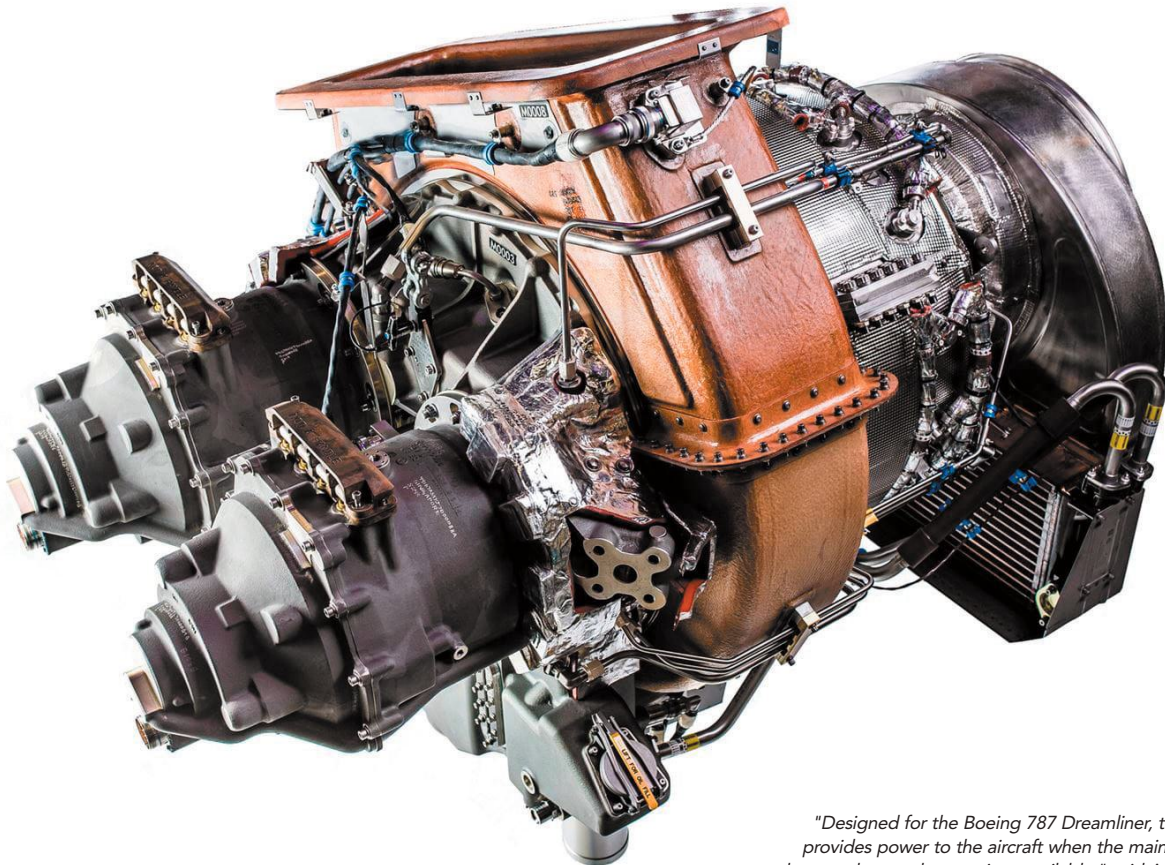
The impact of abruptly removing an APU from an aircraft is complex, affecting maintenance reliability, logistics and finances. First, the operator has to account for the operational disruptions

that arise as a result of an unscheduled shop visit. An unscheduled repair will affect aircraft availability due to unplanned downtime, an increase in the demand for manpower, logistics requirements, and the financial pressure to restore serviceability.

In certain instances, the aircraft might be able to operate under the provisions of the Minimum Equipment List (MEL), within a specified timeframe, often based on the aircraft type and applicable maintenance procedures. This allows operators to continue operations rather than having to ground the aircraft unexpectedly. Through the MEL, a deadline is given, with the possibility of an extension if needed, to carry out the required repairs. Nonetheless, this does not give operators the freedom to continue flying without a functional APU, nor does it fully remove the impact on operations.

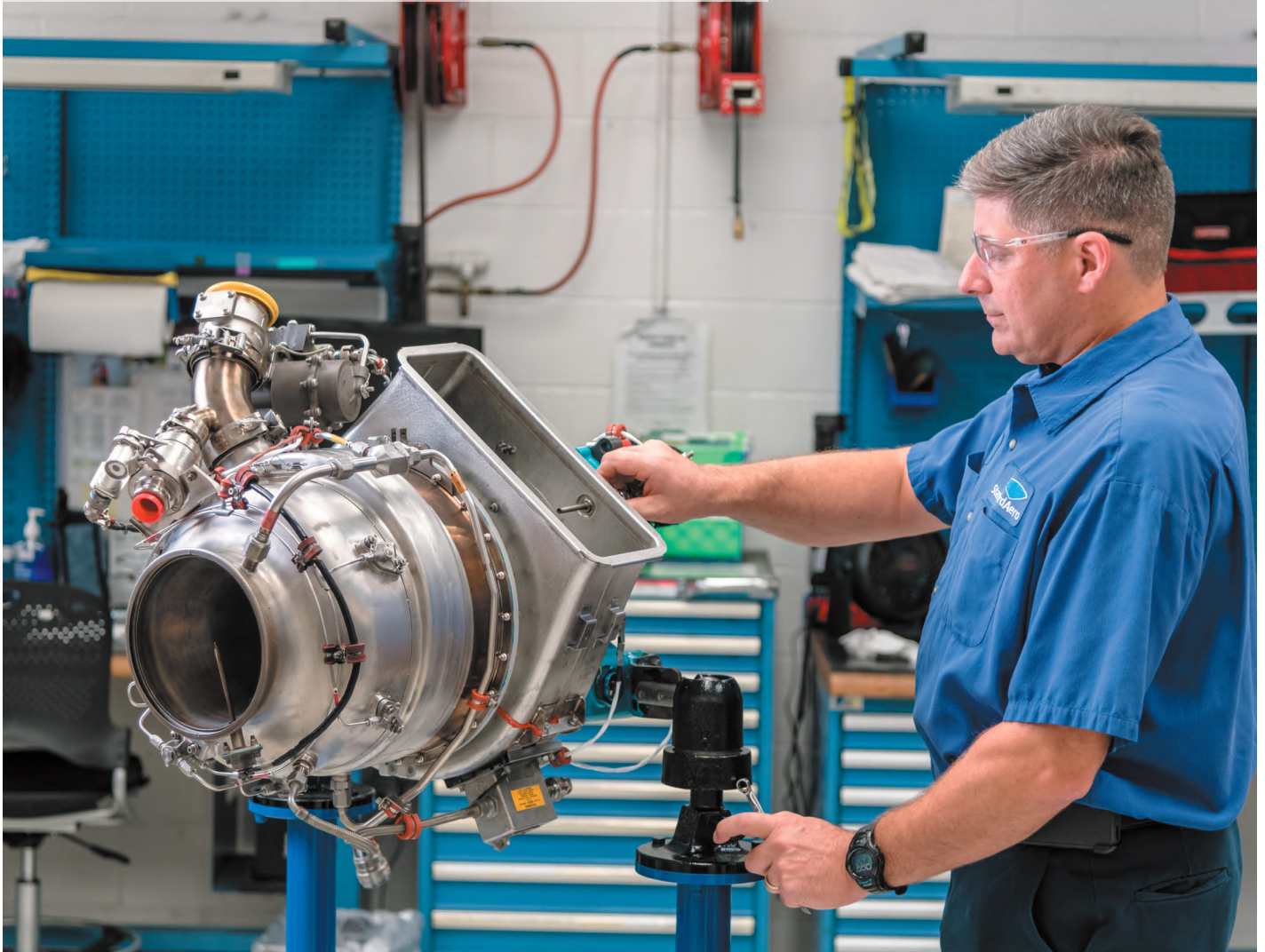
Pratt & Whitney Canada confirms that most of its APUs are for commercial aircraft operated by scheduled airlines for whom dispatch reliability is always critical.

For an extended-range twin-engine aircraft, a reliable APU is important to maintain the Extended-range Twin-engine Operations Performance Standards (ETOPS) approval. In contrast, heavy long-haul aircraft with four engines, like the Airbus A380 or



"Designed for the Boeing 787 Dreamliner, the APS5000 APU provides power to the aircraft when the main engines are shut down and ground power is unavailable," said Anthony Rossi, vice president, customer service, Pratt & Whitney Canada. "Additionally, the APS5000 simultaneously powers twin electric starters for the main engines making it vital to overall dispatch reliability."

StandardAero's Scott Arms, VP Honeywell Commercial Programs at StandardAero said predictive maintenance is giving operators advanced warning and the ability to plan. StandardAero image.



B747, are not affected in this manner. They are legally permitted to fly across the Pacific Ocean under strict regulations established by global aviation authorities.

Ground operations are also affected by an unserviceable APU. APUs are used to start the engines before flight and they provide air conditioning for passengers when boarding and deboarding. When an APU is unserviceable, there is an increased reliance on ground power units (GPUs) and other related ground equipment to perform these functions.

The operator is still required to schedule the required maintenance tasks within the timeframe allowed for rectification, taking into account the aircraft's routing, operating requirements and the availability of replacement components for the aircraft.

The financial implications of an unscheduled APU removal extend beyond the maintenance and repair costs. For every hour the aircraft is grounded, the airline is losing valuable aircraft utilization time and potential revenue from scheduled flights. This disruption can also result in rescheduling flights, additional operational costs and possible refunds or compensation for delayed and cancelled flights. Meanwhile, the airline might have to put more workload on other aircraft in its fleet to meet the affected flights, which in turn will increase their operating time

and result in less flexibility for subsequent flight disruptions.

APU Testing, Troubleshooting and Fault Detection

Testing an APU involves a combination of manual methods and automated systems to assess the unit's functionality and performance. Using these systems, engineers can evaluate the working condition of each component within the unit, identify abnormal indications and determine the root cause of any fault or malfunction. Automated testing can significantly accelerate this troubleshooting process, especially when isolating electrical faults, according to Evans, who further cited the example of the pin-to-pin continuity check on a wiring harness in the Honeywell 331-350 APU Maintenance manual.

"When this process is performed manually, every connection must be verified individually," said Evans. "Even allowing just five seconds per measurement, you're already looking at around 380 seconds of testing time and that's before considering documentation and reporting requirements. With an automated test system such as MK Test's Automeg, that same harness can be tested for continuity, resistance and short circuits in approximately 20 seconds, with every measurement automatically logged and reported."

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Not only do these systems speed up troubleshooting, but they also ease the pressure of reporting and documentation, which is mandatory in aircraft maintenance.

Automated testing is useful in identifying deterioration before it becomes a hard failure. This forms one of the most valuable benefits of using computerized systems in troubleshooting faults such as increasing resistance, intermittent connection and insulation degradation in the APU.

"Using a four-wire (Kelvin) measurement technique, which is a standard feature of MK Test's Automeg systems, very small changes in resistance can be detected down to the milliohm level," Evans adds. "When these measurements are recorded during scheduled maintenance intervals, it becomes possible to monitor trends over time rather than simply assessing whether a component passes or fails on a given day."

Engineers assess the frequency and nature of these patterns, the rate of decline in performance and the likelihood of the need for an unscheduled removal later on. This helps predict the exact fault and determines the appropriate maintenance actions to prevent failure in service.

Predictive Maintenance in APU Testing

Predictive maintenance is essential in maintaining the serviceability and reliability of APUs. It relies on condition and health monitoring, which is the basis of this maintenance approach. Condition monitoring allows operators to track important APU performance parameters while in operation and identify indications that are not apparent in regular inspections.

For this, Honeywell Aerospace adopts the Predictive Trend Monitoring and Diagnostics (PTMD). This technology continuously monitors APU performance and alerts airlines to potential maintenance needs before failure occurs. Operators can see these trends, and when monitored over time, they can identify the abnormal indications which may be a sign of ongoing deterioration.

"The real benefit of predictive maintenance for APUs isn't predicting the exact day of service failure, but giving the operator enough warning to plan maintenance around the aircraft's schedule," said Scott Arms, vice president, Honeywell Commercial Programs for StandardAero.

Health monitoring takes this a step further by combining data obtained from the APU with that of its operating environment. Instead of relying only on the APU's performance data, maintenance personnel can monitor several parameters in other related systems to determine the APU's earlier operating data; if not, they can determine if they need to investigate the changes.

The operators can use these health-monitoring tools to monitor the APU's performance with respect to other aircraft systems during operations and create a baseline for future comparison. Thus, the bottom line of predictive maintenance is the action taken after analyzing these data. Once current datasets begin to deviate from ideal operating parameters, engineers can examine the data, decide the root cause and determine the best maintenance action to be taken.

"Our APUs are equipped with health monitoring tools that allow operators to monitor the APU performance. Operators can use this data to implement predictive maintenance actions based on their expected utilization and operation," according to Pratt & Whitney Canada.

This is why condition and health monitoring is important. They help operators differentiate a one-off incident from a potential

reliability problem. By monitoring these indicators, operators can detect declining APU functionality using sensors and generated aircraft data. This also assists maintenance teams in making safety-critical decisions before failure occurs. Instead of waiting till the APU fails, operators can monitor performance indicators and determine when the component is due to be removed and coordinate a shop visit with scheduled maintenance to avoid unnecessary aircraft downtime, allowing more effective management of maintenance scheduling.

Predictive maintenance is more than just reacting to a fault. Maintenance personnel no longer need to wait till the unit breaks down before maintenance tasks can be done to prolong the service period. Rather, performance data can give maintenance personnel an indication when intervention may be necessary and take corrective action, which can extend the APU's time-on-wing.

Keeping the APU On-Wing Longer

The goal of every operator is to maximize the APU's serviceability, keeping it within the required performance range for safe operations. From an expert's perspective, Arms highlights that understanding and monitoring how the condition of the APU changes over time is the primary factor to extend the on-wing time rather than simply tracking hours. This requires consistent maintenance practices, regular inspections, oil and chip monitoring and paying attention to start performance, which is part of their processes at StandardAero. These will help operators identify problems on time before they become major failures. Manufacturers also have a role to play in this.

Modern APUs are now being fitted with new technologies to enhance APU efficiency and extend time-on-wing. For example, in the Honeywell 131-9 narrowbody APU, the High Efficiency Mode (HEM) is designed to improve both fuel efficiency and time-on-wing.

"HEM offers an additional time-on-wing of 1,500 hours, about 2% fuel savings to the operators that enable this upgrade and delivers 9% better baseline reliability than the next-best competitor due to design," Boyd adds.

These developments show that extending APU time-on-wing is not reliant on only one maintenance practice. Instead, it involves a combination of technology and strategies, with these improvements made by both the operator and manufacturers.

APU Turnaround Time, Repair and Replacement

Turnaround time is also an important factor to consider when determining how long an APU stays on-wing. Many factors such as the inspection findings, work scope and availability of parts and manpower can determine the extent of the turnaround time.

Based on this, not every APU maintenance task will require a shop visit and not all shop visits require an overhaul. Parts of this unit are assessed to determine their individual serviceability, and decisions are made on whether to repair, overhaul or replace in accordance with applicable manuals.

To improve turnaround and parts logistics, Pratt & Whitney Canada confirms, "We continue to invest in our supply chain network and in new hires and new capabilities for our MRO facilities around the world to meet our customers' demands."

To minimize operational disruptions, having a serviceable APU ready for immediate replacement reduces downtime,

speeds return to service, and eases pressure on other available units in the fleet.

Software Takes Aim at APU Turnaround Time

The inherent unpredictability of APU maintenance makes the shop visit particularly challenging to schedule, staff and price. Unlike routine component work, teardown can quickly reveal problems that dramatically alter the original workscope.

"APU is like a self-contained, mini gas-turbine engine, and hence, shares all the complexity of an engine MRO," says Manoj Singh, chief customer officer at Ramco Systems. Teardown findings can generate additional work across fuel, pneumatic, electrical and mechanical systems, changing requirements for labor, parts and testing as the shop visit progresses. APU article-AMM -Ramco inputs

Some of the greatest risks to turnaround time occur at inspection, during parts procurement and in the test cell. NDT inspections can uncover previously unknown hot-section damage; shortages of high-value components and life-limited parts can stall reassembly; and a failure to meet EGT margins or vibration limits during testing can require additional teardown, balancing and retesting. APU article-AMM -Ramco inputs

Increasingly, MRO software is being used to anticipate those problems rather than simply record them. Historical teardown data, operating conditions and APU type can help forecast potential non-routine findings, allowing planners to pre-stage parts and technician capacity. APU article-AMM -Ramco inputs

"Pre-induction visibility lets planners pre-stage materials via a centralized marshalling hub, accelerating execution and significantly reducing Turnaround Time (TAT)," Singh says. APU article-AMM -Ramco inputs

Digital systems can also address a less obvious source of lost time: customer approvals following unexpected teardown findings. Software can connect a newly discovered defect with contract requirements, estimated costs and parts availability, then present that information electronically for customer review.

"The customer receives real-time visibility into the exact teardown findings, cost changes, and parts availability," Singh says. Customers can then approve or amend the revised workscope electronically, potentially eliminating days of back-and-forth communication.

Beyond APU Reliability

As airlines move towards more sustainable operations, the focus is gradually shifting from corrective APU maintenance to a more proactive approach. Instead of waiting till a component fails in service, preventive maintenance measures are now being taken before extending the APU service periods whilst reducing aircraft downtime. This approach is not just a maintenance goal. It is a business strategy for fewer unscheduled removals and reduced disruptions for better operational reliability. This transition from responding to failures to managing operational deterioration is the key to keeping the APU on-wing for longer while maintaining aircraft availability and operational reliability. **AM**

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By Mark Robins

The PMA Market Flies High

PMA Use Continues to Grow as an Alternate Material Option to Ensure Operational Continuity.



Jet Parts Engineering's Alan Voeller, vice president of sales and marketing, says PMA parts deliver equivalent performance at a fraction of the cost and often with better availability. Jet Parts Engineering image.

T

he commercial aircraft Parts Manufacturer Approval (PMA) market plays a critical role in global aviation, offering certified alternatives to original equipment manufacturer (OEM) parts while maintaining equivalent safety and performance standards. Commercial

airlines use PMA solutions to lower operational costs and reduce dependence on OEMs. To ensure safety, the FAA reviews the proposed designs of PMA parts to verify that they meet their safety regulation requirements and are functionally equivalent to the OEM components they are designed to replace. No longer a niche alternative, PMA parts are being embraced by airlines, MROs and leasing companies as reliable, cost-effective solutions that help ensure operational continuity.

The PMA market continues to grow. According to a research



ATS's Joseph Allen says many of their PMA parts incorporate reliability improvements and perform identical to, or better than, the OEM part. ATS image.

report by the market research company IMARC Group, the global commercial aircraft parts manufacturer approval (PMA) market size was valued at USD 11.8 Billion in 2025. Looking forward, the report estimates the market to reach USD 16.1 Billion by 2034, exhibiting a CAGR of 3.37% during 2026-2034. The report states that it's the rapid expansion of the aviation sector, the stringent implementation of a favorable regulatory regulation, aging of the existing aircraft fleet, the comparatively low cost of PMA-made parts, and significant technological advancements in manufacturing processes that make up the key factors driving the market.

How are these PMA parts positively affecting the aviation industry's supply chain, efficiencies and cost control?

The Supply Chain

FAA-approved PMA positively affect the aerospace supply chain by increasing part availability for the airlines and their maintenance providers. "PMA primarily functions as an alternate material option for parts that the OEMs do not routinely have in stock and suffer from long manufacturing lead times," says Joseph Allen, director of alternate parts and design engineering, Aviation Technical Services (ATS), DFW International Airport, Texas. "Additionally, many of our PMAs incorporate reliability improvements. By implementing simple design improvements, ATS ensures all our FAA-approved PMAs perform identical to, and in most cases better than, the OEM part. This directly leads to a longer on-wing time for our parts that reduces required maintenance activities across the life of an aircraft. Maintenance-related delays are ultimately minimized because PMA provides air carriers with available options at high levels of reliability to meet their material part needs."

"By providing an alternative to OEM parts we are keeping aircraft flying," says Paul Bolton, DVP business manager, First Aviation Services, Ametek MRO, Clemmons, North Carolina. "There are continuing supply chain issues causing AOG situations on a daily basis and by working with our customers we are able to provide solutions."

Because of supply chain challenges, Gilbert, Arizona-based EXTEX Engineered Products has entered into agreements with



Paul Bolton of First Aviation Services says PMA parts are helping solve continuing supply chain issues. First Aviation Services image.

engine OEMs to supply licensed PMA parts to the marketplace. These agreements ensure legacy products get supported while OEMs can focus valuable engineering, quality and supply chain resources on newer, higher visibility programs. Larry Shiembob, general manager at EXTEX explains, "Supply chain issues are not improving and OEMs continue to stress their existing suppliers with demanding requirements to support new programs. As a result legacy product lines are experiencing even more delays than in previous years. PMA supplies often utilize non-OEM focused suppliers allowing an independent supply of parts, which can compensate for OEM shortfalls. PMA companies are also smaller and generally more nimble than OEMs. They can respond to supplier questions in days, not weeks/months, which keeps parts moving and they ultimately reach the end customer much quicker."

Keith Lipscomb, chief executive officer and president of Aviation Component Solutions (ACS), Richmond Heights, Ohio, believes PMA parts make the aviation supply chain stronger for a very simple reason: competition is better than dependence. "For decades, many replacement components effectively had a single source of supply. If that source had significant or inconsistent lead times, the customer had very few alternatives. The supply-chain disruptions following Covid exposed the inherent weakness in that model. Airlines and MROs learned that even a very good supplier presents risk when it is the sole-source supplier. PMA changes that equation by introducing another FAA-approved source. At ACS, we have even sold parts to OEMs that could not otherwise fulfill their own customer obligations. That tells you something about the role PMA can play in the supply chain. The argument for PMA, therefore, is not merely that an alternative part may be more

readily available or cost less. It is that a competitive, diversified supply chain is inherently more resilient than a single-source supply chain."

Efficiencies

The efficiency benefit of PMA extends well beyond purchasing a less expensive part. "PMA parts are required to provide the same fit, form and function as their OEM counterparts," explains Alan Voeller, vice president of sales and marketing at Jet Parts Engineering. "With exceptions involving approved product improvements, PMAs deliver equivalent performance at a fraction of the cost and often with better availability. More for less: the very definition of efficiency."

At Hollywood, Florida-based HEICO Aerospace, Patrick Markham, vice president of technical services explains that in addition to the supply chain benefits, HEICO PMA parts bring efficiencies to MROs and airlines by providing alternative sources for the various expendables, consumables and rotatable parts for component, airframe and engine MRO.

Bolton believes that for OEMs, inventory is a bad word, even now. "With our PMAs, we ensure there is availability thus providing a seamless maintenance experience for the end user and allowing them to efficiently schedule the maintenance events."

If an airline can obtain a component in days or weeks rather than months, Lipscomb explains it enables several benefits: carrying less safety stock, responding more quickly to maintenance requirements, and reducing the operational consequences of a part shortage. "If the PMA component also has

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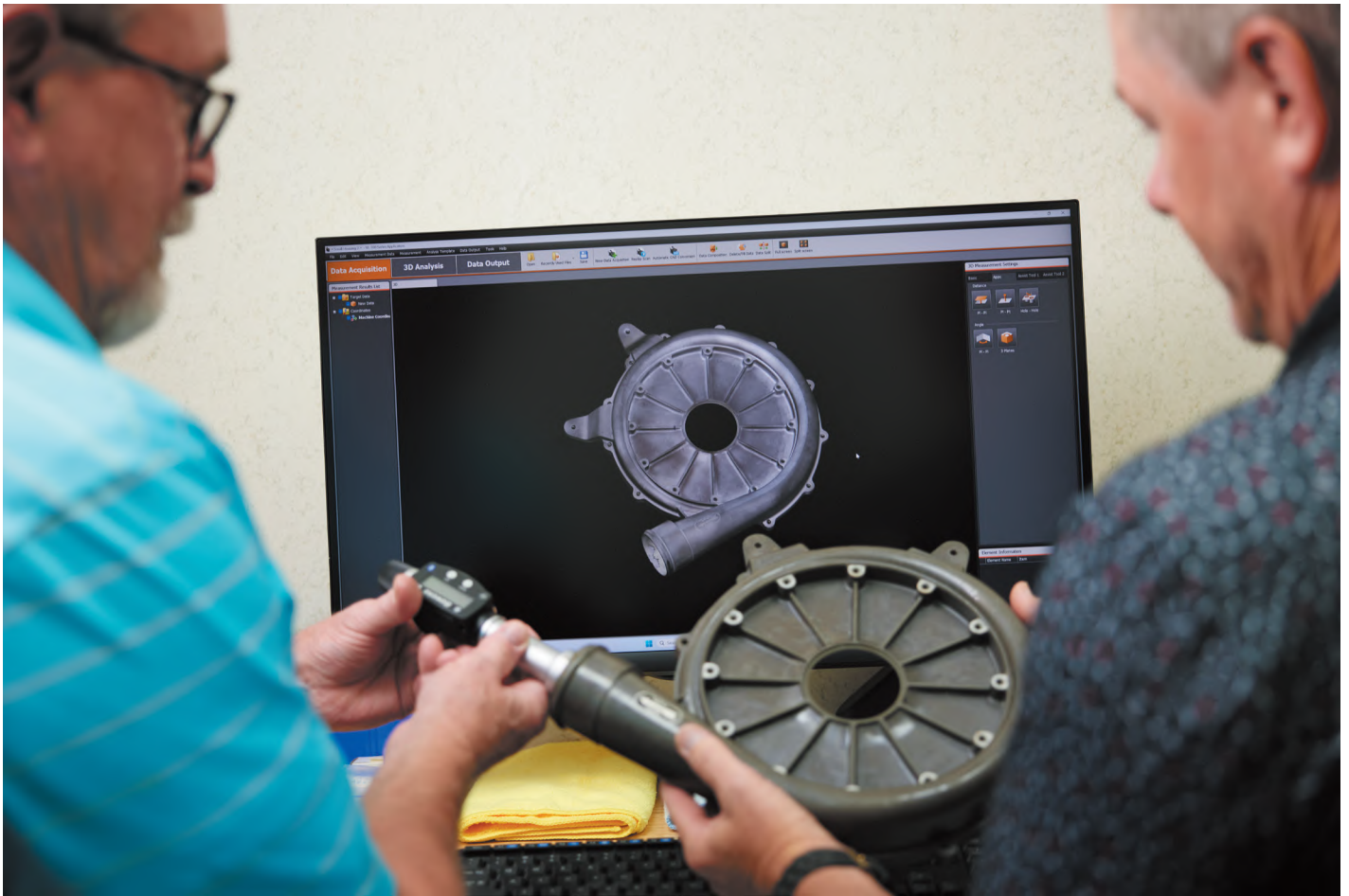


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Keith Lipscomb, CEO of Aviation Component Solutions, says a huge benefit of PMA parts is that a competitive, diversified supply chain is inherently more resilient than a single-source supply chain. ACS image.

an improved design or longer service life, the operator will reduce replacement frequency and associated costs.

"That is why we look at the entire customer problem when evaluating a PMA opportunity. Sometimes the problem is price. Sometimes it is lead time. Sometimes it is premature failure. The best PMA opportunities solve more than one of those problems simultaneously."

ATS branched into developing PMAs consumed during airframe heavy maintenance checks after originally starting as a leading airframe MRO in 1974. "Our wealth of airframe maintenance usage data and experience allow us to forecast upcoming material usage for a given fleet based on its utilization, size and age," Allen says. "This helps our customers understand and prepare for material demand spikes before they occur. The result is shortened span times for heavy maintenance visits and an agile understanding of upcoming material demand."

Cost Control

Many believe cost control is the most straightforward economic argument for PMA. In the aerospace aftermarket, the OEM possesses significant pricing power because the customer historically has had no competing source. PMA and DER repairs introduce competition into that market.

"ACS PMA products, for example, are generally priced approximately 25% to 50% below their OEM equivalents," Lipscomb says. "However, acquisition price is only one cost component. A lower-priced part that is available when the customer needs it is even more valuable, and a lower-priced part that also lasts longer can create an even greater lifecycle advantage. Airlines operate in an extraordinarily competitive

industry. If two airlines operate comparable fleets and one can safely reduce its maintenance costs through FAA-approved alternatives while the other voluntarily pays monopoly prices that cost advantage ultimately matters. PMA gives operators a mechanism to introduce competition and take greater control over maintenance economics."

In addition to inventory management efficiencies and reliability improvements, Allen says his FAA-approved PMAs save multiple major airlines around the world between 40-50% on their applicable material spend, annually. While Bolton states that cost saving has always been a factor within the PMA marketplace, over the last three or four years it has been less of a focus as time-to-market and availability have come to the fore. "We still generally offer a very cost-effective alternative but this is no longer No. 1 on the list of questions when talking to operators," Bolton adds.

"PMAs inherently have a pricing ceiling: the OEM," Voeller explains. "Airlines and third-party MROs that have adopted PMA strategies benefit from lower material costs than those that have not. Even when PMAs are not utilized in every eligible application, maintaining an established PMA program strengthens negotiating leverage with OEM suppliers and can drive more favorable commercial outcomes."

Overcoming Acceptance Issues

FAA-approved PMA parts have been around since the 1950s and Allen says their popularity has been booming since the turn of the millennium. "The reliability and performance of PMA have led to its long-standing reputation as being equivalent in reliability, safety, fit, form and function to an OEM part."

The "lessor non-acceptance" PMA stigma has largely been

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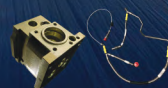
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eliminated with the PMA market/process now reaching maturity. Some of the largest aerospace organizations are now built on PMA such as HEICO/Wencor, Transdigm, LOAR and Ametek. However, Scott R. McNew, president of Aero Brake & Spares Inc., Lago Vista, Texas, asserts that, "There will always be contention in using an aftermarket product. Having inventory ready for repair stations and airlines tends to drive the acceptance of PMAs."

Markham explains that, "As the OEMs suffer supply chain challenges, some OEM or OEM-aligned MROs will look to HEICO PMA parts to meet their Turnaround Time (TAT) commitments. When the OEM asks an airline to approve the use of a PMA part in their repair, the OEMs are affirming that the PMA parts are of equal quality."

Sven Dicke, director of business and services—customer services at Liebherr-Aerospace & Transportation SAS, Toulouse, France, explains that, "There's a misconception that maintenance decisions are simply a choice between OEM and

PMA parts. In reality, operators typically utilize a combination of new OEM components, repairs, service bulletins, exchanges, used serviceable material (USM) and other aftermarket solutions.

Heico's Pat Markham emphasizes that PMA parts bring efficiencies to MROs and airlines by providing alternative sources for the various expendables, consumables and rotatable parts. Heico image.



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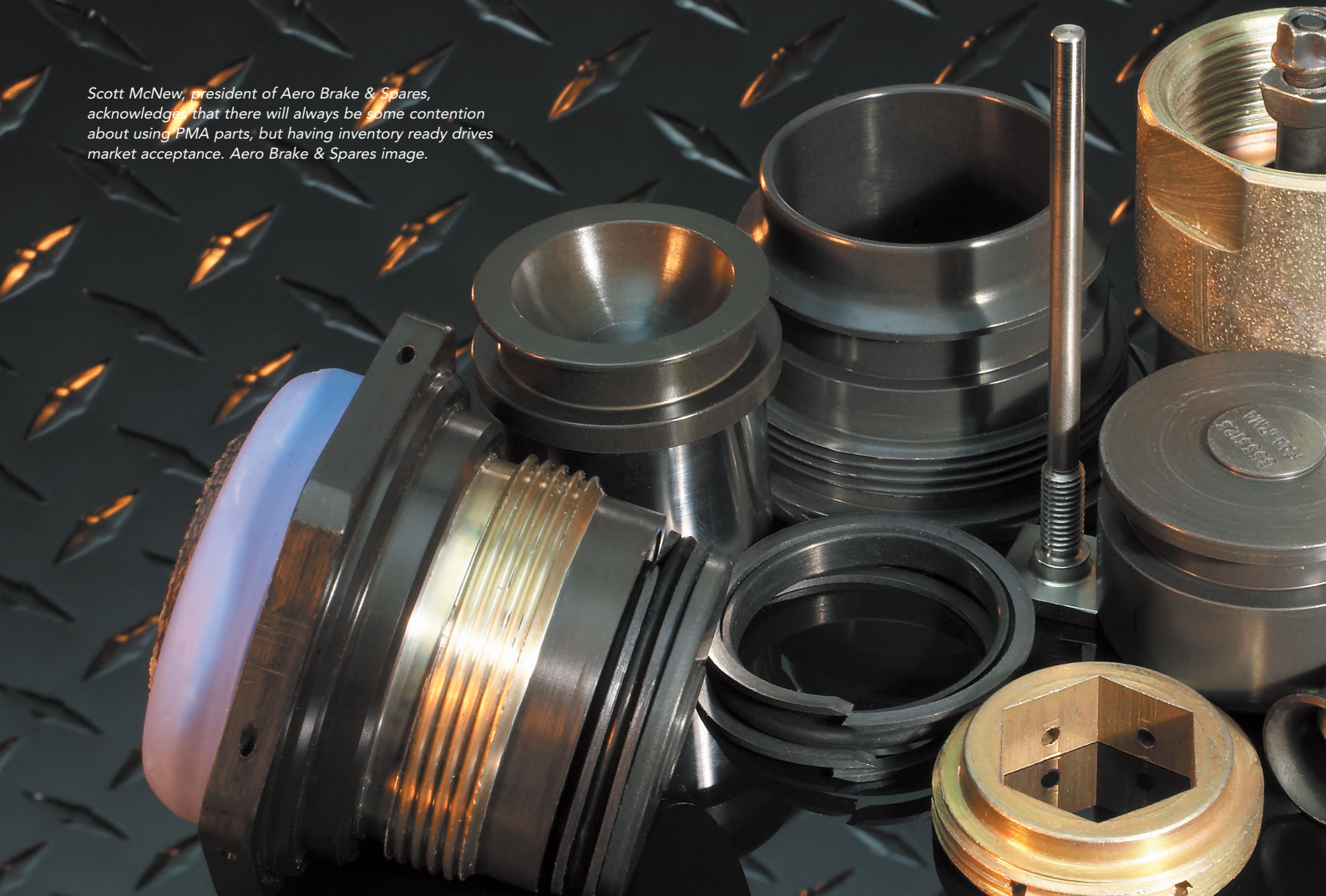
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A QUOTE

Scott McNew, president of Aero Brake & Spares, acknowledges that there will always be some contention about using PMA parts, but having inventory ready drives market acceptance. Aero Brake & Spares image.



A collage of images showing various aircraft, including helicopters and a fixed-wing plane, flying over a mountain range. Below the images are several aircraft parts, including landing gear, landing gear struts, and landing gear fairings. The collage is divided into three main sections: a red helicopter on the left, a yellow helicopter in the center, and a white fixed-wing plane on the right. The background of the collage is a blue sky with white clouds. The aircraft parts are displayed in the foreground, with some parts labeled with numbers like 16.2, 16.3, 16.4, and 16.5. The text "Proven and Reliable FAA-Approved Replacement Parts for Fixed Wing & Rotor Wing Aircraft." is written in white on a black background at the bottom left. The EXTEX logo is at the bottom right.



[Another misconception is] that acquisition price alone determines value. Most operators evaluate total lifecycle cost, including reliability, technical support, repairability, availability, warranty considerations and long-term fleet support."

Nothing is more persuasive than the recommendation of a fellow operator. As airlines and MROs continue to share their experiences, PMA acceptance continues to accelerate, highlighting the important role associations like MARPA play in educating the market. "We recognize that PMA parts are often held to an even higher standard of scrutiny than the OEMs when under review at the airlines and third-party MROs," Voeller says. "That's understandable, and it's a test that PMAs repeatedly pass. Operators gain the same fit, form and function, with better availability and lower cost. Try PMA once, and the value proposition becomes difficult to ignore. For many operators, the question is no longer whether to use PMA, but where to use it next."

In today's environment, operators are increasingly focused on resilience, lifecycle economics and operational performance. "Successful aftermarket solutions therefore combine engineering expertise, technical support, product reliability and a long-term commitment to customer support," Dicke says. "Regardless of the source of a component, the aviation industry relies on trust. Maintaining that trust requires rigorous standards, strong technical oversight and a commitment to continuous improvement across the entire value chain." **AAM**

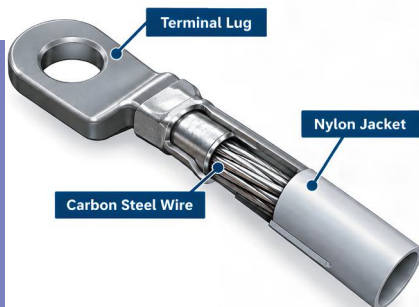
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Team JAS and PMAs: More than an Alternative Source of Supply

Today's PMA parts are positively affecting the aviation market by giving operators more than an alternative source of supply. At Team JAS, we believe the greatest opportunity starts with the operator. Whether a platform is early in its lifecycle and facing emerging technical or supply chain challenges, or has decades

of service experience behind it, operators understand where opportunities for improvement exist. Maintenance teams see recurring removal drivers, supply chains reveal availability challenges, and real-world operating experience provides valuable insight into how components actually perform. By partnering directly with operators and listening to those experiences, Team JAS can identify opportunities and develop practical PMA and repair solutions that improve reliability, availability and long-term value.

One example came from a regional Canadian airline experiencing recurring cracking and removals of heater prop leads on its Dash 8 Classic fleet. Beyond replacement-part cost, every removal meant technician time, maintenance intervention, and aircraft downtime. Team JAS worked with the operator to understand the application and operating environment, conducted material analysis, and engineered a PMA solution better suited to those conditions. Following successful testing and fleet deployment, the operator experienced a significant reduction in related maintenance events and unexpected removals.

That is the value proposition we see for PMA. The economics go well beyond unit cost. A part that improves reliability can also reduce maintenance events, protect aircraft availability, ease supply-chain pressure and help operators economically extend the productive life of their assets.

Utilization creates experience. Experience creates knowledge. And when customers and engineering partners put that knowledge to work together, it creates an opportunity to engineer greater value.

Jonathon Sanders, Team JAS, general manager, Jacksonville, Florida



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Artemis II Orion Capsule Splashdown and What Happened Next

By Marijan Jozic

There was a lot of publicity surrounding the Artemis II mission and the Orion capsule's flight around the Moon. Just to remind you, the astronauts flew from Earth to the Moon, made one orbit around it, and then returned safely to Earth. When I was a little boy, I was fascinated by that great adventure. Apollo 8 was the first crewed spacecraft to leave Earth's gravitational sphere of influence and the first human spaceflight to reach the Moon. The crew orbited the Moon ten times without landing and then returned to Earth. The three astronauts — Frank Borman, Jim Lovell, and William Anders — were the first humans to see and photograph the far side of the Moon and witness an Earthrise. All of that happened between 21 and 27 December 1968.

Many things happened after that, and eventually, after Apollo 17 in December 1972, there were no more crewed flights to or around the Moon. In the spring of 2026, mind you, 54 years after Apollo 17, NASA decided to send people around the Moon again. That was not an easy task because the blueprints and technology of Apollo could not simply be reused in a new environment. Technology has changed and improved, and new ideas and engineering approaches have made the spacecraft completely different. This time NASA sent four astronauts (three men and one woman), and the Orion spacecraft is significantly larger than the Apollo Command Module. The flight was successfully completed, and Orion splashed down in April 2026 at 00:07:27 UTC. The splashdown occurred within one mile of the target location. Orion was recovered by the U.S. Navy, and for the media that was essentially the end of the coverage.

But the story continues. If you are an engineer, you always ask yourself: what happens next? The rest of the story is just as fascinating. But let me start from the beginning. Space vehicles are, in many ways, similar to aerospace vehicles, and engineers always want to collect data and analyze it. You can always learn something from the information obtained and perhaps improve the design to make it even more reliable. That is exactly why NASA wanted to bring Orion back to the Cape. After a thorough investigation, there would always be time to send it to a museum and display it to the general public.

What could be investigated? Well, every aircraft maintenance program includes regular inspections of parts that have been subjected to stress. Orion experienced extreme stress during launch and throughout the mission. Think about the vibrations, enormous temperature changes, pressure differences between the cabin and the vacuum of space, and many other factors.

But first they had to transport that large spacecraft from San Diego, California, to the Kennedy Space Center (KSC) in Florida. If you transport bricks, you can find thousands of trucking companies willing to haul your cargo. If you transport wind turbine blades, there are only a limited number of companies capable of doing the job. But if you want to transport a spacecraft, you can probably count the qualified companies on the fingers of

one hand. It is highly specialized work that you may only do a few times in your lifetime. Yet there are companies that are both willing and able to take on such a challenge. They do this kind of work not because it is easy, but because it is difficult, and that makes completing it so rewarding.

The shipment was too large and too complicated to transport by aircraft. Therefore, NASA contracted Frontier Heavy Haul & Support Inc. to haul the Orion capsule from Naval Base San Diego, California, to the Kennedy Space Center, Florida.

Because it was such a delicate assignment, Frontier Heavy Haul & Support completed five practice runs. Altogether, they hauled the test capsule back and forth five times. These trial transports gave NASA the confidence that Frontier could safely transport the Orion capsule back to KSC. Needless to say, there were many technical coordination meetings. Every detail of how and when the capsule would be transported was carefully discussed.

Three trucks were used for the operation. The primary truck carried the capsule, a generator, and an air-handling unit. The generator and air-handling system were required to maintain a constant temperature inside the protective enclosure where the capsule was secured during transport. The idea behind this was to keep Orion in a stable temperature and humidity environment to prevent introducing additional stress to the spacecraft. You can imagine that if the capsule were transported through Arizona and New Mexico without temperature control, the spacecraft's outer skin could overheat, potentially causing additional microscopic cracks. NASA certainly did not want that to happen.

Because the convoy had to be completely self-sufficient, a secondary truck carried a spare generator, a spare air-handling unit, tools, and a forklift as backup equipment. The third truck was a bobtail tractor unit that served as a spare power unit in case one of the other trucks experienced a mechanical breakdown. The convoy was accompanied by two civilian escort vehicles from Frontier, two vehicles carrying seven NASA engineers, a security vehicle, and police escorts as required throughout the transport from California to Florida.

The first launch of Artemis II was originally scheduled for February but was postponed, so the entire transport project also had to be delayed. Frontier had to reschedule trucks and personnel for the next planned launch in March. The March launch was also postponed until April, when NASA finally succeeded in launching the rocket.

After splashdown in California, it took five days to load the capsule and all of its supporting equipment onto the trucks. The loaded dimensions of the primary transport vehicle were 80 feet long, 17 feet 6 inches wide, and 14 feet 6 inches high, with a gross weight of 96,000 pounds. On April 20, 2026, at 8:00 p.m., the convoy departed Naval Base San Diego and traveled across the southern United States, covering approximately 2,700 miles before arriving at the Kennedy Space Center on April 28, 2026,

at 5:00 p.m. During the journey, six different state police agencies escorted the convoy through their respective states. Every night, a two-person security team guarded the load while the NASA engineers continuously monitored the condition of the capsule throughout the trip.

A tremendous amount of planning and effort went into selecting the transportation route because permits had to be obtained for every state along the journey. Frontier also had to comply with state curfews, road restrictions, and construction schedules while still maintaining the planned delivery date. In Arizona, the convoy had to wait for a day and a half before it could continue because of highway construction. Despite these challenges, the load was delivered safely and on schedule, with zero accidents and zero incidents during the eight-day journey.

The spacecraft is now safely secured by NASA at the Kennedy Space Center in Florida. I briefly spoke with people from Frontier about the project and quickly realized that they do this work not because it is easy, but because it is difficult. Quite often, NASA and the astronauts receive all the recognition for a successful mission, while important details such as transporting a spacecraft 2,700



The Orion capsule was too large and too complicated to transport by aircraft, so NASA decided to send it home by truck. Frontier Heavy Haul & Support image.

miles across the United States receive only a brief mention in a local newspaper. Most people never realize how large and complicated such a transportation project is, or how many NASA requirements must be met to move a spacecraft safely from coast to coast.

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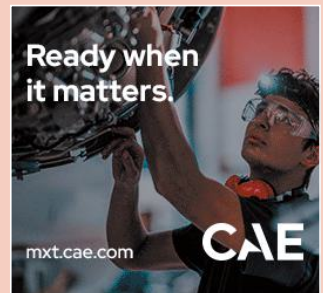
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Hidden Hazards: Dangerous Goods (Hazmats) on Aircraft

Hazardous materials are found throughout the aircraft. They can represent a physical danger to mechanics, but they can also represent a regulatory concern for the repair station that works on an aircraft (or on the components from an aircraft). Whether your repair station manages complete aircraft, or handles component-level work, it is important to be aware of (and to be properly trained on) hazardous materials regulations.

The international term for hazardous materials is "dangerous goods." While the law recognizes subtle differences between the definitions of "hazardous materials" and "dangerous goods," the practical differences are slight, so these two terms can often be used interchangeably.

When we think of dangerous goods in aviation, the media usually picture forbidden items in passenger luggage — like lithium batteries, aerosol cans, or fireworks; however, there is actually a substantial volume of hazardous materials installed in every aircraft. Awareness of these components can be important.

Many components are classified as dangerous goods. Because these items are essential to the airworthiness of the aircraft, and are typically called out in the type certificate or other government design approval, they are legally permitted on the aircraft. But when removing such components, it is important to protect persons from the practical dangers associated with these parts.

When shipping hazmats (such as when they are shipped to a repair station for component-level work, or when they are returned following such work) the law imposes strict requirements related to classification, identification, packaging, marking, labelling, documentation, etc. Even if your facility does not typically handle hazmats, it frequently happens that hazmats are mis-shipped to a facility. If your facility receives unwanted or unplanned hazmats, you cannot simply return them without complying with the legal requirements surrounding such goods (which include proper training for each person who affects the safe transportation of such goods).

What Systems Include Hazmats?

Here is a breakdown of some major systems that feature dangerous goods installed on modern aircraft.

1. Oxygen Generation and Storage Systems

Passenger cabins and flight decks require dedicated emergency oxygen systems. If the cabin depressurizes at high altitudes, these systems activate immediately, relying on two main types of hazardous materials:

- **Chemical Oxygen Generators:** Often found in the passenger service units above seats, these canisters contain sodium chlorate and iron powder. When activated, a chemical reaction produces oxygen. This reaction releases intense heat, making the generators a significant fire hazard if mishandled or improperly stored. They are typically classed as "oxidizers" under class five. Shipping these units requires special care. The United States system for shipping such oxygen generators varies from the international system, and U.S. law requires compliance with the different U.S. system (thus you cannot rely on the international norms). The United States system typically requires a government

permit to be issued to the manufacturer for the chemical oxygen generator. As a shipper, you should obtain a copy of this permit and follow its instructions.

- **Gaseous Oxygen Cylinders:** The flight deck and portable therapeutic units typically use high-pressure cylinders filled with compressed aviator's breathing oxygen. These cylinders can pose a risk of rupture if exposed to extreme heat or mechanical impact. When shipped, they are typically required to be packaged in specialized outer packaging that has been tested and shown to be resistant to both flame and heat (this specialized packaging is required under U.S. law for oxygen generators, as well).

2. Fire Suppression and Safety Systems

To combat fires in inaccessible areas like the cargo holds, engines, and auxiliary power units (APUs), aircraft are equipped with built-in fire extinguishing systems.

- **Halon Extinguishers:** Built-in fire suppression bottles utilize liquefied compressed gases (typically Halon 1301 or 1211). These cylinders are highly pressurized and must be handled with extreme care during maintenance.
- **Cartridges and Actuators (Squibs):** You would not want to rely on a valve that had to be operated in order to release the fire-suppressing chemicals. Such a valve would be used rarely and thus would be susceptible to sticking or other malfunction. To release the fire extinguishing agent instantly, these systems rely on a diaphragm that contains the chemical agent, and then a small, electrically triggered explosive device known as squib whose job is to remove the diaphragm when the fire suppressant is needed. These sorts of squibs are class one hazmats, and are typically shipped under a permit that is first issued to the manufacturer. Make sure you get a copy of that permit and follow its instructions. They are also typically subject to regulation by the Justice Department's Bureau of Alcohol, Tobacco, Firearms and Explosives, which has licensing mechanisms for those who handle and store explosives.

3. Evacuation and Survival Equipment

In an emergency evacuation, life-saving equipment relies on rapid inflation mechanisms driven by hazardous materials.

- **Evacuation Slides and Rafts:** The emergency slides at aircraft doors must inflate within seconds. They are packed alongside high-pressure cylinders containing a mix of carbon dioxide and nitrogen gas. Similarly, inflatable rafts and life preservers typically rely on high-pressure cylinders. The cylinders themselves are regulated as class two hazmats, while the slides, rafts and life preservers are typically regulated under class nine.

4. Advanced Battery Technology

Modern aircraft feature complex electrical systems that require reliable backup and auxiliary power, increasingly fulfilled by powerful battery systems.

- **Lithium-Ion Batteries:** Utilized for main aircraft batteries and auxiliary

power unit starts on newer aircraft, these batteries offer high energy density but carry the risk of thermal runaway if damaged or overcharged. Lithium battery shipping instructions have been changing rapidly for the last decade and it is particularly important to be correctly trained on the most current shipping instructions for lithium batteries. As part of our hazmat course, we publish an annually updated video on how to correctly ship lithium-ion batteries; the 2026 version of this video is available online at <https://www.youtube.com/watch?v=g3EcIIFz8ZA>.

- **Nickel-Cadmium (NiCad) Batteries:** Frequently used on older or mid-sized commercial aircraft for emergency backup power, these contain corrosive electrolytes and heavy metals. Most non-lithium batteries are regulated as class eight hazmats.

5. Instruments and Lighting Components

Even navigation and illumination systems can rely on materials categorized as hazardous.

- **Radioactive Materials:** Certain older flight instruments, navigational aids, and emergency exit signs utilize tiny amounts of radioactive isotopes (like Tritium or Krypton-85) to provide self-luminous glow-in-the-dark capability without electrical power. The modern trend has been to design radioactive luminescent articles (like emergency exit signs) so that their radioactivity level falls below the regulated level, so investigate your radioactives carefully to see if they are actually regulated under the radioactive shipping rules. Make sure you also comply with the regulations of the nuclear regulatory commission, which has a licensing mechanism for those who handle and store such materials.

- **Mercury:** Mercury can be found in older attitude gyros, tilt switches, and anti-ice system controls. Beyond its toxicity, mercury causes severe liquid metal embrittlement when it contacts aluminum, rapidly destroying the structural integrity of airframe components (I was once present for a D-check where the mechanics discovered evidence of damage from a mercury spill). It is typically treated as both a class eight corrosive and also a class six toxic material.

6. Fuel System Components

- **Residual fuel** is a class three hazard, and anything with residual fuel remaining in it is a class nine "dangerous goods in articles." Mechanics often want to know if there is a de minimis level of fuel that is no longer regulated. The answer is "no." As long as there is fuel residue in a component, it is still regulated as dangerous goods. If you can smell the fuel, then you are smelling the volatile portion that is most likely to be combustible, so you should treat such a smell as prima facie evidence that the component is a dangerous good.

As soon as a component is removed from the airframe, it can become a regulated hazardous material. It should be handled by someone who is trained on hazardous materials. In fact, U.S. and international law require that any person who classifies, packages, marks, labels, and/or documents such a dangerous good component must have been trained, tested and certified in hazardous materials regulations. We offer a public class twice a year to train and certify people in the aviation industry in how to properly handle and ship hazardous materials. **AVI**

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Getting Your Due

By Brett Levanto, Vice President of Operations, Aeronautical Repair Station Association

Complying with the rules entitles you to a certificate. Holding a certificate means you have rights. The aviation safety regulations include privileges and protections constraining industry non-compliance and government excess.

The United States Constitution guarantees "due process." The fifth amendment is famously invoked in high profile witness testimony, but it also declares: "No person shall ... be deprived of life, liberty, or property, without due process of law." In the practical sense, this right requires the government to establish and follow fair and objective procedures before taking punitive action.

For aerospace certificate holders, part 13 provides those procedures. The FAA's rules for enforcement include required actions and response timelines. The non-emergency process described in § 13.19(b) requires notices of proposed action including the following response options:

- (1) Surrender the certificate or pay the fine.
- (2) Answer the charges in writing.
- (3) Request an informal conference to discuss the matter.
- (4) Request the order be issued so it can be appealed.

ARSA members, particularly those who are clients of its management firm, have used informal conferences and written responses — often both — to mitigate wrongheaded government action and protect their aviation business. Upholding the requirements of due process allows an opportunity to either make a case or require the government to justify its actions. When justification is unsatisfactory, the system provides continuing opportunities for appeal to other tribunals.

A certificate is protected by the plain language of the rules. Failing to use the rules to your benefit is foolish; doing so effectively gives away the rights guaranteed by the law. Failing to use the response options of part 13 when facing either certificate action or civil penalty has immediate costs and long-term consequences of ongoing regulatory misbehavior.

An extreme example of such a consequence is the complete loss of legal protection. In June, ARSA informed Congress of an ongoing lawsuit against the FAA alleging the unlawful termination of FAA designees through the improper promulgation and enforcement of rules that deprive individuals of procedural due process. The plaintiffs claim the agency violated the Fifth Amendment as well as the Administrative Procedure Act by removing designee privileges without cause and directing designee action without the authority to do so.

The complaint filed with the district court includes a thorough history of delegated authority showing designees clearly "operated under a certificate" in the 1950s. Subsequent amendments to the rules gave the administrator unfettered discretion to terminate a designation and eventually altered the enforcement rules to separate its treatment of designees from any protection under the law.

"For reasons known only to the FAA, the FAA subsequently



asserted that Designees are not subject to [part 13's legal enforcement action rules]," the complaint said. "Rather, without legal support, and in direct contravention to the representations made to Congress ... the FAA has asserted that [procedural enforcement requirements] '[have] nothing to do with the FAA's termination of Designated Pilot Examiners or, for that matter, any other category of non-FAA employees whom the agency certifies to perform particular functions.'"

Given the historical movement stripping designees of due process protections, the complaint's "prayer for relief" seeks, among other compensation, re-establishment of clear rights for designees to appeal actions taken against them by the FAA.

No certificate holder should let the government take away basic rights. The class action suit represents an extreme situation after decades of changing law and policy. ARSA's greatest (perhaps) value to industry is leading in the example of vigilance against government actions that can impact the "life, liberty, and property" central to aviation business. **AM**

Brett Levanto is vice president of operations of Obadal, Filler, MacLeod & Klein, P.L.C., managing firm and client communications in conjunction with regulatory and legislative policy initiatives. He provides strategic and logistical support for the Aeronautical Repair Station Association.

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