Q4 DECEMBER 2024

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Aerospace Innovations brings you news, views and analysis of the commercial and defence sectors, in print and online, highlighting the latest innovations, technologies and solutions that are key to the future of the aerospace industry to meet performance and sustainability targets.

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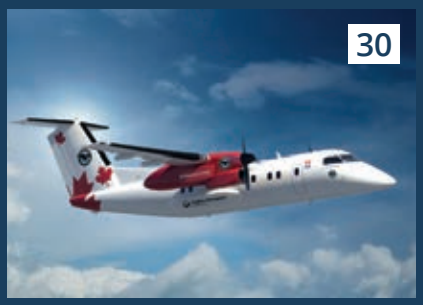

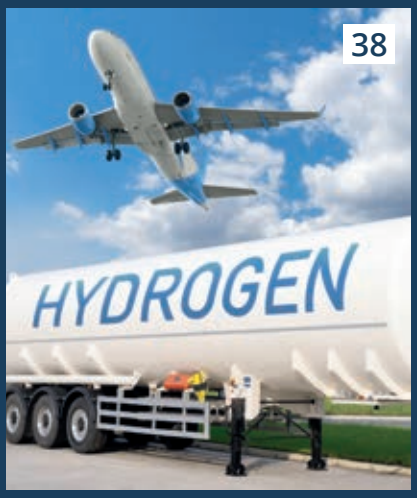

Aerospace Innovations Q4 December 2024 Issue

Welcome to the latest edition of Aerospace Innovations, at the end of another interesting and challenging year for the aerospace industry.

In our packed Q4 (December 2024) edition, Alex Preston continues his discussion with software engineering companies about DO-178C compliance and standards for safety-critical software testing. In his next article, Alex looks at EFB cybersecurity and speaks to numerous experts who have differing views and opinions as to what cyber risks exist with EFBs. The next article is by Ian Harbison, who talks with Rolls-Royce, GE Aerospace and Pratt & Whitney (an RTX business) about the next generation of engines that each company is developing to power the next aircraft platforms, and meet the ever-increasing sustainability targets.

James Careless dives into the world of real-time simulation and validation used in testing. Next, James speaks with the ESA and Viasat about the Iris ATC modernisation programme and finds out how it will be a game-changer for ATM in the coming years. In his third article, James speaks to a number of spare parts vendors about the challenges associated with Vertical Integration in the aviation supply chain. Next up, Mark Robins looks into the subject of predictive maintenance, and he talks with Airbus and other companies about how efficiencies in the MRO market can be gained with the increasing use of advanced software tools and in-depth data analytics. We have two guest feature articles in this edition. The first is from Cranfield University which talks about their Hydrogen Integration Incubator (CH2i) project. The second guest feature is from Rob Mather at IFS who discusses the growing use cases of AI in the MRO sector.

We hope to meet those of you who will be attending the Embedded World 2025 show, which is taking place in Nuremberg, Germany on March 11th-13th 2025. Aerospace Innovations is proud to be an official media partner of this important annual gathering of engineers and embedded software companies for various industries, including the aerospace, defence, automotive, and industrial sectors. We also hope to meet many of you who will be participating in our own Avionics & Testing Innovations Conference. The event is scheduled to take place on May 20th-21st 2025 in London.

We hope you enjoy reading this edition of Aerospace Innovations magazine and find it to be both informative and engaging. We would be delighted to hear from you if you have any comments or suggestions about our publication.

Meantime, we would like to wish all our readers and advertisers a Merry Christmas and a Happy New Year!

Best wishes,
Simon Barker & Neil Walker
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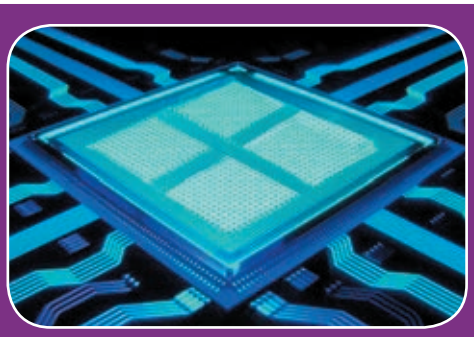
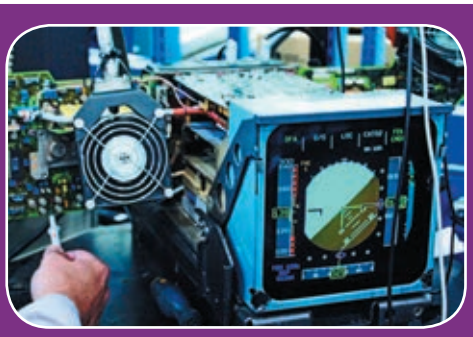



FLYHT Strengthens Partnership with WestJet for AFIRS™ 228 Order on Boeing 737 MAX-10 Fleet

FLYHT Aerospace Solutions Ltd has announced that it received an order from WestJet Airlines, Ltd. to install the Company's TSO approved AFIRS™ 228S satcom solution on WestJet's fleet of Boeing 737 MAX-10 aircraft.

"As we execute on our fleet growth and modernization plan, FLYHT's Iridium satcom solution provides us with the long-range data and voice communications that we require, while enabling us to maintain fleet commonality across our aircraft types," said Gandeephan Ganeshalingam, WestJet Vice-President Technical operations. "We are pleased with FLYHT's solutions on our 737 MAX-8 and 737NG aircraft, and are confident to utilize the product following the delivery of our Boeing 737 MAX-10 aircraft."

"WestJet's order of the AFIRS 228S TSO for their fleet of Boeing 737 MAX-10 aircraft expands our long-standing and valued relationship and is the latest demonstration of the strength of our AFIRS 228 product line," commented Darrel Deane, Chief Revenue Officer at FLYHT. "The solution enables WestJet and other airlines with MAX-10 aircraft on order to install and activate the AFIRS 228S TSO for safety services functions immediately after delivery. This contract deepens our relationship with WestJet and opens up additional growth potential for FLYHT."

This increase to the contract previously announced in 2020 is valued at approximately US$900,000, provided that all products and services are delivered over the contract term.

Lynx Software Technologies Announces Acquisition of Core Avionics & Industrial

Transaction positions Lynx to access the rapidly growing software enablement market for graphics processing units, which is expected to exceed $20 billion by 2030 .

Lynx Software Technologies, Inc, a leader in foundational, open architecture software solutions for edge computing, has announced the acquisition of Core Avionics & Industrial, Inc. CoreAVI is the leading provider of development tools, software libraries, and deployable software packages that enable safety-critical graphics processing unit ("GPU")-based computing, including certified graphics rendering, autonomy, and AI applications. The acquisition positions Lynx to tap into the rapidly growing market for GPU-enabled safety systems, which is forecasted to reach $20 billion by 2030 across aerospace, defense, space, and other mission-critical end markets.

Since its founding in 2005, CoreAVI's solutions have enabled semiconductor partners and customers to leverage the power of GPU-driven processing in safety-critical systems, initially to run safety-certified graphics in high-assurance systems, and then as technology progressed, to run machine-learning, neural networks, and AI workloads. Its differentiated products and technical software engineering capabilities support the expanding uses of GPU-based computing in mission-critical avionics platforms, space-based systems, military ground and naval applications, automotive, medical, and other industrial use cases.

Emirates receives its first of 65 A350-900s

Emirates has taken delivery of its first A350-900 aircraft, marking an important step in Emirates' fleet growth strategy. It marks the long-standing partnership between Emirates and Airbus which is built on innovation, efficiency and operational excellence. The A350 is set to enhance Emirates' medium and long-haul operations beyond the airline's existing network.

Emirates has ordered a total of 65 A350-900s as part of the airline's' broader plans to support Dubai's' Economic Agenda, which aims to add 400 cities to Dubai's foreign trade map over the next decade. The A350 will play a vital role in establishing the newly announced Dubai World Central (DWC) mega hub, further strengthening Dubai's position as a global aviation leader.

Emirates A350-900 will feature three spacious and comfortable cabin classes, accommodating 312 passengers (32 business, 21 premium economy and 259 spacious economy class seats). Emirates will also be the first airline in the Middle-East to introduce Airbus' new HBCplus satcom connectivity solution, offering seamless, high-speed global connectivity.

Teledyne's New Generation Onboard Secure Data Loader eADL XS™ Certified on Boeing 737NG Aircraft

Teledyne Controls, a leading provider of innovative avionics and aircraft data management solutions, is pleased to announce that its new onboard enhanced Airborne Data Loader (eADL XS™) has received certification for use on the Boeing 737NG aircraft series. Certification for other aircraft platforms is in progress.

Teledyne's eADL XS represents a new generation of dataloading technology and is the first onboard data loader to meet the stringent ARINC 645-1 requirements for OEM secure dataloading. With advanced features, such as built-in cellular and Wi-Fi connectivity, comprehensive validation of digital signature, and secure boot, the eADL XS ensures the integrity of software parts and protects against unauthorized access at every stage.

"We are thrilled to achieve this certification for the Boeing 737NG," said Mehrdad Radmehr, President of Teledyne Controls. "As aircraft continue to integrate powerful new systems and networks into their design, the software distribution process becomes more complex, opening more opportunities for cybersecurity attacks. This certification milestone demonstrates our commitment to providing cutting edge solutions to enhance the safety and efficiency of our customers' operations."

magniX Achieves Historic Milestone in Completing NASA Test Campaign

magniX, the company powering the electric aviation revolution, has announced a historic milestone in completing testing of its magni650 electric propulsion unit (EPU) at NASA's Electric Aircraft Testbed (NEAT) in Sandusky, Ohio.

The magni650 successfully performed at an altitude of 30,000 feet at a maximum continuous power of 700 kilowatts (kw) – an unprecedented achievement for an electric engine. The breakthrough performance of magniX's EPU under simulated flight conditions at altitude demonstrates its readiness for the flight test phase of NASA's Electrified Powertrain Flight Demonstration (EPFD) project and moves it closer to the world's first electric engine certification.

In the next stage of EPFD, one of the four turbine engines on magniX's De Havilland Dash 7 test aircraft will be replaced with a magni650 electric powertrain, with test flights planned for 2026. The final stage of the program will see a second turbine engine substituted with another magniX powertrain. This configuration is expected to reduce fuel consumption by up to 40% on a typical flight.

TAP Air Portugal goes live with AMOS

Swiss Aviation Software (Swiss-AS) is pleased to announce that TAP Air Portugal (TAP) has gone live with AMOS in October 2024. This marks a significant milestone for Swiss-AS, reflecting five years of unwavering commitment and collaboration to bring this transformative solution to life for TAP.

The successful implementation of AMOS at TAP, including the Component Repair, Overhaul, and Manufacturing (CROM) modules, is testament to the resilience and dedication of both teams. The pandemic presented unforeseen challenges, but our joint efforts have resulted in a highly tailored solution that meets TAP's needs and streamlines their maintenance and engineering operations.

Following the implementation of AMOS, TAP now has comprehensive process coverage, with only five of the 95 standard AMOS processes initially excluded from this scope. The new system replaces an impressive 39 legacy software systems previously used across TAP's operations, including both internally developed and third-party solutions. TAP now benefits from a unified platform that supports efficient, secure and scalable M&E processes.

CommuteAir signs Part Exchange Plus Program contract with Embraer for inventory management and repair services

CommuteAir and Embraer have expanded their cooperation by entering into a contract for the Exchange Plus Program to support CommuteAir's E-Jet fleet. Through the program, CommuteAir will be able to access tailored inventory management and repair services from Embraer's worldwide supply chain.

"CommuteAir is excited to build on its existing partnership with Embraer for our ERJ145 aircraft to now include parts inventory and repair support for our E-Jet aircraft," said Lon Ziegler, CommuteAir's Vice President of Technical Operations. "Embraer will help ensure we have a ready supply of parts to support our charter operations using the 76-seat E170 aircraft."

Exchange Plus Program is an integrated solution for customers seeking efficiency and cost-effective management of repairable components. With tailored inventory management and comprehensive repair services, customers can optimize their operations while minimizing downtime and associated costs. CommuteAir and Embraer have already partnered on rotable and expendable parts support for the ERJ145 fleet through the Pool and Inventory Planning programs.

Alliance Aerospace granted EASA Part 145 Maintenance Approval

Alliance Aerospace, as part of the Alliance Aviation Group, has been awarded EASA Part 145 approval from the Irish Aviation Authority. The accreditation bolsters capabilities at its 3000m2 FBO Hangar facility located at Westlands Apron, Dublin Airport (EIDW), Ireland.

The process of approval was completed within six months. With helpful assistance from the Irish Aviation Authority (IAA), Alliance Aerospace was able to establish the required procedures, equipment and personnel required to attain the approval. It can now provide MRO/AOG Support services from its Dublin base to General Aviation customers.

Initially targeting the Gulfstream family of aircraft, this EASA Part 145 approval augments Alliance Aviation Group's extensive portfolio of services, which includes CAMO support, aircraft management, aircraft charter, hangarage, ground handling and trip support services, plus technical assistance, all whilst operating to the highest quality safety standards.

Dassault Systemes and Cranfield University Launch Applied MBSE Course to Address Key Skills Shortages in UK Aviation

Dassault Systemes and Cranfield University have come together to launch their first-ever Applied Model-Based Systems Engineering (MBSE) continuous professional development (CPD) course, seeking to address key skills shortages in the U.K. aviation industry.

This new program is designed to equip system engineers with essential MBSE mindsets and skillsets, addressing industry demands for enhanced methodologies in product development. Developed in collaboration with leading industry partners, the Applied MBSE course bridges the gap between theory and practice, ensuring attendees are prepared to tackle complex challenges in modern engineering.

MSBE is crucial for the future of U.K. aviation as original equipment manufacturers (OEMs) grapple with increasing product complexity and global collaboration requirements. The Applied MBSE course aims to fill the skills gap by providing up-to-date training that emphasises early error detection, collaboration enhancement, and cost reduction.

Learners will become proficient in Dassault Systemes solutions such as CATIA applications and the 3DEXPERIENCE platform that allows OEMs and suppliers to view their shared projects in a virtual environment and handle everything from design and simulation to predicting supply bottlenecks and ultimately speeding up delivery times.

GE Aerospace, Boeing and NASA to study performance of installed Open Fan engine design for future of more efficient flight

A new project led by GE Aerospace, with collaboration from Boeing, NASA, and Oak Ridge National Laboratory will model the integration of an Open Fan engine design with an airplane, supporting the aviation industry's efforts to develop more energy efficient technology.

The U.S. Department of Energy announced that the effort has been awarded 840,000 supercomputing hours through its INCITE program. INCITE is a highly competitive program that supports the world's most computationally intensive projects.

GE Aerospace engineers have previously used exascale computing to model the performance and noise levels of Open Fan engine components. Open Fan architecture is a new design of jet engines that removes the traditional casing, allowing for a larger fan size with less drag to improve fuel efficiency.

Now, engineers will be able to study the aerodynamics of an Open Fan mounted on an aircraft wing in simulated flight conditions. This allows the engine design to be optimized for additional efficiency, noise, and other performance benefits.

Replicating a full-size integrated engine and airplane in the design phase would be impossible without the computational power of the newest supercomputing machines.

Airbus to provide UK Ministry of Defence with next-generation satellite modems for Skynet milsatcoms

Airbus has signed a contract with the UK's Ministry of Defence to provide the next-generation modems for the nation's Skynet satellite communications constellation.

The new modems are delivered for the Future Protected Modem Type-A project. They will replace the current Paradigm Modem System, support the Skynet 5 satellites and the yet-to-be-launched Skynet 6A satellite, and will provide several significant capability enhancements.

The new-generation, sovereign modem has been designed, developed and manufactured in the UK.

The FPMA Modem advanced Software-Defined Radio (SDR) system combines multiple techniques to provide a highly resilient solution, and is capable of hosting multiple waveforms. It will deliver safe and secure internet protocol (IP) communications on all commonly-used frequency bands, including X-band.

Airbus delivers first A330neo for Malaysia Airlines

Malaysia Aviation Group (MAG), the parent company of Malaysia Airlines, has taken delivery of its first A330neo. The A330-900, is the first of 20 to be leased from Avolon by MAG, setting new standards for fuel efficiency and passenger experience.

MAG's A330neo is configured with a premium two-class layout, featuring 297 seats, with 28 fully-flat Business Class suites and an all-new Economy cabin accommodating 269 passengers. Passengers will enjoy more personal space throughout, with larger overhead storage, improved air quality and the latest in-flight entertainment and high-speed Wi-Fi connectivity.

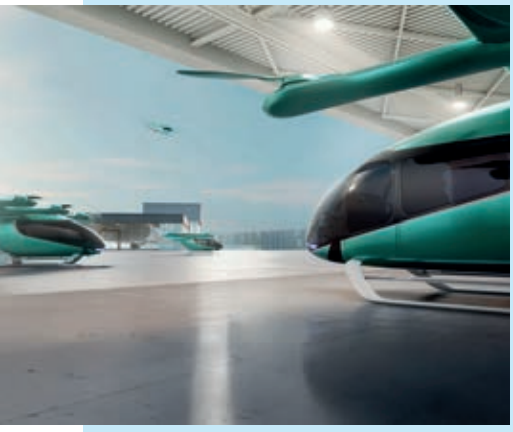
The airline will deploy the aircraft on routes across Asia and the Pacific, as well as on selected routes to the Middle East.

Eve Announces Additional US$35 Million from BNDES Line to Support eVTOL Development in 2025

Eve Air Mobility has announced a US$35 million* fund from Brazil's National Development Bank (BNDES), further solidifying its financial position for continued eVTOL development. This second-phase funding follows a US$92.5 million line of credit secured in 2022 for R&D and a recent US$50 million investment from Citibank, both dedicated to supporting Eve's eVTOL development program.

This second-phase investment from BNDES, sourced from the Climate Fund, will be allocated to manufacturing Eve's conforming prototypes and, subsequently, the commercial vehicle. The fund will also be used for testing processes. BNDES has been a key partner of the company's vision for Advanced Air Mobility (AAM).

The National Civil Aviation Agency of Brazil (ANAC) recently published the final airworthiness criteria for Eve's eVTOL, an important step towards type certification. This follows a public consultation period and allows Eve to proceed with defining the means of compliance for its eVTOL with ANAC.



Avia Solutions Group Orders up to 80 Boeing 737 MAX Jets to Gear Up Expansion

Boeing and Avia Solutions Group, the world's largest ACMI (aircraft, crew, maintenance, insurance) provider, recently announced its first order with the company for 40 737-8s, with the potential to order 40 more later.

Avia Solutions Group has 11 air operator certificates (AOC) including Avion Express, Smartlynx, Klasjet, Air Explore, BBN, Ascend Airways and Skytrans among others. These AOCs operate year round in over 60 countries on behalf of various scheduled airlines and tour operators.

As the world's largest ACMI provider, carrying over 35 million passengers annually for our clients, we have committed to a strategic approach of expanding our capacity to meet our customers' seasonal needs, and our first order with Boeing is a key pillar of this," said Gediminas Ziemelis, Chairman of Avia Solutions Group. "This is a proud moment for all of us at Avia Solutions Group and is testament to the fact that Avia Solutions Group is now entering a clear phase of sustained growth. These 737 MAXs will enhance the fleets of our airlines, giving their customers both operational flexibility and greater fuel efficiency."

The 737-8 is the market's most versatile single-aisle airplane, capable of operating profitably on short- and medium-haul routes. This flexibility is crucial for an ACMI operator like Avia Solutions Group, enabling it to provide additional capacity to airlines during peak travel periods or support operations during unexpected aircraft or staff outages.

FlexVNX+ Development Platform from Elma Offers Next-gen Testing Platform

Elma Electronic has released the portable FlexVNX+ development chassis that accelerates the development and testing of VNX+ plugin cards (PICs) aligned to both VITA 90 and The Open Group SOSA™ Technical Standard.

The new VNX+ standard defines an extremely compact footprint that reduces per-slot size by up to 70% over 3U VPX, making it ideal for space constrained applications, especially in rugged environments.

The benefits of VITA 90 standard, or VNX+, include high speed communications, with data rates up to 25 Gbps between modules per lane, within a scalable, modular architecture enables exceptional design flexibility for critical defense applications.

Specific uses of the new FlexVNX+ include mission control, secure communications, surveillance and data and image processing as well as weapons and navigational control, target tracking and display and threat detection.

Embraer strengthens industrial and research cooperation in the Netherlands

Embraer has taken a significant step in advancing its industrial and research cooperation with the Netherlands, fully aligned with Dutch policies aimed at developing the NLDTIB (Netherlands Defense Technology and Industrial Base). This effort builds on and expands the country's acquisition of the C-390 Millennium Military Transport Aircraft.

Embraer has selected Fokker Services Group to deliver an extended modification package, including turnkey engineering, certification and modification services for the C-390 military aircraft. These modifications will prepare the aircraft for use as a tactical transport for Special Operations of NATO (North Atlantic Treaty Organization), enabling a wide range of military and humanitarian missions.

Additionally, Embraer has signed an agreement with the Royal Netherlands Aerospace Centre (Royal NLR), to develop innovative technologies for aircraft maintenance. Multisim will also contribute by developing cutting edge technologies for virtual training, in collaboration with Rheinmetall, Dutch suppliers have been chosen to provide components for the C-390 Millennium full-flight mission simulator for the Netherlands.

ICEYE to lead industry consortium to deliver advanced space technologies and analytics to Finnish Government F-35 Industrial Participation program

ICEYE, the global leader in Synthetic Aperture Radar (SAR) satellite operations for Earth Observation, will be the consortium lead in an industrial participation program for the Finnish Ministry of Defense F-35 program. The consortium will develop advanced space and joint intelligence technologies, and Intelligence, Surveillance, and Reconnaissance (ISR) capabilities for military users such as the Finnish Defense Forces.

The consortium, comprised of ICEYE, and prominent Finnish industry players Insta, Huld, DA-Group, and the Finnish Meteorological Institute as a supplier, will work together with Lockheed Martin on advancing technological development. This will include the progression of disruptive capabilities such as analytics with Artificial Intelligence (AI), and encompass mobile ISR cell development, advanced analytics, and high-performance SAR imaging for all weather and light conditions, making it especially suitable for the demanding Arctic weather and light conditions of NATO's Northern Flank. Space-based intelligence remains a vital tool to support military operations across the land, sea, and air, and the program demonstrates Finnish willingness to develop and adopt advanced dual-use technologies that enhance operational efficiency and effectiveness on the modern battlefield.

The partnership between leading innovators within the defense and aerospace industry aims to support the Finnish Defense Forces with the goal to enhance the security of supply and strengthen Finland's position as a leader in cutting-edge aerospace technology. The advanced capabilities will also present opportunities for further expansion and collaboration with NATO Allies and other friendly nations, paving the way for export growth for the members of the consortium.

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Iris Set to Revolutionise European Air Traffic Control

Europe's airspace is one of the most congested in the world. Despite the heavy impact of COVID-19 on the world economy - including on the aviation sector - the number of flights returned to about 2019 levels in 2023 and is expected to reach the anticipated 50% forecast increase by 2050.

The problem with this growth is that the current terrestrial-based air traffic control (ATC) infrastructure is already getting saturated with current traffic (i.e., number of flights), at least in some major areas,and it is exhibiting issues in coping with the required Data Link Services (DLS) performance levels.

Iris is a secure solution based on Inmarsat (now VIASAT) space infrastructure. It is apparently able to solve this capacity issue, while increasing ATM resilience and performance. It's worth noting that a more efficient ATM also means shorter flights, less delays, and thus a greener --- less CO2 emitted --- air transport.

"Iris is a satellite datalink service for aviation whose definition, development and validation have been conducted under a Partnership Project between ESA and VIASAT and funded by the ESA`s 4S strategic programme line 'Space Systems for Safety & Security," explained Antonio Harrison-Sánchez, Product Assurance, Safety and Certification lead in the Iris Program. "Iris extends SB-S oceanic/remote service supported by VIASAT geostationary satellites operating in L-band to busy continental airspace, starting with Europe and scalable to provide global coverage. Iris supports safety services and applications for the current and future Aeronautical Telecommunication Network (ATN-B1 and ATS-B2) such as controller-pilot datalink communications (CPDLC) and automatic dependent surveillance contract (ADS-C) which enable amazing things like trajectory-based operations."

"What we're doing with Iris is providing essentially a lot more bandwidth and a lot more spectrum to provide more advanced services for air traffic communications," said Alex Holt, Viasat's Marketing Director for Flight Safety. "Right now there's a lack of things like VHF over the oceans for air traffic communications, and limited capacity of VHF in some continental regions. Iris solves that problem by providing a lot more spectrum and a lot more capability, via satellite. An Iris-equipped aircraft can share ATS B2 Extended Projected Profile, which is communicated with the air traffic controllers and telling them where the aircraft would like to go in order to be more efficient. This results in negotiations between air traffic and the aircraft in their area — allowing them to manage their airspace far more efficiently and optimise capacity."

The Power of 4D Trajectory-Based Operations

The capability being described by Alex Holt is known as 4D Trajectory-Based Operations, or 4D TBO, for short. 4D TBO refers to the sharing of trajectory and intent-based information between an Iris-equipped aircraft and air traffic control in four dimensions: latitude, longitude, altitude, and time. Through the sharing of such forward-looking trajectory information (aka the Extended Projected Profile/EPP), air traffic controllers have much more ability to manage their airspace in a proactive manner. They can optimise the amount of time that aircraft spend aloft burning fuel, through giving them the shortest available routes and the best altitude for engine performance, and minimising the need to put them into holding patterns.

Iris will also allow aircraft to employ continuous climbs and descents in order to save fuel. According to www.viasat.com, continuous climbs and descents [CCDs] can save an average 500 kg of fuel per flight. "Just 10% more CCDs per day will save 120 tons of fuel, enough to fly round trip from London to New York," the website said. Meanwhile, "It is estimated that up to 8% fuel savings could be

Thales AVIATOR 200S (Light Cockpit Satcom)

achieved across Europe by making direct routes flight plannable," said www.viasat.com.

The projected environmental impact of this improved flight management is significant. According to Viasat.com, the Single European Sky ATM Research (SESAR) Joint Undertaking "estimates that 5-10% of CO2 emissions generated by flights are avoidable due to outdated aviation infrastructure, which generates unnecessarily long trajectories and congestion in the air. Iris technology reduces fuel burn and emissions, reducing aviation's impact on the environment. Iris is a quick win for de-carbonization and the journey to net zero aviation. Thanks to Iris, the average CO2 savings per year in Europe alone are estimated to be around 2 Million tonnes."

How Iris Works

Iris' architecture consists of three main components: a ground segment, a space segment (satellite) and the aero segment (aircraft). The space segment consists of 1-4 Viasat geostationary satellites. The aero segment consists of Thales Aerospace Communications SwiftBroadband-Safety (SB-S) satellite terminals onboard Iris-enabled aircraft. SB-S equipment supports data links for Air Traffic Service (ATS) (ATN B1), plus ATS B2, ACARS (CPDLC & AOC), voice, and Airline Operational Communications (AOC), including IP connections for EFB (Electronic Flight Bags), all in one single system.

According to the VIASAT website, Iris is the only solution mature enough and available today to complement the existing terrestrial solution (VHF Data Link Mode 2 or VDL-m2), and offload excess traffic in a multi-link (or dual-link) fashion. "In line with the SESAR Joint Undertaking (SJU) ATM Master Plan, Iris was designed not only to comply with standards and performance requirements for ATS communications (RCP 130 and RSP 160 for ATS B2), but also to enhance safety and security and to support data-hungry AOC services. It is easily scalable with the potential to meet future needs," the website said. "An Iris capacity study, carried out by the Iris consortium and based on SESAR Deployment Manager traffic assumptions, has indeed confirmed that Iris has sufficient capacity, by large margins, to support both the volume of data expected to be offloaded from VDL2 and the increased traffic anticipated in the coming years."

Finally — and this is a top priority for aviation in this age of cyber terrorism — "Iris represents a secure, reliable and cyber resilient solution, with cyber resilience to malicious attacks," said www.viasat.com. "The satellite offers immediate coverage across Europe and has scalable potential to become a global service, as well as supporting data hungry services."

Progress to Date

At present, Iris has been deployed and is in its pre-commercial operational phase, with the active support of easyJet. "Several Airbus A320 NEO aircraft from easyJet have been equipped with Iris satcom technology and are participating in 'pre-commercial flights' in Europe since early 2024," said Harrison-Sánchez. "Nearly 4000 flights have been logged to date with excellent performance. The expectation is to continue the deployment of Iris equipped aircraft in Europe, with the goal of reaching a substantial percentage of the aircraft fleet and unlock all of the safety, operational and environmental benefits, and to start the Iris service expansion globally to Asia and the USA."

easyJet exhibited justifiable pride in announcing its Iris participation to the world on January 29, 2024. "easyJet has taken to the skies as the

Copyright: ESA-Pierre Carril

first airline partner of the ground-breaking Iris programme, an initiative led by the European Space Agency (ESA) and global communications company Viasat, which is using the latest generation of satellite technology to help modernise air traffic management (ATM)," the airline company declared in a news release. "The EASA-certified Iris service provider ESSP [European Satellite Services Provider] has involved 15 [now 19] leading Air Navigation Service Providers (ANSPs) in support of the first commercial flights taking place across Europe this year — with up to 11 easyJet Airbus A320neo aircraft taking part. This initiative is a European first in putting the Single European Skies initiative into action."

The importance of this advance was emphasised by Hugh McConnellogue, easyJet's Director of Operations & Navigation. "More efficient use of airspace is a critical way we can tackle the industry's emissions right now," he said. "Adopting Iris technology on these aircraft will enable easyJet to fly more directly and efficiently, thereby reducing carbon emissions as well as enhancing our on time performance — which in turn improves our customers' experiences. We're thrilled to be paving the way in this area whilst working towards our goal to achieve our net-zero ambitions by 2050, as outlined in our roadmap."

ESSP Chief Executive Officer Charlotte Neyret was similarly enthusiastic. "These first commercial flights are bringing to reality a decade of both vision and investment in this new datalink communication solution to achieve safer and greener aviation," she said. "ESSP is delighted to operate this moment of synchronisation between all stakeholders, from industry to airlines, with the proactive contribution of numerous Air Navigation Service Providers. Thanks to all partners, ESSP is proud to provide Iris Satcom datalink service to Europe, as well as to initiate the Iris flights with a key airline such as easyJet. Iris technology allows the development of new environmentally friendly routes, which will improve ATC management, reduce fuel costs and lead to the deployment of more efficient air operations."

The fact that EasyJet is using Iris today is a big boost for this transformative technology. "It's always important to get flights under your belt and to be in the position that we're in today, with the test flights going extremely well," said Holt. "The performance of the Iris service is proving to be super high

in terms of minimal latency, and it is meeting all the criteria for next generation services in Europe."

Since Viasat's plan is to deploy Iris globally, the company's engineers are working to ensure that the system will run on the ATN/IPS standard that Asia and the US are looking at, as well as the ATN/OSI standard being used in Europe. "No matter what protocol the different parts of the world are using, we're going to have a special router built into our systems that can easily convert between the two," Holt said. "So we'll be ready to go global."

As for deploying Iris equipment on board commercial airliners? Holt said that this equipment is available for Airbus aircraft as a "line fit" option, meaning that customers can specify it to be installed as their aircraft are being built. (Retrofits are also available for Airbus aircraft.) Meanwhile, "Iris is also available on Boeing, although it requires one or two elements of avionics upgrades to get the full capability out of it," he told AI magazine.

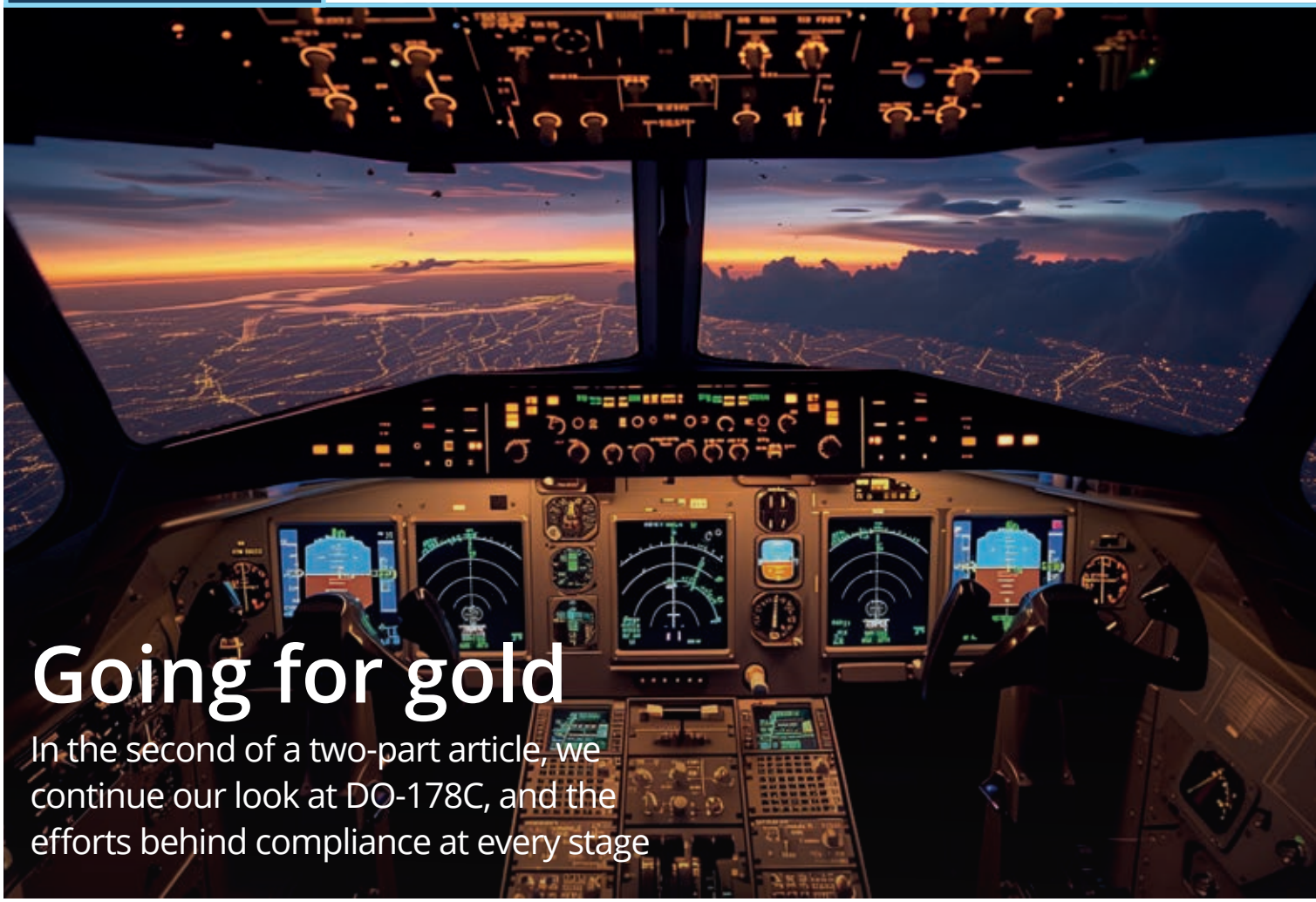
So far, 11 easyJet Airbus A320neo aircraft are Iris-equipped, with three of them using the technology in flight so far. "In the next three years, there'll be approximately 250 aircraft in Europe rolling off the Airbus production line fitted with Iris hardware," said Holt. "So yes, we're live and flying."

This being said, there have been challenges associated with getting the Iris Programme up and running. "Some of the challenges include the buy-in of all stakeholders in Iris, the large-scale deployment, and the global expansion beyond Europe," Harrison-Sánchez said. "ESA and partners are working on addressing these challenges through stakeholder working groups, engagement of the European Union aviation institutions, and ongoing ESA-funded projects such as 'Iris Global'.

With success will also come a capacity issue over the mid/long term, which must be anticipated today to have the appropriate responses deployed in a timely manner."

Nevertheless, "Iris technology is already transforming aviation in Europe by delivering benefits to the operator and air navigation service providers," he said. "Some of these benefits include: alleviating pressure on the terrestrial VHF datalink networks, offering the potential to enable optimised paths through trajectory-based operations, reducing fuel consumption, and cutting CO2 emissions. To fully unlock these benefits, a substantial percentage of the aircraft fleet needs to be equipped. But ultimately, Iris will help increase airspace capacity to accommodate future sustainable growth."

By James Careless



Going for gold

In the second of a two-part article, we continue our look at DO-178C, and the efforts behind compliance at every stage

As was discussed in our previous article ('Making Do with safety Standards', Aerospace Innovations Q3 October) DO-178C was introduced to address several deficiencies and ambiguities in DO-178B. The revision primarily sought to enhance clarity, reflect modern software engineering practices, and provide better guidance on using advanced technologies without increasing the effort needed to demonstrate compliance.

The revision was necessary to align the standard with technological advancements and to address the evolving complexities in software development, ensuring that the standard remains relevant and effective in mitigating risks in safety-critical software.

According to Dr Daniel Wright, technical writer at Rapita, DO-178C is used not only in the context of civil avionics, but is often seen as the gold standard for safety-critical software verification in other contexts, and many of the principles of DO-178C are used by standards in other fields such as military avionics or space software.

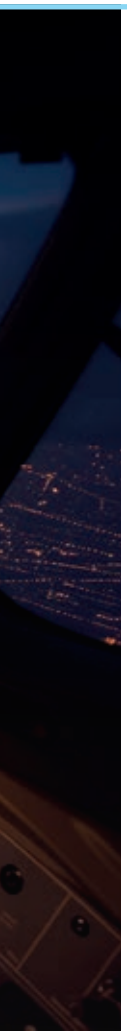
"DO-178C and associated guidance acts as an appropriate safeguard to the release of novel, unproven technologies into commercial airspace, such as AI technologies. These technologies can offer huge benefits in many areas, but first and foremost, we need to make sure they're used safely."

As Dr Benjamin Brosgol, a senior member of the technical staff at AdaCore explains, "DO-178C is applied as part of an overall systems engineering effort; safety is a pervasive system-level property that needs to be addressed early." Expounding, Brosgol says that as part of the system life processes, system requirements are specified and allocated to either software or hardware, and the software level (DAL) is determined. These requirements include functional requirements for ensuring correct operation, and safety requirements for preventing hazardous conditions. The requirements and associated DAL serve as input to the software life cycle processes defined in DO-178C.

DO-178C defines three kinds of software life cycle processes, which are performed concurrently: Software Planning Processes, Integral Processes (Software Verification, Configuration Management, Software Quality Assurance, Certification Liaison), and Software Development Processes (Software Requirements, Software Design, Software Coding, and Integration). An organisation complying with DO-178C needs to have a well-defined software production infrastructure in order to meet the objectives specified for these processes. "Effectively performing integral processes such as Configuration Management and Quality Assurance (QA) is critical," Brosgol asserts.

Digital demands

"Most aviation system providers have been developing software to DO-178(A/B/C) for many years



DO-178C checklist review process. (Copyright: Visure)

and have refined their processes in conjunction with the certification authorities designated engineering representatives (DERs) to meet their development needs," states Gary Gilliland, VP of Marketing at DDC-I. "I believe the digitalisation of the design has prompted more use of model-based development and the use of simulation environments to design, build and test new systems. Utilising the guidance in DO-178C to certify these systems presents a challenge for the certification authorities to understand these new technologies and how the proof of the design is represented."

With the increasing digitalisation of aviation—encompassing everything from design and manufacturing to operation and maintenance—the need for standards like DO-178C has grown.

Brosgol agrees that digitalisation introduces new complexities and a greater reliance on software, heightening the risks associated with software failures. "Adherence to DO-178C helps mitigate these risks by ensuring that digital systems are developed with the required attention to safety and reliability," he says.

It's a point of view upheld by Sysgo's Technical Product Marketing Manager, Amani Karchoud. "The growing digitalisation in aviation heightens the need for such standards to ensure software integrity and reliability given the increased complexity and integration of digital systems in aircraft."

To all intents and purposes, DO-178C is the codification of best software engineering practices for developing and verifying airborne systems. Its benefits are multitude and includes increasing the confidence in the safety, reliability, maintainability and traceability of airborne software, facilitating regulatory certification, and providing a transparent, structured approach to conducting the software life cycle processes. It helps organisations avoid the potentially catastrophic consequences of software failures, thereby protecting lives and reducing legal and financial liabilities.

A question of costs

Following DO-178C to realise these benefits does come with an increased cost of development, testing, and certification. However, as Steve DiCamillo, Technical Marketing and Business Development Manager at LDRA points out, this saves money in the long run by practically avoiding catastrophic failures resulting in loss of life, loss of equipment, and civil penalties.

While upfront costs are higher due to the stringent processes, these are often offset by the benefits of having highly reliable software in critical applications.

It's an assessment shared by Brosgol, who adds that over the lifetime of an airborne system, adhering to DO-178C can reduce costs associated with fixing post-deployment issues, avoiding legal repercussions, and maintaining a solid industry reputation. He acknowledges that while compliance with DO-178C does add additional costs to software development — due to the rigorous processes, extensive documentation, and thorough verification required — these costs are justified by the high level of safety assurance that the standard provides.

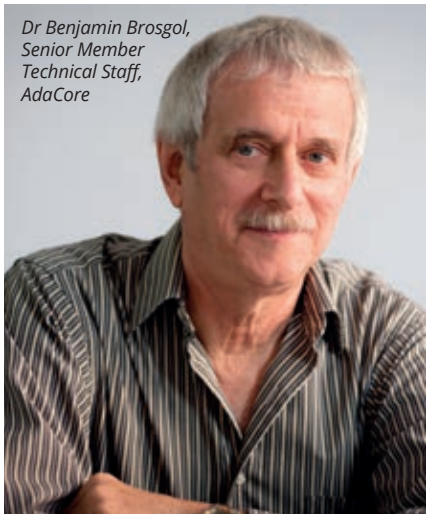
Admitting that compliance adds additional costs to software development, Wright says this is commensurate with the importance that the software does not fail. More details are given by Gilliland.

"DO-178C processes do add additional costs to the software development process. This is really about the manpower required to guarantee the software does what it is supposed to do reliably. The development of detailed requirements, requirements-based test code, code reviews and verification with independent engineering groups is a significant effort especially for DAL A. The benefit of this process if done correctly, is that the software has very few defects and if defects are found the documentation, tests and traceability from requirements to code provide an easily understood explanation of the problem."

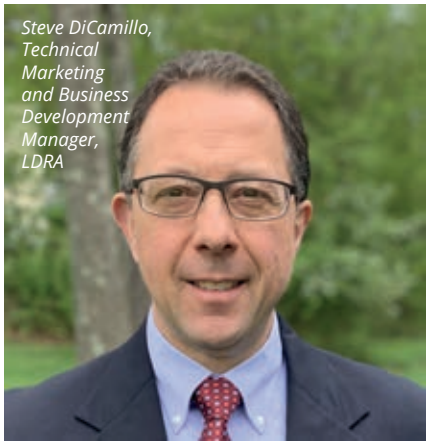
Amani Karchoud, Technical Product Marketing Manager, Sysgo

"The growing digitalisation in aviation heightens the need for such standards to ensure software integrity and reliability given the increased complexity and integration of digital systems in aircraft."

Amani Karchoud, Technical Product Marketing Manager, Sysgo.



Dr Benjamin Brosgol, Senior Member Technical Staff, AdaCore



Steve DiCamillo, Technical Marketing and Business Development Manager, LDRA

Development goals

Companies work hard to accomplish the criteria of system requirements and system implementation conforming to these obligations. They typically establish robust development environments with strong quality assurance processes, use advanced tools for design and verification, and conduct extensive testing, says Karchoud, who adds that building the right product involves close collaboration with stakeholders, rigorous compliance to standards, and continuous feedback loops during the development process.

Rapita's motto is safety through quality. The company develops its products, shares recommendations, and delivers training and engineering services, including process definition services, with DO-178C guidance firmly in mind. Wright says that while efficiency is a key motivating factor in its solutions, within the context of DO-178C solutions, safety is always the most critical factor.

Gilliland believes that DDC-I as a real-time operating system (RTOS) provider is in a unique position in the certification process. For example, the company's Deos RTOS was first certified in a system in 1998 and is currently certified and flying in systems in over 10,000 aircraft.

"Deos was designed from the ground up to meet the safety and certifiability requirements of avionics systems," explains Gilliland. "As such, Deos provides some unique capabilities that enable the developer to create applications built out of components that are independently verifiable and linked on the target. This component-based model greatly reduces the cost of certification and enables rapid product line innovation."

According to Gilliland, for multi-core systems, Deos provides patented capability to manage contention for resources such as cache and memory busses. "All the requirements for the Deos RTOS are derived requirements based on the set of capability that we believe the industry needs," he states, adding that, "Our customers system requirements trace to the Deos functional requirements for the application interfaces that they use to implement their software. This provides the necessary traceability throughout the entire system. Over the years as we create new verification baselines, we add capability to support new processors and functionality as well as additional software APIs and compiler functionality to meet the needs of our customers"

Conversely, DiCamillo says that LDRA solutions focus on the verification of software – ensuring the software (product) is built correctly, in compliance with its requirements. "That is somewhat different than assuring the requirements are correct," he asserts.

For DiCamillo, the LDRA tool suite plays a crucial role in achieving DO-178C compliance for software projects in the aerospace industry, providing comprehensive support for the achievement of objectives throughout the software development life cycle. He claims that static and dynamic analysis capabilities allow developers to identify and rectify issues early in the development process in accordance with the standard.

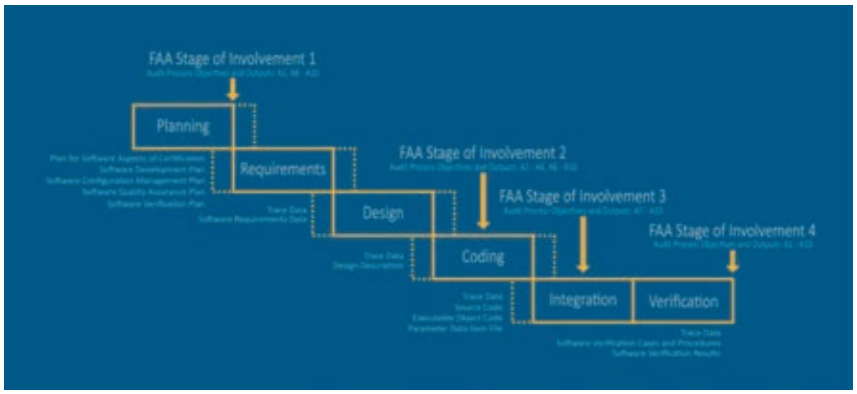
As an example, he cites that LDRA static analysis tools automate the scanned "inspection" of the source code, highlighting non-conformances as required by DO-178C §6.4.3d. Static analysis is valuable both for catching errors as code is written, and for highlighting those issues that only become apparent during integration (DO-178C §5.4).

Other highlights include the on target "test cases and procedures" supported by the dynamic analysis functionality of the LDRA tool suite include low-level tests, integration tests, and system tests in accordance with DO 178C §6.4.4.2. The tool suite automates structural coverage analysis for all metrics specified in the standard, including MC/DC. LDRA also offers a range of tools to support project managers as comprehensively as developers and testers, particularly through Stage of Involvement (SOI) reviews.

Taking counsel

DO-178C addresses more modern software development practices such as use of object-oriented technology, model-based development and formal methods, to expand the acceptable methods for verifying software. Organisations developing safety critical software are required to provide detailed documentation of the design and proof that the software performs its functions correctly, reliably and safely. By reason of these requisites, it can be daunting to those embarking on developing safety critical software in compliance with DO-178C, but words of encouragement are at hand.

"Start at the beginning," advises Gilliland. "In order to be successful, you must have a good understanding of what you are trying to accomplish and how to manage development of the software."



Visual Summary of DO-178C Processes. (Copyright: EXB Solutions)

A detailed set of requirements are key to developing safety critical software. Both Brosgol and Karchoud advocate for investment in the training development teams and their familiarisation with DO-178C processes. Without this the constant changing of requirements and iteration of software tends to adversely affect the software development costs, warns Gilliland.

Brosgol also favours emphasising requirements engineering. "Invest time in accurately capturing and validating system requirements and in specifying whether these requirements will be met through software or through hardware. Ambiguities or errors at this stage can lead to significant issues later," he cautions.

Another piece of advice proffered by Brosgol is the use of safe languages. Stating that programming languages vary in their ability to catch errors early in the development life cycle, Brosgol says an organisation can reduce its certification cost by choosing a language that helps avoid vulnerabilities such as "buffer overrun", referencing the Ada language, which was designed to enforce sound software engineering principles.

A common recommendation from those approached was to utilise automation and qualified tools to streamline compliance. Leveraging static and dynamic analysis tools can improve the safety and reliability of software and simplify the certification effort.

For example, conforming with "Code Standards" (i.e., ensuring that the source code stays within a specified subset of the programming language and adheres to complexity or other restrictions) is one of the objectives in DO-178C. Qualified analysis tools can expedite demonstrating that this objective is met, whilst dynamic analysis tools can help show that the relevant requirements-based test coverage objectives have been met.

At the highest software level (DALA) formal methods and tools such as AdaCore's SPARK Pro can facilitate meeting some of the verification objectives. As Brosgol explains, SPARK Pro starts with a firm foundation - the SPARK language. "Unlike most programming languages, in which it is easy to misuse pointers or get an unexpected result on integer overflow, SPARK Flow and SPARK Proof prove that code is memory safe, free from runtime errors, and uses pointers and other features correctly," he says.

Getting into more details, Brosgol asserts that SPARK Proof provides formal verification that is automatic, reproducible, and integrated into the software development process. "In many software applications, especially low-level, embedded applications like firmware, testing is impractical for some parts of the code. But once you've used the SPARK language to capture your functional requirements as contracts (assertions about the state of the program at specific points in the source code), SPARK Proof will prove, with mathematics-based logic, that your code satisfies its contracts. This is done through static analysis, without executing the program; there is no run-time overhead. So, you can be sure your software meets the requirements embodied in the contracts, even when testing is impossible or impractical," he states.

Other points on the advisory list include implementing rigorous documentation and traceability processes. Adopting an iterative development approach with regular reviews and audits can help ensure compliance and catch potential issues early. DO-178C also requires the preparation of a large number of artefacts: plan and allocate resources to produce and maintain the necessary artefacts throughout the development process; Engage with certification authorities early in the development process to ensure that the approach to compliance is aligned with their expectations; and encourage a culture where safety is prioritised in every aspect of software development. This mindset should permeate the entire organisation, from developers to management.

Expect the unexpected

For DiCamillo, ultimately, no matter how well a company plans for cost, time-to-market, and risk factors, an evolving landscape hides unexpected setbacks, which can range from supply chain and workforce shortages to cybersecurity threats and new regulatory requirements.

"The avionics and aerospace industry are cautious for good reason," he says. "But in many organisations, that caution can lead to hesitation to change development and testing processes, tools, and models. Gap analysis to assess the additional processes and resource to achieve compliance allows business executives to question development and testing processes and tooling, even as standards are evolving and issues such as cybersecurity are gaining attention and enforcement."

He believes that successful organisations understand that the future will only become more challenging, and that the time to

Dr Daniel Wright, Technical Writer, Rapita

Gary Gilliland, VP, Marketing, DDC-I

address concerns and make fundamental changes is now—not during a future critical product launch.

"A flexible, robust, and scalable development process offers the best chance for successfully addressing challenges and reducing risk and uncertainty," he says.

"With a comprehensive verification tool suite boasting consistent user interface for all aspects of verification and validation, teams are well-armed with documentation and shared knowledge throughout the process. Integration with associated development tools throughout the product development lifecycle provides a foundation for overcoming the challenges of certifying next-generation flight software."

Wright agrees asserting that for organisations new to DO-178C, one of the biggest cost drivers is underestimating the impact of compliance on the project as a whole, including the development process.

"For efficient software development and compliance, the entire project life cycle, from planning to approval, should be DO-178C compliant. For some organisations, that may mean forgetting everything you think you know about project planning, software development and verification, and starting again with DO-178C training, gap analysis, process definition and selection of hardware, software language, standards, and architectural models, and verification tools."

By Alex Preston

Trends in Real-Time Simulation and Validation Testing: An Aerospace Innovations Roundtable

Real-time simulation and validation testing is an effective way for the aerospace industry to test aviation systems and diagnose potential problems in the digital realm, before committing resources to build actual equipment in the physical world

Two of the leading companies in the real-time simulation and validation testing sector are dSPACE (dspace.com) and RTI (www.rti.com). In this exclusive Aerospace Innovations Roundtable, top experts from both companies will reveal the advances, market trends, and customer requirements that are driving this sector. Francisco J. Flores Sanchez is the Business Development Manager for dSPACE Aerospace & Defense. John Breitenbach is RTI's Director of Aerospace and Defense Markets

Aerospace Innovations: To begin, what is new in real-time simulation and validation testing for aerospace?

Francisco J. Flores Sanchez: As the aviation market continues the path to introducing alternate fuels and harnessing electrical power, their need to test these concepts becomes crucial as they seek to move through a path to certification. dSPACE has been at the forefront of aiding the automotive industry in the same endeavor; thus, is in a unique position to take on this task with current and upcoming aircraft companies.

Our battery management testing solutions allow these companies to simulate the behavior of battery cells to meet the strict requirements to operate within the acceptable safety margins of aircraft operations. dSPACE Power HIL solutions provide real power to facilitate inverter development by emulating motors and batteries during hardware in the loop testing. Our Power HILs provide the flexibility of testing advanced failure scenarios not feasible with a real motor to meet the wide range of strict requirements needed to ensure their safe operations.

John Breitenbach: In aviation, real-time simulation and validation testing are advancing quickly, with a strong push for digital twins, model-based engineering, and new capabilities in simulation software. These tools help developers and operators create realistic virtual models of aviation systems, making it easier to test performance limits and predict outcomes with greater accuracy.

There's a rising demand for training on real systems, where using real-world data has become a critical requirement. The more realistic the training environment, the better operators retain and apply what they've learned. Training within the actual system and incorporating real data into simulations builds confidence and prepares operators to perform effectively when it matters most. At the same time, there's a strong push for simulations that support multi-domain operations as the prevalence of these systems on the battlefield rises, showing how manned and unmanned systems work together in complex environments will be evermore critical.

Furthermore, the drive to develop superior systems faster has led to innovations in testing, where decoupled systems are tested together. This approach has proven effective in accelerating deployment. Altogether, these advancements are not only speeding up system development and certification — essential for next-generation aviation technologies — but are also transforming training by providing personnel with hands-on, data-driven experiences that build readiness more effectively.

At RTI, we're directly addressing these industry priorities with RTI Connext®. Our solution is built to support faster development cycles, enabling operators to train with real data, in real-time, for real-world results.

Our high-performance data

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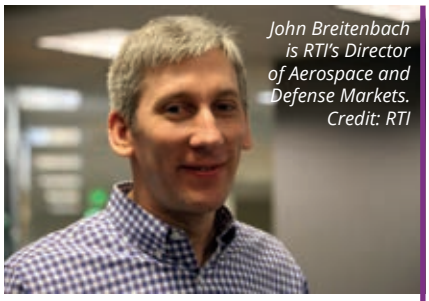
distribution service supports complex aviation simulations by delivering reliable, low-latency data, enhancing real-time situational awareness and speeding up decision-making and validation testing. Connext seamlessly integrates diverse systems, with modular configurations that adapt to the latest technologies in aviation. We're also enhancing safety-critical applications with RTI Connext TSS (Trusted Systems Solution), which provides real-time, reliable data connectivity that complies with a path to DO-178C certification. Built for interoperability, Connext TSS gives aerospace engineers a powerful framework for testing in realistic simulations, allowing both development and training efforts to meet the highest standards of reliability and performance.

Aerospace Innovations: What other trends in real-time simulation and validation testing are driving the marketplace?

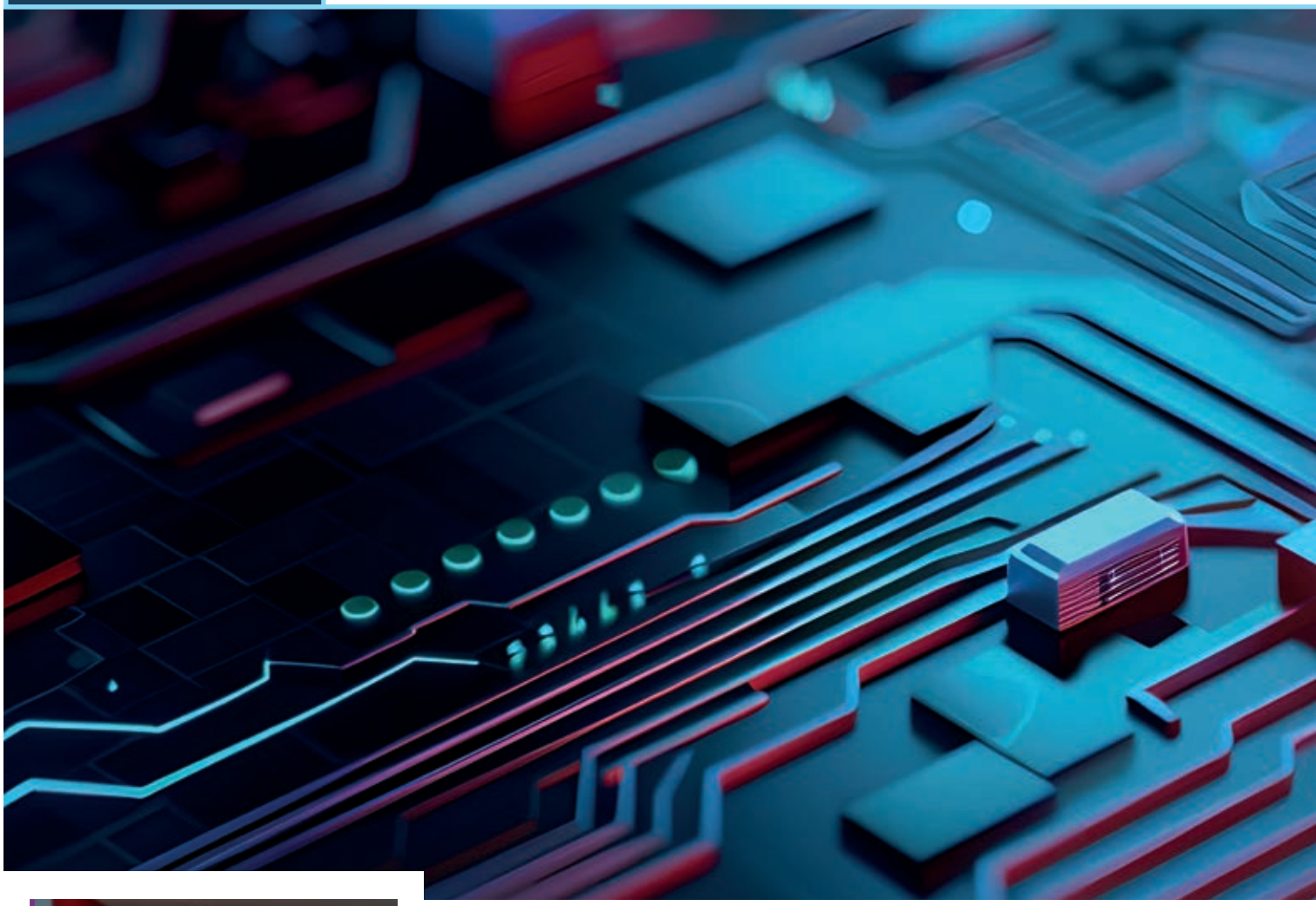
John Breitenbach: Apart from the ones mentioned above, we're seeing shifts in areas like AI and machine learning integration, cross-domain interoperability, and the growing demand for digital twins. AI-driven simulations are expediting testing cycles by predicting potential faults or anomalies, while machine learning enhances simulation adaptability, creating dynamic scenarios that better reflect real-world complexities earlier in the development.

Cross-domain interoperability is


John Breitenbach is RTI's Director of Aerospace and Defense Markets. Credit: RTI

"In aviation, real-time simulation and validation testing are advancing quickly."

John Breitenbach, RTI's Director of Aerospace and Defense Markets.



Francisco J. Flores Sanchez is the Business Development Manager for dSPACE Aerospace & Defense. Credit: dSPACE

"Customers want to find issues early in their development cycle."

Francisco J. Flores Sanchez, Business Development Manager for dSPACE Aerospace & Defense.

also a critical focus as the industry advances towards interconnected systems, where real-time, secure interoperability is essential. For example, Connext TSS's standards-based framework enables seamless communication across diverse systems, supporting today's distributed simulation environments and the broader shift towards a "mosaic" approach. Additionally, digital twins continue to gain traction as they offer high-fidelity, real-time models that support comprehensive testing and validation, allowing developers to simulate real-world conditions more accurately and speed up development cycles.

Francisco J. Flores Sanchez: One of the most noticeable trends is the increase in scaled Software in the Loop Simulation utilizing cloud computing. The addition of this capability allows for the expansion of team collaboration, even when working in different geographical locations.

Cloud computing allows these teams to increase the number of resources that can be applied to the validation process. In traditional validation methods, test cases run sequentially on one single platform whereas the cloud allows parallel jobs to run at the same time, achieving further test coverage in shorter periods of time.

Another trend we are seeing is the increase in use of automated testing frameworks with the inclusion of continuous integration and continuous deployment pipelines; these allow engineers to reduce human error and achieve faster testing cycles.

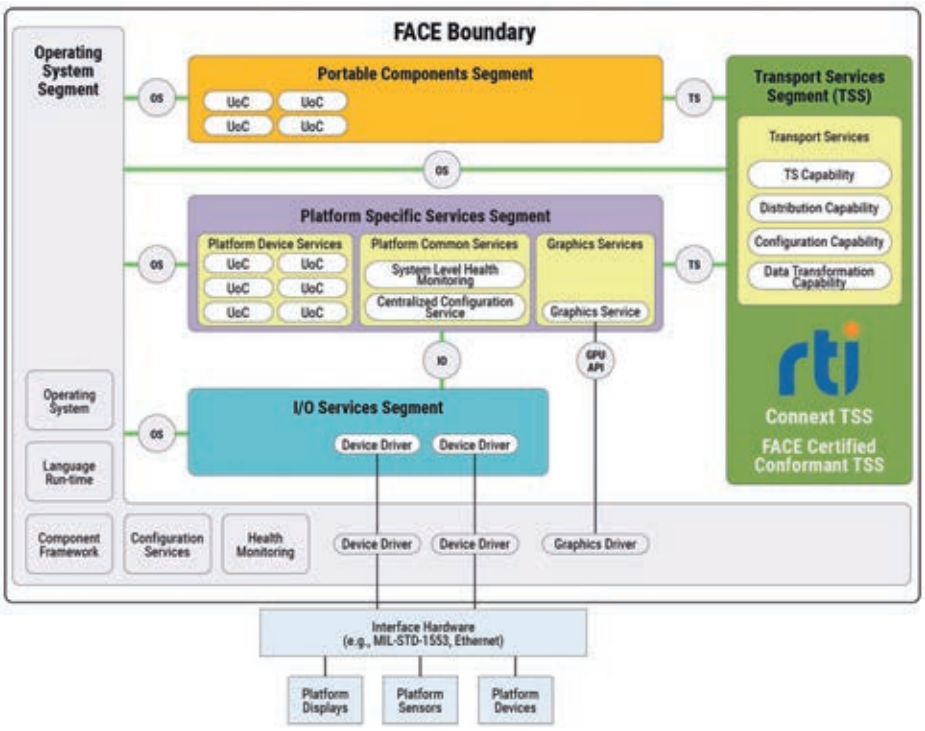
Aerospace Innovations: What do customers want most from real-time simulation and validation testing, and how are you giving it to them? What are the benefits?

Francisco J. Flores Sanchez: Customers want to find issues early in their development cycle. Real-time simulation and validation systems provide customers with the means to test and validate

their implementations against their requirements early on.

dSPACE provides solutions along all development stages to help our customers meet their goals. MIL testing allows customers to test their model implementation during function development. SIL testing provides customers with the ability to perform functional testing based on virtualized ECUs at a higher integration level. And lastly, we provide HIL testing in which the expected final hardware is then put under test to validate its performance against the validated system models and software.

John Breitenbach: Customers are looking for real-time simulation and validation testing that delivers high accuracy, reliability, and a clear path to safety certification, with the flexibility to grow as their needs evolve. They want solutions that seamlessly integrate real-world data and work across both legacy and new systems, helping them make the



Credit: RTI. Graphic shows FACE Reference Architecture with Connext TSS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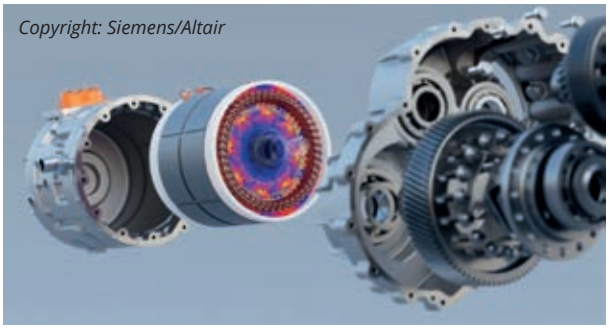
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most of current investments while staying ready for the future.

RTI Connext TSS is built for exactly this — providing a modular, safety-certified framework that enables real-time, high-performance data exchange, making simulations feel as close to real operations as possible. The benefits of Connext TSS include reduced testing costs, path to safety certification, improved system safety, and minimized risk. With its scalable and adaptable data connectivity, RTI Connext offers a robust, future-proof solution that accelerates system development, testing, and validation, even in complex and dynamic environments.

Aerospace Innovations: What are the challenges in the real-time simulation and validation testing today, and how are they being overcome?

John Breitenbach: One of the main challenges in simulation today is finding the right balance between meeting strict regulatory requirements and achieving high performance, especially as environments get more complex. Safety-critical standards are demanding, and meeting them without slowing down development can be tricky. Data-centric, standards-compliant frameworks are helping simplify the certification process, making it faster and more manageable.

Another common challenge is integrating legacy and next-generation systems, which often vary widely in setup and capabilities but need to work together for a truly effective solution. Open, standards-based interoperability is helping to bridge these differences, allowing diverse systems to communicate seamlessly. Additionally, scalable architectures and cloud technology enable aviation companies to manage massive datasets more efficiently, reducing bottlenecks and making it easier to meet the demands of advanced, safety-certified simulations.

Francisco J. Flores Sanchez: Final testing during the certification process remains a very expensive and time consuming task. Customers can reduce the amount of time they spend during acceptance testing if they can run their test cycles with a high level of software quality.

Simulation and validation in combination with automated testing processes help improve the software quality by finding implementation errors in early development stages. This increased software quality leads to reduced efforts to move a product through acceptance/final testing for certification.

Aerospace Innovations: Finally, what new products in real-time simulation and validation testing are on the horizon, and how will they benefit the aerospace industry?

John Breitenbach: Emerging products like Connext TSS are advancing simulation fidelity and modularity, enabling flexible, scalable testing environments that adapt to rapid technological advancements. Connext TSS supports traditional aviation as well as future applications, including Urban Air Mobility (UAM) and autonomous and hybrid electric aircraft. This modular, safety-certified platform allows aerospace companies to test and validate complex systems in controlled environments, accelerating innovation cycles and enhancing safety across evolving aerospace technologies — from drones to next-gen passenger aircraft.

Francisco J. Flores Sanchez: dSPACE is investing heavily in our software solutions to allow users to test, validate and verify software models and code within both MIL/SIL applications which provide a window to see deviations from requirements during the early stages of development. To add to this capability, we have also investments in scaling up Simulations via Cloud simulations, thus allowing for large scale simulation in the cloud utilizing the same models as deployed on a real time HIL system, to improve confidence in the systems being developed and tested, identifying edge and corner cases that need to be further scrutinized and improved as necessary to deliver a robust and reliable system.

The immediate benefit to the aerospace industry is the ability to test and validate requirements during the early stages of requirements conceptualization. This may translate in less hours spent at later stages, where correcting errors while utilizing real components becomes more expensive and time consuming.

By James Careless

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The Hybrid-Electric Flight Demonstrator will integrate a 1MW gas generator engine with a 1MW electric motor and use a gearbox to drive the propeller. Copyright: Pratt & Whitney Canada

Future Proofing

Engines are the key element in aviation achieving its environmental targets and that includes electric, hybrid, hydrogen and SAF. Ian Harbison spoke to the leading players.

Dr Michael Winter, previously Principal Fellow of Advanced Technologies at Pratt & Whitney and now Chief Science Officer at parent company RTX, says 80% of aviation emissions are produced on flights of greater than 950 miles, so the current focus has to be on those types that are the main cause of CO_2 emissions, with non- CO_2 emissions likely to attract more attention as well. There may be opportunities in the future to look at aircraft with lower range and lower payload, He says the company is ideally placed to bring new technologies together and integrate them into propulsion systems. The main focus is continuous improvement of the gas turbine engine, which, since jets were first introduced about 85 years ago, has measured at a rate of about 1% per year in terms of average fuel efficiency across the fleet.

There are two key factors affecting engine design:

- thermal efficiency, coming from the engine core, where the energy in the fuel is released and turned into mechanical energy to turn the shaft.
- propulsive efficiency, which comes from the fan, the bypass ratio and the nozzle.

The company made a significant breakthrough with the Pratt & Whitney Geared Turbofan (GTF), which enabled fuel savings of up to 20% over previous engine types. By June 2023, having entered service in 2016, GTF-powered aircraft saved airlines more than 1.7 billion gallons of fuel and over 17 million tonnes of carbon emissions. It is now working on the GTF Advantage, which should reduce fuel consumption and CO_2 emissions by up to a further 1% as well as offering a 4-8% higher take off thrust and higher thrust at altitude.

He says improving thermal efficiency has been the target of all the engine companies but climate change means the world is getting hotter and dirtier, so more attention is needed on improving the resilience of the components. Higher ambient air temperatures mean that wings generate less lift, so more power is needed to maintain the same performance. Reduced air quality in some parts of the world means that non-volatile particulates are continuing to increase. Some of these, like sand, can erode blades or melt and form a glass that blocks cooling holes but the main problem is the extreme temperatures in the engine that bring about chemical changes to the pollutants.

Sustainable aviation fuel (SAF) is also important. He says: “Today, the Pratt & Whitney modern products are capable of 100% SAF. We are working with other members of the

Below: Pratt & Whitney Canada, in collaboration with Next Hydrogen Solutions, will demonstrate hydrogen combustion technology on a PW127XT regional turboprop engine as part of the Hydrogen Advanced Design Engine Study (HyADES) project supported by Canada's Initiative for allySustainable Aviation Technology (INSAT). Copyright: Pratt & Whitney

industry to bring SAF forward, as there is clearly not enough today, and are an active partner with the industry and the approval boards, such as ASTM International."

Hybrid electric

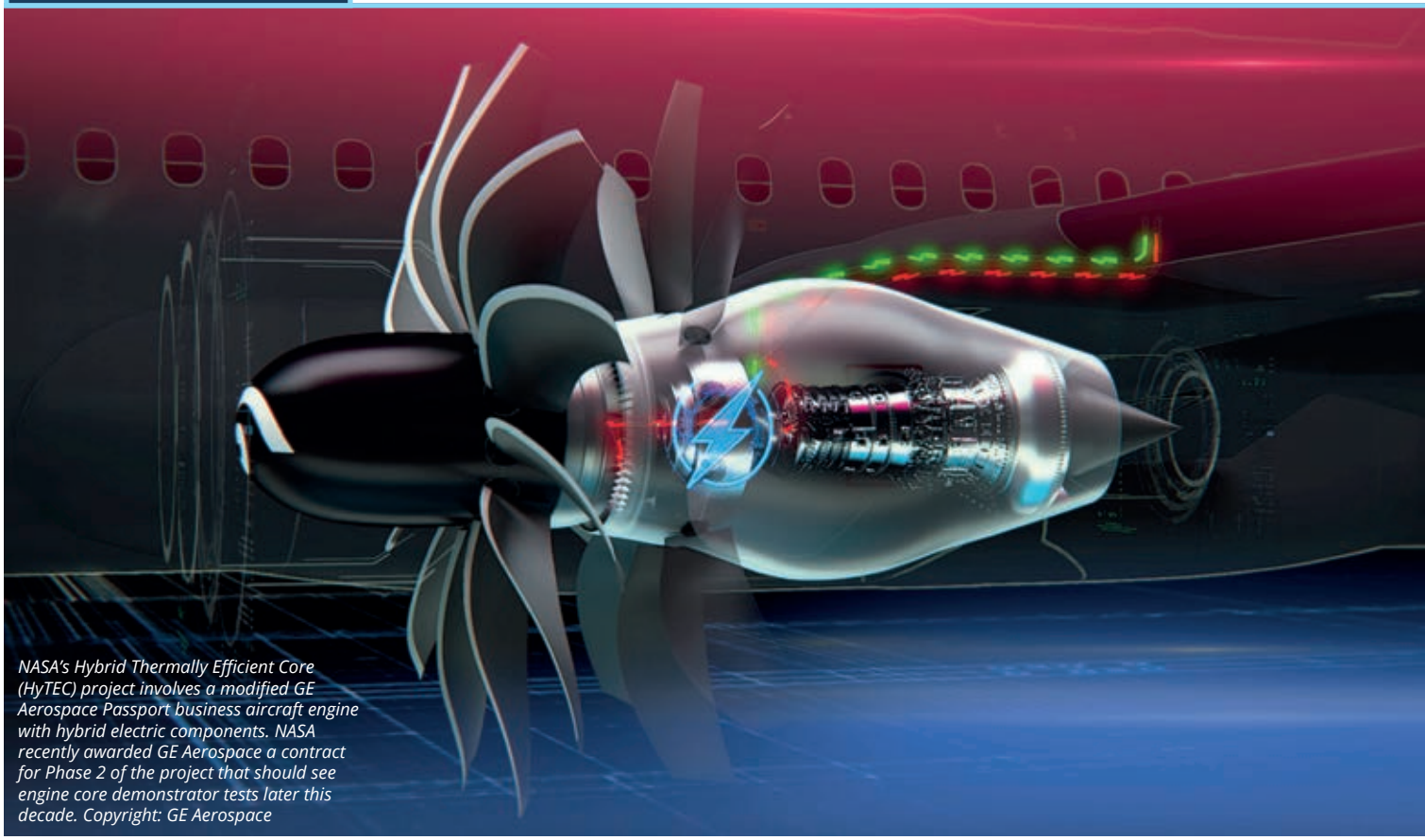
He points out that jet fuel is 'a really good molecule for powering a plane'. It releases about 45MJ/kg and is relatively stable. Even the best batteries available, or under development, have significantly less energy per unit mass and per unit volume. In addition, they are heavy, as they require a box, a thermal management system and fire protection. In fact, jet fuel has forty times more energy to release per unit mass.

However, there is continuous development and the current technology is mature up to about 1 megawatt, including the batteries, motors, generators, drives and distribution systems. The company is in partnership with Collins Aerospace, another RTX company, and is working on several hybrid-electric demonstrator programs addressing a range of future applications. For the entry level STEP-Tech project, they are developing a scalable system in the 0.1 – 1 MW range for distributed propulsion concepts. This integrates a new, very efficient gas generator engine from Pratt & Whitney Canada (P&WC) with batteries, control logic and propulsors.

At Farnborough, RTX announced that it had successfully validated sustained operation of the thermal engine, electrical generator, battery system and propulsors to demonstrate energy transfer between these components through the high-voltage electrical network.

With funding from the Canadian and Quebec governments, a de Havilland Canada Dash 8-based Hybrid-Electric Flight Demonstrator is being developed that will integrate the 1MW gas generator engine with the 1MW electric motor and use a gearbox to drive a propeller. This will be mostly contained within the existing nacelle. The fuel burn can be optimised depending on the mission, such as using both for climb and just the gas generator engine for cruise.

A derivative of that 1 MW motor will be used on the hybrid-electric GTF demo as part of the Sustainable Water-Injecting Turbofan Comprising Hybrid-Electrics (SWITCH) programme. This is supported by the European Union Clean Aviation Joint Undertaking with a consortium of Airbus, Aristotle University of Thessaloniki (Greece), Chalmers University of Technology (Sweden), Collins Aerospace, DLR German Aerospace Center, GKN Aerospace, MTU Aero Engines and the University of Stuttgart. The goal is to achieve up to a 25% improvement in fuel efficiency and reduced CO_2 emissions compared to current engines powering short and medium range aircraft. The



NASA's Hybrid Thermally Efficient Core (HyTEC) project involves a modified GE Aerospace Passport business aircraft engine with hybrid electric components. NASA recently awarded GE Aerospace a contract for Phase 2 of the project that should see engine core demonstrator tests later this decade. Copyright: GE Aerospace

consortium is coordinated by MTU. RTX recently announced the completion of the preliminary design review of the hybrid-electri GTF engine demonstrator.

It combines hybrid-electric propulsion and the Water Enhanced Turbofan (WET) using a GTF engine. The hybrid-electric powertrain will optimise the performance of the gas turbine while WET recovers water vapour from the engine exhaust and re-injects it into the combustion chamber to significantly improve fuel efficiency, reduce NO_x emissions, and lessen contrail forming emissions

As a typical narrowbody (which he describes as 'the heart of the market'), an Airbus A320 has two 30,000lb thrust engines, equivalent to a total of 36MW. About 5% of that power could be augmented by putting a 1 MW motor starter generator on the core of each engine and a 0.5-1MW motor on the low pressure spool of the engine that turns the fan. Moving power between the two provides opportunities to optimise efficiency throughout the flight.

He says whenever the next generation of aircraft will start development – likely around the mid-2030s or later – they will still be flying in the 2060s, so entirely different batteries will be progressively available, ofering greater flexibility in optimising efficiency with the systems.

Hydrogen

Pratt & Whitney has had a long involvement with hydrogen propulsion. In 1956, it was working on an engine for Project Sun Tan, a CIA long-range reconnaissance aircraft. This was the Lockheed CL-400, from Kelly Johnson's Skunk Works. It was intended to fly at Mach 2.5 at altitudes around 100,000ft, where the air is so thin that hydrogen is the only possible fue, but was cancelled in 1958 to be replaced by the SR-71 Blackbird.

The atttaction of hydrogen as a fuel, he explains, is that it releases 102-122MJ/kg but it takes up four times the volume of jet fuel even when it stored as a liquid (at -253°C). When burnt, it could produce more NO_x than jet fuel, as well as 2.6 times more water, poentially meaning more contrails, both undesirable.

In 2022, the company was selected by the US Department of Energy (DoE) to develop the Hydrogen Steam Injected, Inter-Cooled Turbine Engine (HySIITE) for commercial aviation, as part of DoE's Advanced Research Projects Agency-Energy (ARPA-E).

HySIITE has a thermodynamic engine cycle that incorporates steam injection, hydrogen combustion and water vapour recovery to achieve zero CO_2 emissions, while reducing NO_x emissions by up to 80% and fuel consumption by up to 35% for future generation single-aisle aircraft. The water will be used for cooling and intercooling, reducing temperatures and increasing durability. It will also increase thrust levels, so the core of the engine can be smaller and the water capture may assist with some of the non- CO_2 emissions to reduce contrails.

In a further development, Pratt & Whitney Canada will demonstrate hydrogen combustion technology on a PW127XT regional turboprop engine as part of a project supported by Canada's Initiative for Sustainable Aviation Technology (INSAT). The project, named Hydrogen Advanced Design Engine Study (HyADES), will be in collaboration with Next Hydrogen Solutions, a designer and

manufacturer of water electrolysers that use water and electricity as inputs to generate clean hydrogen for use as a green energy source or a green industrial feedstock. They will develop high-efficiency, low-cost electrolyzers needed for establishing hydrogen production infrastructure.

Funding for the first phase of the project will include fuel nozzle and combustor rig testing using hydrogen fuel, while future phases will target full engine ground testing. The PW127XT engine is the most advanced member of Pratt & Whitney Canada's PW100 engine series, which has powered regional turboprop aircraft for forty years and accumulated more than 220 million flight hours. Launched in 2021, the PW127XT engine offers over 3% better fuel efficiency, 40% improved time on wing, and 20% reduced maintenance costs compared to previous PW100 family models.

As part of a second INSAT-supported project, Turbine Engine Advanced Materials for Efficiency (TEAME), Pratt & Whitney Canada will work with Derivation Research Laboratory (DRL) to explore advanced materials for hot section components of gas turbine engines, which will help to improve thermal efficiency and reduce fuel consumption and emissions. Pratt & Whitney Canada will lead the overall project providing both technical input and project management, while DRL will provide world-class materials testing capability for a wide variety of critical material properties.

GE Aerospace

Arjan Hegeman, general manager of future of flight technologies for GE Aerospace, says the CFM RISE (Revolutionary Innovation For Sustainable Engines) programme has a target is of more than 20% lower CO_2 emissions than current engines by using an advanced open fan architecture.

The company has previous experience in this area. The GE36 Unducted Fan was flown on a McDonnell Douglas MD-81 in the late 1980s. It demonstrated excellent fuel efficiency but was extremely complex and noisy. It was cancelled in 1989.

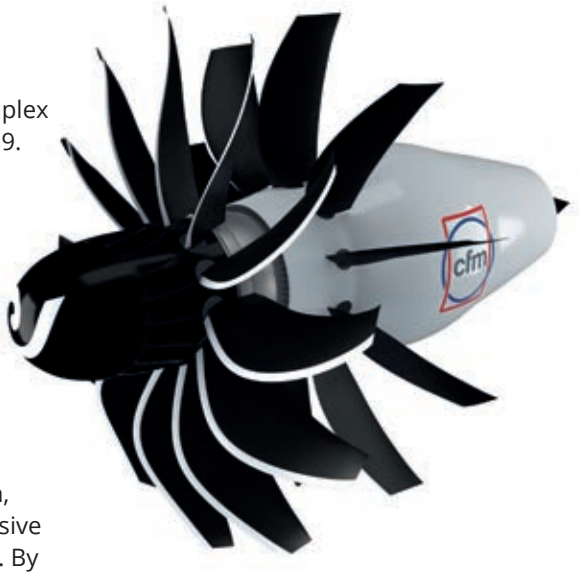
The RISE development cycle began with demonstrations at component level, followed by system level tests and will finish with flight tests before the end of this decade. This is the largest demonstration programme in the company's history, with four technology pillars that will eventually merge together. The first is the open fan, which will achieve greater propulsive efficiency. The second is the core. By using next-generation compressor technologies and materials, and higher operating pressures, increased thermal efficiency means the core can be smaller. Third is a MW class hybrid electric powertrain. This could be used to drive the fan, or to generate power for aircraft systems to charge batteries. Finally, the use of alternative fuels, from SAF to hydrogen, are possible.

Again, RISE is targeted at the A320/737 replacement market in the 2030s but it is scalable, so could be used for smaller regional aircraft as well.

He says the aim is always to increase the bypass ratio (CFM56: 6, LEAP: 11) but there is a limit in size with a ducted fan as the duct adds weight and drag. With improvements in Computational Fluid Dynamics, it has now been possible to optimise the airfoil shapes. Instead of two contra-rotating fans, as on the GE36, there is now a single fan with a static second stage. As for noise, the airfoil shapes have also been tuned to produce noise levels below LEAP engines. The fan diameter is slightly larger than the current LEAP nacelle but there should be no configuration problems with next generation narrowbody designs.

In July, CFM International announced that progress is accelerating for RISE, with more than 250 tests completed and new research partnerships formed as technologies continue to mature on the way to full-scale Open Fan tests.

For example, CFM parent company Safran Aircraft Engines' agreement with French aerospace research agency ONERA to conduct wind tunnel tests is demonstrating the aerodynamic and acoustic performance of Open Fan designs. More than 200 hours of wind tunnel testing have been completed at Onera Aerospace Lab using a 1:5 scale model of an Open Fan, including a version of the model mounted on a demonstrator plane wing section for testing with Airbus. A high-speed, low-pressure turbine test campaign with advanced turbine blades also ran.



The CFM RISE (Revolutionary Innovation For Sustainable Engines) programme has a target is of more than 20% lower CO2 emissions than current engines by using an advanced open fan architecture. Copyright: CFM

Aslo in July, GE Aerospace and the US Department of Energy's Oak Ridge National Laboratory reached a new Cooperative Research & Development Agreement (CRADA) on supercomputing, to develop new computational modelling and simulation capabilities. This will help the company better manage large simulations, more efficiently extract information, incorporate Artificial Intelligence (AI) tools to improve understanding of results, and streamline the process to visualise the physics, expanding its capabilities to design next-generation aircraft engine technologies like Open Fan.

Oak Ridge National Laboratory is home to Frontier, the world's fastest supercomputer, capable of crunching data at exascale speed, or more than a quintillion calculations per second. It is also renowned for its computing

expertise. After an initial simulation in 2023, GE Aerospace now has run additional simulations of improved designs on Frontier that analyse different engine operating conditions to better understand aerodynamic characteristics and acoustic signatures.

The company is partnering with NASA on several propulsion research programmes. In a direct partneship, it is developing a hybrid electric demonstrator engine that will embed electric motor/generators in a high-bypass commercial turbofan to supplement power during different phases of operation (also applicable to RISE). This includes modifying a Passport business aircraft engine with hybrid electric components for testing through NASA's Hybrid Thermally Efficient Core (HyTEC) project.

Initial component-level testing of electric motor/generators and power electronics has been completed and systems testing has been carried out at GE Aerospace's EPISCenter in Dayton, Ohio. Additionally, a baseline test of the Passport engine to characterise performance before hybrid electric components are added was completed at the company's Peebles Test Operation, also in Ohio.

Results of the hybrid electric component and baseline engine tests are being used to evaluate and update models in preparation for a ground test.

NASA recently awarded GE Aerospace a contract for Phase 2 of the HyTEC project to continue developing technologies for an aircraft engine core demonstrator test later this decade. Phase 2 builds on work completed in Phase 1 of HyTEC for high-pressure compressor and high-pressure turbine advanced aerodynamics, as well as the combustor.

Under NASA's Electrified Powertrain Flight Demonstration (EPFD) project, it has partnered with Boeing and its subsidiary Aurora Flight Sciences to fly a megawatt-class hybrid electric powertrain in the middle of this decade using a modified Saab 340B aircraft with CT7 engines.

In addition, it is working with Airbus on a hydrogen demonstration programme that will take flight around the middle of this decade. CFM will modify the combustor, fuel system, and control system of a GE Passport turbofan to run on hydrogen, which will be fitted to an A380 testbed equipped with liquid hydrogen tanks. Airbus will also define the hydrogen propulsion system requirements and oversee flight testing.

A further NASA partnership was

For Rolls-Royce, the main development programme is UltraFan, unveiled in 2014 and incorporating the largest geared design to date. It is designed for the next generation of larger aircraft in the 2030s. Copyright Rolls-Royce

announced in November, for a series of unique flight tests using new test methods and technologies to help further understanding of contrails.

Flights for the Contrail Optical Depth Experiment (CODEX) were conducted with NASA Langley Research Center's Gulfstream G-III aircraft following GE Aerospace's Boeing 747 Flying Test Bed and scanning the aircraft wake with Light Detection and Ranging (LiDAR) technology. This will advance the use of LiDAR by NASA to generate three-dimensional imaging of contrails to better characterise how contrails form and how they behave over time.

For GE Aerospace, this represents new operating methods for its 747 Flying Test Bed, expanding capabilities ahead of flight tests

planned this decade to evaluate performance of new commercial engine technologies, including Open Fan, advanced combustion designs, and other propulsion systems being developed through CFM International's Revolutionary Innovation for Sustainable Engines (RISE) programme.

Rolls-Royce

Alan Newby, Director of Research and Technology at Rolls-Royce, says that having facilities in the UK and Germany has given it access to number of sustainability projects funded by both national governments, the State of Brandenburg in Germany as well as the EU. In the UK this includes the Aerospace Technology Institute (ATI) and Innovate UK, plus LUFO in Germany and the EU's Clean Sky programme. The German programmes have had a focus on fuel cells and hydrogen combustion.

He explains that electric propulsion is best suited to short range operations, while hybrid engines can go a little bit larger and fuel cells have a power density that could power regional aircraft. For narrowbody and widebody aircraft, there will be no alternative to the turbofan for some considerable time. However, there is plenty of room to improve current turbofan efficiency.

For Rolls-Royce, the main development programme is UltraFan, designed for the next generation of larger aircraft in the 2030s and with a target of net zero by 2050 but there are other projects as well.

Advance2, for the large cabin corporate jet market, is a two-shaft design with a 50:1 overall pressure ratio (OPR) for greater efficiency (the current Trent engine is 20:1) to deliver improvements in SFC performance and noise and emissions.

Advance3 is a three-shaft jet engine with a new core architecture with a lightweight, low-pressure system, a composite fan, lean burn combustion and innovative manufacturing and materials technologies including 3D printing and Ceramic-Matrix Composites. It has a 60:1 OPR.

The UltraFan concept was unveiled in 2014 and incorporates the largest geared design to date, with a power gearbox introduced between the fan and intermediate pressure compressor) to ensure that the fan, compressors and turbines all continue to run at their optimum speed. It has a 15:1 bypass ratio, treble that of the Trent 700 family, and an OPR of 70:1 for a typical large engine application.

Compared to the Trent XWB, which the company says is its most efficient engine, UltraFan should be 10% more efficient and provide significant reductions in fuel consumption (-10%), CO_2 emissions (-10%), NO_x emissions (-40%) and, with 100% Sustainable Aviation Fuel (SAF), almost zero particulates (Newby says water vapour attaching to particulates are the main cause of contrails, another environmental concern).

The engine is scaleable from 25,000-110,000lb of thrust.

In May 2023, Rolls-Royce successfully completed the first tests of its UltraFan technology demonstrator at its Testbed 80 facility in Derby. The first tests were conducted using 100% Sustainable Aviation Fuel (SAF). Six months later, it achieved full power in the same facility.

Newby says the company is playing a leading role in developing the use of SAF. It ran an extensive compatibility test programme of 100% Sustainable Aviation Fuel (SAF) that ended in November 2023 having successfully demonstrated that all its in-production civil aero engine types were compatible with 100% SAF with no effect on engine performance. These comprise the Trent 700, Trent 800, Trent 900, Trent 1000, Trent XWB-84, Trent XWB-97, Trent 7000, BR710, BR725, Pearl 700, Pearl 15 and Pearl 10X.

The company was also involved with a Virgin Atlantic Boeing 787 flight from London Heathrow to New York JFK on 28 November last year using 100% SAF.

The flight followed more than a year of collaboration by a Virgin Atlantic led consortium including Boeing, Rolls-Royce, Imperial College London, University of Sheffield, ICF and Rocky Mountain Institute. It was part funded by Department for Transport and approved by the UK CAA and other regulators including the FAA.

A full lifecycle analysis showed a saving of 95 tonnes of CO_2, or 64% of the emissions produced from a standard flight on the same route, along with a 40% reduction in non-CO_2 particulate emissions. The SAF also produced 1% more energy compared to the same mass of fossil fuel.

Looking further ahead, he says SAF will come to dominate but hydrogen is likely to take some time to establish itself due to production and infrastructure challenges – SAF can use the same JET-A1 distribution network and equipment. Still, the company is involved in the technology and, in late 2023, in partnership with easyJet, it carried out a full-scale hydrogen ground test of an AE2100-A engine at MOD Boscombe Down in the UK. Next year, it will be turn of a Pearl 15 engine at an outdoor, full-scale gas turbine hydrogen test stand at NASA's Stennis Space Center in Mississippi.

The lessons learnt from the testing will be saved until more of the problems have been solved and a viable hydrogen powered aircraft is under development. That includes how hydrogen can best be combusted in an engine while minimising any resulting emissions such as NO_x; how to deliver it (from a cryogenic liquid at -253°C to a gas at room temperature into a combustion chamber, while continuing to deliver performance and reliability); and how the technology can be best integrated with the engine (requiring changes to engine external fixtures).

One of the challenges of ramping up production of SAF and hydrogen are the huge energy demands. Rolls-Royce is developing factory-built nuclear power stations called small modular reactors that could help meet the need.

By Ian Harbison

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Cranfield's Hydrogen Integration Incubator (CH2i)

The 'third aviation revolution' — the development of a sustainable aviation infrastructure that protects both the environment and economic growth — is an essential and urgent ambition. The UK's net-zero aviation emissions by 2050 target is beginning to feel imminent.

Once the outsider in the race to deliver zero-carbon flight, hydrogen has become the frontrunner as the middle to long-term solution. Just as automotive manufacturers have become market leaders from investing early in electric vehicles, aviation businesses now have the opportunity to establish a lead in hydrogen. The kind of lead and experience that will be difficult for competitors to catch up with.

Cranfield Hydrogen Integration Incubator

Work on delivering hydrogen-powered aviation is being driven forward by the Cranfield Hydrogen Integration Incubator (CH2i), based in and around the University's own airport facilities, workshops and a new set of hydrogen-focused lab spaces. Partnerships with industry

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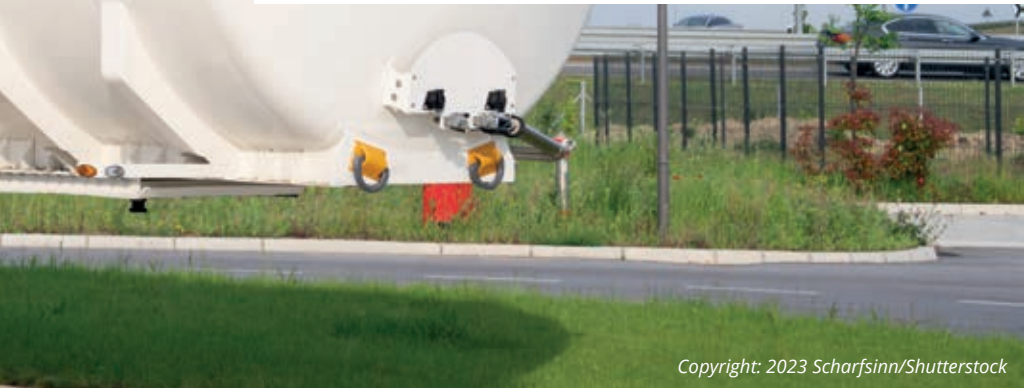
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are beginning to define programmes of work at CH2i as a means of unlocking the technology challenges, including hydrogen production technologies, catalysts, materials, structures, storage tanks and both engine and whole aircraft designs: an incubator geared towards rapid innovation in a regulated and safety-focused environment.

No doubt, creating a viable hydrogen ecosystem comes with huge challenges. But the large-scale lab spaces needed for working out the processes, from green production to transportation, storage and use both airside and in aircraft, are in place. Industry players such as Airbus, Heathrow Airport, Marshall, Siemens Energy and Toyota have become involved. All that's needed now is wider collaboration between research institutions and aviation businesses, manufacturers, airports, airlines and their suppliers to innovate, test and demonstrate the most workable technologies and processes. Joint activity that leads to a robust offering and the development of certification processes and rules to ensure the introduction of hydrogen meets or even improves current safety standards.

CH2i is being developed on the basis of £23 million from Research England's Research Partnership Investment Fund (UKRPIF) and £46 million from industry partners and academic institutions. The Hydrogen Integration Research Centre will include new labs for advanced materials synthesis and testing and a dedicated innovation area to develop next generation hydrogen pilot plant demonstration, electrolysis, catalyst development and green hydrogen. And alongside this, an Enabling Hydrogen Innovation test area focused on gaseous and liquid hydrogen fuel systems, both storage and propulsion system integration at mid- and high-technology readiness levels.

Hydrogen tradition

The facilities and ambition of CH2i are rooted in Cranfield's experience in hydrogen applications research since the early 1990s. Within the last decade, as the limitations of electric and other fuel sources became apparent (the problems around the weight of electric batteries in

particular), hydrogen has become an important candidate — the large challenges involved in transforming the industry infrastructure into hydrogen-based rather than a kerosene one are looking increasingly worth taking on, because the benefits for the long-term are so clear.

The change has come about largely due to the European Horizon 2020-funded project ENABLEH2 (ENABLing CryogEnic Hydrogen-Based CO2-free Air Transport), which has provided hard evidence for the case for hydrogen. Findings and the roadmap forward, including the need for the makings of a new regulatory framework, have gained EU approval. Cranfield played a leading role in ENABLEH2, alongside Chalmers University, London South Bank University, Heathrow Airport, GKN Aerospace Safran, the European Hydrogen Association and Arttic. Industry involvement included support from Airbus, IATA, ICAO, International Airlines Group, Mitsubishi Power Systems, Rolls-Royce, Siemens and Total. Cranfield's contribution to the UK's Fly Zero programme provided further impetus.

In essence, the research has confirmed the qualities of liquid hydrogen as a zero-carbon emissions fuel, one that would also remove sulphur oxide and soot from the aviation emissions profile. Hydrogen brings a promise of much leaner combustion than any hydrocarbon fuel (fossil, bio or synthetic) delivering ultra-low nitrogen oxide emissions (nitrogen oxides contribute to acid rain and the 'ozone hole').

Cryogenic hydrogen tanks

The introduction of a new world of hydrogen flight means a full re-design of aircraft and the fuelling infrastructure of supplies and storage on the ground. While hydrogen gas can be used for short hop flights, longer distance flights will need a higher energy density, meaning the storage on-board of liquid hydrogen. Liquid hydrogen has a higher energy density than conventional aviation fuels and offers a much leaner combustion than any hydrocarbon fuel, as well as ultra-low nitrogen oxide emissions. There are no sulphur oxide or soot emissions or CO2 emissions. There is more flexibility in terms of how the energy is extracted: it can be burnt or used within a fuel cell, meaning there is no need for a combustion process on-board the aircraft. The future viability of liquid hydrogen flight, though, is dependent on safe storage on-board.

In general, the storage, transfer, and combustion of hydrogen requires special care because of its highly explosive nature when mixed with air (oxygen). Made up of tiny molecules, hydrogen is known for its diffusion into any type of material, causing different forms of structural damage to whatever material it might be. Using traditional metals for example, such as steel or aluminium, the hydrogen works its way into the lattice of the metal and causes it to become brittle over time, leading to cracking. And with polymers, using a carbon-fibre and glass-fibre tank with a coating inside, the hydrogen will penetrate through the lining and without additional care to the level of tank emptying and filling, the coating will buckle and ultimately fail.

Storage tanks need to be able to withstand extreme variations in temperature: between -253 degrees centigrade and room temperature. Past studies have shown that -200 degrees centigrade has been a challenge in itself for developing cryogenic tanks that need to be lightweight, moving the parameters to -253 for liquid hydrogen brings a whole new level of problems. Absolute reliability and resilience of the cryogenic tank structure is essential for hydrogen flight of any kind. Given the nature of temperatures involved, an incorrect selection of materials or issues with the cryogenic system would lead to a catastrophic failure. Most importantly in aerospace, the design of tanks needs to involve lightweight materials to minimise overall aircraft weight and fuel demands. Stainless steel tanks might provide safety but are unrealistic in terms of the added tonnage.

Over the past year, the University has been working on developing the most efficient aircraft designs, hydrogen combustion systems and workable materials for next generation fuel tanks. This is part of the Airbus driven project to develop the world's first commercial hydrogen aircraft by 2035. The streams of research and development, jointly funded by the UK government's Aerospace Technology Institute (ATI), are based around the company's new Zero Emission Development Centre (ZEDC) for hydrogen technologies in Filton, Bristol.

In order to use hydrogen as fuel in the skies, there is the need for a design of a type VI cryogenic tank. This involves a new bill of materials and deployment of three levels of safety features — each one of which means exploring new generations of materials. The first level is ensuring the hydrogen is kept at the right temperature; the second that there is the guarantee that even if the energy input and active cooling or other systems fail, the materials being used will keep the liquid hydrogen at a safe temperature and pressure environment for long enough for the aircraft to land and the issues be resolved. The third is that if there is an unforeseen and uncontrollable event, that the fuel or the tank itself can be disposed of safely — and the aircraft still has enough fuel to land.

One type of materials under development is based around a new form of self-healing polymers. To minimise safety concerns, there is the need for a material that is capable of both self-diagnosis and self-healing of damage caused to its structure. A self-healing polymer is particularly effective in repairing minor cracks and avoiding a worsening of the damage. The next critical material for the tank is made up of high performance, lightweight insulators like aerogels: the synthetic porous ultralight materials derived from a gel which retain their form even when the liquid element is replaced with a gas. The nature of the materials makes them the lightest possible material yet created.

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Finally, a two-dimensional graphene layer is being used to maximise the reduction of hydrogen leaks and to take the mechanical stability of the overall structure to another level.

Extensive work is ongoing at Cranfield around the material development and molecular tuning to achieve the levels of performance needed, as well as the use of different combinations in order to find the optimal mix of tank materials for performance and safety. The very first prototype of the type VI cryogenic hydrogen tank will be tested over the coming year, with flight testing (possibly from Cranfield airport) expected to start in 2026, and a system in use between 2030-35.

Production and refuelling

Hydrogen has been used for centuries in industry like mining, chemicals and water — but not in the quantities, types and conditions that are planned for civil aviation. Cranfield's big picture-modelling of hydrogen needs in the UK suggests around 25,000 tonnes would need to be produced each day (for total fuel needs, not just for aviation, around 10,000 tonnes of the total would be necessary as liquid hydrogen for aircraft use). To put this into context, global production of liquid hydrogen currently stands at under 100,000 tonnes a year.

Green hydrogen production is crucially dependent on electricity for electrolysis. To meet hydrogen demand, the UK would need an estimated fourfold increase in electricity supplies. This is not as unrealistic as it might appear: the UK power generation system achieved fourfold increases due to changes in the nature of population and industry demands in both the 1920s and 1940s. Hydrogen would be another major driver for the shift to renewable energy provision. Electrolysis also depends on large volumes of water: 25,000 tonnes a day production would require 250,000 tonnes of water. Compared with the rest of the world, the UK has a major advantage in being able to access supplies of freshwater rather than seawater which is both more expensive and leads to serious problems with corrosion of hydrogen production plant facilities. Only a few countries such as Canada and Russia have ample freshwater supplies.

A new generation plant has been used for testing production of 'blue' hydrogen on the University campus. The Bulk Hydrogen Production by Sorbent Enhanced Steam Reforming (HyPER) project (funded through the Department for Business, Energy and Industrial Strategy and its Energy Innovation Programme) has led to a 1.5 megawatt-hour pilot plant. Partners include the US-based Gas Technology Institute (GTI) and British energy company Doosan Babcock.

The plant is based on a compact technology that captures carbon dioxide during the hydrogen-production process and shifts the chemical reactions to favour the production of more hydrogen. HyPER has the potential to produce high purity hydrogen at up to 30% lower cost than conventional steam methane reforming methods that require CO2 capture as an additional and expensive step in the process. Hyper also captures carbon in solid form, much more convenient to sequestrate and store. The process is scalable for use in much larger hydrogen production plants and leads to the production of both high-purity hydrogen and carbon, which can be stored, sold and transported to where it is needed. Once scaled up, the process is predicted to have

the potential to produce a significant proportion of the UK's hydrogen needs by 2050. The H2 production facility based on sorption enhanced reforming, demonstrated in HyPER, is cheaper to build than a conventional hydrogen production facilities (50% less) and leads to hydrogen production at a 20-30% lower levelised cost. Carbon emissions are cut by 97%. Building on this work, Bio-HyPER research is testing the feasibility of using biogas feedstocks (supplied from anaerobic digestion plants processing food, plant and animal waste around the UK) for the HyPER pilot plant.

Other research is exploring how hydrogen production processes can be made more efficient and cost effective; storage vessels for compressed and liquefied hydrogen; the use of ammonia for carbon-capture hydrogen storage and waste-to-fuel processes; and the value of hydrogen aviation for reducing 'contrail' effects, the vapour trails from aircraft that can produce cirrus clouds with potential implications for climate change. The Centre for Air Transport Management at Cranfield is investigating the practicalities of implementing hydrogen refuelling across airports using compressed gas and/or liquid hydrogen. This has included a study alongside Heathrow Airport. The University is building up direct experience of production and refuelling via its own solar-powered electrolyser, producing up to 40kg of 'green' hydrogen per day (meaning hydrogen produced using a renewable source of energy). An electric refuelling truck supplies research projects working on hydrogen fuel-cell aircraft.

Other research is exploring the use of ammonia for carbon-capture hydrogen storage and waste-to-fuel processes; and the practicalities of implementing hydrogen refuelling across airports using compressed gas and/or liquid hydrogen alongside Heathrow Airport. Cranfield is trialling airside hydrogen vehicles: a hydrogen fuel cell baggage tractor at Bristol Airport alongside easyJet; a hydrogen-powered aircraft tow-tug at Cranfield's own airport; and, at Exeter Airport, a system of multiple hydrogen vehicles, the tractor and tow-tug, as well as a ground power unit (using a hybrid of diesel and hydrogen fuels) that demonstrates the cheapest and most pragmatic way of implementing hydrogen for airport ground equipment.

Cranfield researchers continue to work on each aspect of technologies needed to make the shift to a hydrogen-aviation infrastructure, from hydrogen production, storage and transportation, to airport fuelling processes and safety. A key challenge and focus of large R&D

investments is the development of certification processes and rules to ensure that the introduction of hydrogen will continue to deliver the safety standards of today, or better.

The networks of activity are growing. As a result of its history of research, expertise and facilities around hydrogen, the UK-Aerospace Research Consortium (an aerospace consortium of 11 universities) has appointed Cranfield as its hydrogen theme lead. In 2023 Cranfield hosted a Hydrogen and Fuel Cell Showcase event with 250 delegates from more than 100 industries, including leaders from Airbus, Barclays, Heathrow Airport, Rolls-Royce, Siemens, BP; alongside academics from Bristol, Southampton, Coventry, Wolverhampton and Aston universities.

Engineers for safety

At a recent Aerospace Technology Institute event involving representatives from Rolls-Royce, GKN Aerospace, Airbus, the Health and Safety Executive and BOC, the major challenges around adopting hydrogen-powered aviation were identified as being the need to characterise material properties, establish test facilities, and determine the conditions for safe operations. In other words, the industry doesn't yet fully understand how hydrogen will interact with the conditions involved.

There are precedents in engineering for working in extreme conditions and extreme parameters, such as in space and subsea environments; and there is confidence that the use of hydrogen will be safe: when the materials, equipment and standards have been adopted with the appropriate care. The key challenge is around skills and expertise. Thousands, if not tens of thousands, of engineering professionals will be needed with a specialist understanding of hydrogen in order to deliver the necessary infrastructure of production, transport and storage, and to maintain standards of safety throughout day-to-day operations.

As part of this growing network of practical activity around hydrogen for aviation, the University is working alongside an industry partner (IndEx, a provider of solutions for engineering, compliance, quality, and safety in hazardous areas) on approaches to development and training. More widely there is a need for academics and industry — where there is still only a relatively small number of experienced professionals — to pool their practical hydrogen knowledge and experience in order to train the next generation of engineers and develop the necessary specialisms, such as leakage detection, propagation modelling and the application of explosion protection principles. In universities, for example, the tools are available in terms of computational modelling and computational fluid dynamics, to play through hundreds of different scenarios to assess the particular risks around hydrogen use in different circumstances and in combination with different materials, gases and powders, as well as the potential impacts of an accident.

UK leadership

The UK has the chance to be the prime mover of transformation by taking a global lead in green aviation with hydrogen and electric propulsion as a practical and long-term solution for delivering on all criteria: protecting the environment through zero or ultra low carbon and other greenhouse gas emissions, while also ensuring economic viability. That will mean UK leadership across decades, new market and investment opportunities internationally, employment and upskilling opportunities, and a means of inspiring and engaging generations of young people with careers in STEM and what is explicitly a world-changing technology.

The CH2i hub will be a way to make things happen, make vital progress in proving the viability of a high-potential technology. That means a lead for businesses willing to be early investors and adopters — as well as for the UK aviation industry as a whole.

For more information on hydrogen developments at Cranfield University and airport, please email: hydrogen@cranfield.ac.uk

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EFBs: Cyber safety

With increasing rates of connectivity and integrations, today's advanced Electronic Flight Bags, are an inviting playground for cyber risks. Device and data integrity are crucial to remaining safe and secure

For a significant amount of time, the aviation industry's security and safety agenda has been preoccupied on physical risks, such as mechanical failings and terrorist threats. However, as the rollout of onboard connectivity gathers pace and the connected aircraft becomes more of a reality, a new actor has been introduced into the discourse – cyber threats.

In their paper, Cyber-Security

In 2021, Airbus migrated to full EFB-based operations across all Airbus family aircraft. A dedicated Airbus department, Aircraft Security, develops solutions to provide all the necessary levels of security. (Copyright: Airbus/ Adrien Daste)

Regulators have developed security defense mechanisms to ensure EFB devices and data are protected from accidental or unauthorised acts that could compromise the safety and security of flight operations. But more work is needed. (Copyright: Lufthansa Systems)

Challenges in Aviation Industry: A Review of Current and Future Trends, Ukwandu et al point out that the onboarding and integration of digital devices, as airlines migrate away from manual processes, has exposed the inherent vulnerabilities in the software tools that such platforms reside on. This is especially true of Electronic Flight Bags (EFBs).

Since their introduction over two decades ago, EFBs have evolved from being a simple digital replacement for a stand-alone paper-based flight bag or data provided to the flight crew by an operator's "flight dispatch" organisation, to a sophisticated, technologically advanced device. These systems now consolidate a growing list of onboard documentation onto a highly accessible and digitalised device, that enhance situational awareness pre-, in- and post-flight, and deliver new levels of operational efficiency and safety.

As Julia Larsson, Director of Operations, EMEA at Web Manuals explains, operators often work with several different types of software and hardware while in flight and on the ground. With EFB apps providing real-time access to important information such as weather updates, NOTAMs and weather charts, she says that working with more interconnected systems can introduce some security risk[s]. "For example, integrated technology means critical flight data is more exposed and therefore, potentially at a higher risk of malicious attacks."

It should be noted that, while these tools are crucial to flight safety, paragraph 6 of the Federal Aviation Administration's (FAA) Advisory Circular (AC) 120-76E, released in June 2024, clarifies that "In order to qualify as an EFB application, the failure effect should be considered a minor hazard or have no safety effect."

Protecting probity

Larsson identifies several security risks associated with EFB systems. One of the main risks to device integrity is unauthorised access to the system, which risks manipulation and access to sensitive flight data. Threats to data integrity could lead to misinformation or compromised safety protocols.

It's a view subscribed to by Klaus Olsen, CEO EFB Admin Services. He states that with increased connectivity comes the greater susceptibility of EFBs to cyber threats. He adds data breaches into the cyber cauldron. "Ensuring data integrity is critical, especially in scenarios where real-time

In late 2022, Jeppsen, whose FlightDeck Pro EFB has been enabled on over 300,000 devices since its introduction in 2012, was a target of a cyber incident which affected certain flight planning products and services. (Copyright: Jeppesen, a Boeing Company)

operational data is accessed mid-flight," he says.

Ken Munro, Partner at Pen Test Partners, a provider of cyber security consulting and testing, discloses that most critical issues the company has found stem from data integrity. "By tampering with something as simple as runway length in the underlying database, engine performance will be miscalculated. A hack of an EFB puts at risk the integrity of that data resulting in errors – when these align with other factors (weather, high workload) – the Swiss cheese model – this is when the potential for incidents occurs."

Ken Munro, Partner, Pen Test Partners

"By tampering with something as simple as runway length in the underlying database, engine performance will be miscalculated."

Ken Munro, Partner, Pen Test Partners.

Munro continues. "There are numerous cases of mis-transposing of data from an EFB then leading to a safety incident. However, we found vulnerabilities in EFB apps that would cause the pilot to be given the wrong performance or weight & balance data."

According to Munro, there are several threat actors, ranging from the obvious nation state, to those motivated by the various armed conflicts in progress, to those simply proving that they can hack sensitive aviation assets. "My personal view is that large sums could be made by shorting airline stock, then causing a flight safety incident to occur through a security issue in an EFB. The stock drops; profit [drops]."

Class action

To understand why these advanced EFBs present a new attack surface, a quick dive into the taxonomy of EFBs is needed.

The host platform i.e. the hardware used to run the software programs can be portable or integrated.

EFB systems were initially categorised into different hardware classes: Class 1 covered portable commercial-off-the-shelf (COTS); Class 2 covered mounted, specialised, and Class 3 covered installed EFBs. These classes were retired in AC120-76D (Oct 2017), simplified and reclassified as 'portable' and 'installed' to harmonise with EASA and ICAO guidelines.

A portable EFB is a portable EFB host platform, used on the flight deck, which is not part of the certified aircraft configuration. As per the International Civil Aviation Organization (ICAO) definition, portable EFBs are often pilot-issued and considered Portable Electronic Devices (PEDs). Other characteristics include having self-contained power and that they may rely on power and/or data connectivity to achieve full functionality. Any aircraft modifications to support portable EFB must be design approved.

Apple iPad EFB approval was obtained in 2011, and Microsoft's MS Surface EFB approval was granted in 2014.

An installed EFB is an EFB host platform installed in the aircraft and subject to normal airworthiness requirements and design control. They are included in A/C type certificate (TC) or supplemental type certificate (STC).

According to Olsen, portable EFBs, particularly those brought off the aircraft, carry higher risks due to varied environments and Wi-Fi connections. "Operating system-specific vulnerabilities exist, with iOS generally seen as more secure due to its controlled ecosystem, while Android and Windows devices may require additional layers of security and are more prone to exploits," he says.

Munro agrees. "The operating system in use can have a significant bearing on the security of the EFB. iOS is relatively straightforward to secure, owing to the walled garden of Apple operating systems. Android can be somewhat more straightforward to compromise, as can Windows. That said, any of these operating systems can be locked down and made very secure."

In most cases today, the EFB

leaves the cockpit and goes home with the pilot, or to their layover hotel, says Munro. "EFBs are critical devices, given they calculate weight and balance and take-off and landing performance and alongside access to corporate data. Their security should be given equal attention when compared with flight deck and avionic component security, yet this is often overlooked by smaller operators."

The European Union Aviation Safety Agency (EASA) and other regulatory agencies have outlined specific guidelines detailing how EFBs should be classified, what software is approved, and certification requirements.

EFB applications are categorised as Type A or B, depending upon the applications loaded on the host and can be hosted on either portable or installed components.

As per EASA definitions in its AMC 20-25A Airworthiness considerations for Electronic Flight Bags (EFBs), Type A applications are EFB applications whose malfunction or misuse have no safety effect. They may be hosted on either portable or installed EFBs and do not require any approval.

Type B applications are applications whose malfunction or misuse are limited to a minor failure condition, and which do neither substitute nor duplicate any system or functionality required by airworthiness regulations, airspace requirements, or operational rules. They may be hosted on either portable or installed EFBs; require an operational assessment and do not require an airworthiness approval. They are authorised as part of the operator's authorised EFB program and listed in the operator's EFB program catalogue.

In its AC 120-76E, the FAA clarifies that "the appropriate level of EFB security depends on the criticality of the usage of the EFB application (e.g., an EFB which only holds a list of fuel prices may require less security than an EFB used for performance calculations). Beyond the level of security to ensure the EFB can properly perform as intended, the appropriate level of security ultimately depends on the capabilities of the EFB, including connections to other systems. Security impacts of connections to aircraft systems should be addressed, and special conditions may need to be addressed."

Mixed report card

EASA's regulatory framework also emphasises the importance of cybersecurity measures to protect data on EFBs from unauthorised access. The agency also supports the European Centre for Cybersecurity in Aviation (ECCSA) initiative which aims to increase collaboration and information sharing amongst aviation stakeholders, a key enabler for implementing a resilient aviation cyberspace.

"I believe more work is required to address cyber threats," says Larsson, "and as always, a joint effort from industry experts, regulatory bodies, lobbying organisations and associations are the best mix." This mix includes the AEEC/IATA EFB Users Forum which recently met in Portugal. The EFB Users Forum is a joint activity with IATA that enables airlines and other aircraft operators to state their preferences in the evolution of EFB hardware, software applications, and connectivity to the ground. This ensures operational benefit to the flight deck crew and the economic benefit to the airlines. Flight Operations, Information Technology, Engineering, and Maintenance disciplines are represented among the participants of the Forum.

The 'could do better' opinion is shared by Munro and Olsen.

Although both EASA and the FAA have issued general guidelines on EFB security, Olsen believes they remain focused on broader compliance rather than prescriptive, granular security protocols. "As threats evolve, there may be a need for these bodies to adopt a more standardised, stringent policy approach to ensure all operators adhere to consistent cybersecurity practices. However, flexibility in security measures allows operators to tailor solutions based on specific needs."

Klaus Olsen, CEO, EFB Admin Services.

> **"with increased connectivity comes the greater susceptibility of EFBs to cyber threats."**
>
> **Klaus Olsen, CEO, EFB Admin Services.**

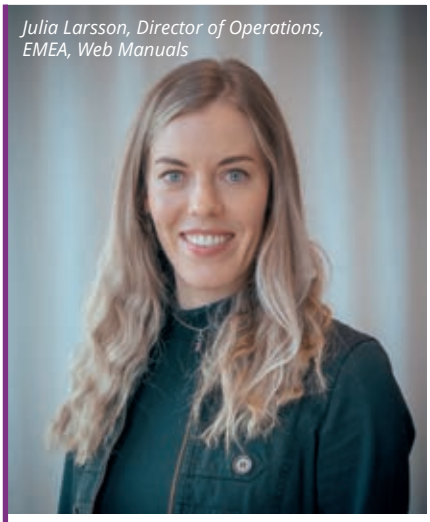
For Munro, while installed EFBs that are a permanent fixture in the cockpit are adequately covered by regulation, portable EFBs are not so well covered. "FAA regulations are weak for portable EFBs," he asserts. "EASA regulations for portable EFBs are significantly more robust but could still be improved."

The weakest link

Regulators may be responsible for setting general cybersecurity frameworks for aviation businesses to comply with, but OEMs and operators are not absolved of accountability.

The responsibility of risk mitigation, on the other hand, must lie with both OEMs and air operators that develop the technology and have a real understanding of how EFBs are applied during operations, says Larsson.

It's a view shared by all those spoken to for the purpose of this article. "While regulatory bodies set baseline standards, the primary responsibility for risk mitigation often lies with OEMs and operators. OEMs design security features within devices, but airlines must also implement strict operational protocols, given the variability of


Julia Larsson, Director of Operations, EMEA, Web Manuals

"Working with more interconnected systems can introduce some security risks."

Julia Larsson, Director of Operations, EMEA, Web Manuals.

threats and differing device usage scenarios across operators. A collaborative approach between OEMs, operators, and regulators is essential for robust EFB cybersecurity," states Olsen.

Munro believes that installed EFBs are well covered, and OEMs are doing a good job in installed EFB space. "Semi-portable EFBs, such as those found in the A350, is an interesting case as they have integration with flight displays but can be removed from the cockpit.

"Risk mitigation for a portable EFB comes from both the software developers providing the various applications, through to the operator securing the EFB, together with giving and enforcing good training and guidance around EFB use."

The FAA agrees. In its AC120-76E, it emphasises that "the operator is responsible for ensuring security controls are in place to mitigate against the risk of IUEI [Intentional Unauthorised Electronic Interaction] to an EFB's OS architecture, its specific hosted applications, and any of the databases or data links used to enable its hosted applications. The operator is also responsible for protecting the EFB from possible contamination from malware. Evidence should be provided, through analysis, testing, or a combination of both, to ensure EFB security is effective. The operator should define the processes and procedures to maintain the security level of the EFB during its entire operational life cycle."

In the UK, the Civil Aviation Authority (CAA) must review the risk assessment, procedures, testing and approve the application.

Prime technique

There are several measures operators can take to secure EFBs. For Larsson, best practice includes frequently installing the latest software updates. She also advances encrypting the data, requiring a strong password and restricting app access to authorised personnel. According to Olsen, effective EFB security also requires regular security audits and risk assessments, policies that enforce strict data access and storage protocols, and ensuring all data transmitted between the EFB and airline systems is encrypted and that the devices are secured when outside the aircraft environment.

An EFB provider should also have a resilient and robust cybersecurity structure in place. As Larsson explains, Web Manuals' apps utilise encrypted data transfer, secure login functions that use tokens, and store customer data in app-only storage. Operators must also employ cybersecurity measures to their devices, such as multi-factor authentication (MFA).

"Additional functions such as MFA are important as there is only so much the app can do on its own," she says. Olsen agrees that MFA is a necessary measure as it adds a layer of security beyond passwords.

Furthermore, Olsen says that a cybersecurity structure should include end-to-end encryption for the protection of sensitive data during transmission, a network security, to ensure connections (e.g., onboard Wi-Fi) are monitored and secured. While not a software supplier, EFB Admin Services we maintain close relationships with leading EFB software providers to ensure it can support a wide array of EFB suites and applications. This includes Mobile Device Management (MDM) solutions such as Intune, Kandji, and Miradore that enable centralised control over device security, user permissions, and updates.

Munro judges MDMs to be an important part of securing a mobile device against misuse by the user. He believes an EFB is a safety critical device, and therefore should be treated as such. Pilots shouldn't be using these devices to watch Netflix or use personal email, he insists. "Operator IT departments should not turn on every single restriction available to them in an MDM as these can have unintended impacts on the flight deck. A careful approach needs to be taken," he says.

MDM solutions enhance security and operational efficiency by enabling remote management, security updates, and policy enforcement. They allow administrators to control access, update software, and monitor device status. Using an MDM, airlines can ensure regulatory compliance and maintain device integrity across varied operational contexts. They also help reduce security risks on devices by limiting human interaction, for example, by limiting browser usage. MDMs also contain data lost through remote device locking and wiping.

Web Manuals' Reader App, for example, supports MDM configuration per device by predefining the customer, username and password, and locking the configuration to the device.

Can we fix it?

Gremlins can appear in an EFB. If an efficient reporting and escalation system is in place, a quick resolution is feasible. Once a bug is identified, immediate actions include disabling vulnerable components, issuing

An inside view

My name is Will Ware, and I am a Captain for a major US carrier. I'm also the Program Manager for the EFB program at my airline since 2011, and I have been the Co-Chair to the AEEC/IATA EFB Users forum for the past 13 years. Our EFB program is one of the top five largest with over 12,000 pilot EFB's and 22,000 flight attendants. We are currently on our fourth version of EFB since 2014.

I agree that cyber security is necessary and important, and that each airline and vendor have a cyber security team that protects our assets and brand.

Let's set a real-life baseline on EFB operations. These EFBs are highly regulated by FAA, EASA and other CAA's. Today we have had over 260 million portable Tablet EFB flights, that is over 250 million flights with no significantly issues with security.

The statement that EFBs are "Critical to flight Safety" is not completely accurate. .

You must know that EFB functions are defined by AC120-76E as having a Minor or No safety effect. This means that the CAA will review EACH EFB function for procedures, training and mitigations in case of failure. Some EFB programs are simple, like only charts and manuals, others have more complex apps like performance and electronic quick reference manuals, but those would require more scrutiny in the regulatory approval process.

We must be careful and ensure that we are not using fear to drive home a point. In this article I would like to provide some depth to some of the assertions that have been made.

Installed EFB's are not used very much anymore because the software is dated and due to aircraft certification requires a decade to change. Portable EFB's like the iPad are where we can make significant innovation with multiple vendors, and we see new features in months not years.

The statement of "Making large sums of money by shorting an airlines stock then causing a crash" is simply ludicrous. Pilots are highly trained, and aircraft have so many safety features, the EFB itself will not cause and airplane crash.

Most all airlines use iPad, why, because there are plenty of vendors building software for iOS, but mainly because iOS is a "walled garden" and apps work independently of each other. Yes, there are some airlines with aircraft attached Windows EFBs, but most all have Pilot attached Apple EFB's

There was concern mentioned about personal use of an EFB. A few airlines lock their EFB down and do not allow personal use, but the majority of the airlines not only allow it, but they also encourage it. It's a term we call "Carry Value". If a pilot uses their EFB personally, they will ensure it is charged, updated and protected from damage. As mentioned in the iOS world, apps are separated. Even if there was a hack, remember the EFB function has a minor or no safety effect.

MFA, (Multi Factor Authentication). Some of the responders were encouraging the enforcement of MFA on EFB's. I could not disagree more, and this is where the fear vs fact comes to a head. You know how MFA works; you get a text on your phone and use that text as a two-step verification. Now let's apply that to pilots in the flight deck. First, my personal cell phone (PED) must not be used as per FAR 121.542. Secondly, my phone would not be connected in flight to even get the MFA text. Third, do you want your pilots doing MFA in flight or on an approach?

I agree that parties need to work together and ensure EFBs are safe. That is exactly what is done at the AEEC/IATA EFB Users Forum. We need to not use data points where the full story is not known. Why, because the regulators will produce unnecessary obstacles that slow or block the innovation, we are seeking on tablet EFB.

Will Ware

updates, or deploying patches. Airlines should coordinate closely with OEMs and software providers to ensure vulnerabilities are addressed without delay, particularly in mission-critical software, advises Olsen.

Larsson elaborates further. "The general process of remediation is to confirm the bug, develop a new solution, test it, create a public test version – and once all feedback and checks have been resolved – share to the app store. This process will vary in time depending on the type of bug/weakness found, and the level of urgency will impact how long it takes to be resolved."

Munro argues it's not realistic to expect a quick resolution. "Safety critical code such as that found on an EFB will need to be recertified after a change. Whilst a vulnerability might only take a day to fix, recertifying the code can take months. That certification process is really important – we need to be certain that a code change doesn't result in the EFB failing at a critical point."

Having discovered vulnerabilities in various EFB platforms over the years, Munro says that without pointing fingers, some OEMs are more receptive than others, though all have improved over the last few years. He advises testing an EFB after every significant change, such as the addition of a new package, new functionality/connectivity or a change of hardware.

"Flying is safe," he assures, "owing partly to years of learning from mistakes. Cyber security evolves far faster, changing overnight in some cases (e.g. Heartbleed). At times like this, safety can be seen to get in the way of cyber. Careful risk assessment is the way forward, balancing the risk of an immediate fix versus the status quo."

By Alex Preston

Manufacturing of Adapter Plates for a TCAS antenna program at Camtronics, a HEICO Company. Copyright: Heico

Bringing Vertical Integration to the Aerospace Industry: Can It Be Done?

For almost 100 years, the automotive industry has streamlined manufacturing through the process known as "vertical integration". According to the authoritative website wardsauto.com, "Vertical integration, through which automakers owned part or all of their major suppliers, started around 1918 with General Motors Corp.'s takeover of United Motors. Henry Ford took the concept to its logical conclusion in 1929 with the fully integrated Dearborn manufacturing and assembly complex."

In today's modern world, automotive companies do outsource some of their products from third-party suppliers. But they do this so seamlessly, that their vertically integrated production process remains smooth and streamlined.

In contrast, the aerospace industry's supply chain is disjointed and inefficient, leading to delays in manufacturing, repair, and product delivery. Still, the fact that both Industries rely on mass production begs a question: is it time to apply the lessons of vertical integration, as used by the automotive industry, to aerospace manufacturing and repair?

According to Bob Loycano, Vice President of Supply Chain with FDH Aero, the answer is yes. "The way automotive companies build their products — with everything arriving to the assembly floor perfectly on time — makes it feel like a well-oiled machine compared to building an airplane," he said. "In aerospace, we often say, 'Yeah, but we're different.' But in the end, when it comes to the assembly process, we're really not that different. Sure, we have stricter requirements, but so does automotive. If there's one area where aerospace could really learn and benefit, it's in how we manage the final assembly, adopting a more streamlined process."

The current state of vertical integration in OEMs and MRO

When it comes to vertical integration, there's a substantial difference in how much this approach has been adopted by aerospace OEMs and MROs.

"For a number of years prior to the COVID-19 global pandemic, there was a focused effort by aerospace OEMs toward less vertical integration and organic production toward moving manufacturing of core cost driver products offshore to low cost regions," said Daniel Adamski, Executive Vice President – Distribution with Kellstrom Commercial Aerospace. "Then came the COVID-19 global pandemic, which crippled global supply chains from raw materials, specialty processes, intermediate goods, component subassemblies, and end products. The OEMs that had moved to a heavily outsourced manufacturing model struggled most during and coming out of the COVID-19 pandemic compared to those OEMs who maintained a vertically integrated organic production model."

This was not the case with MROs: Quite the contrary. Instead, "In the MRO Supply Chain, the industry has gone through a phase of consolidation of smaller component and engine MROs by larger MROs," Adamski said. "As such, when faced with competition, the MRO providers that are vertically integrated fare best when faced with competition because they have the ability to compress end to end turn-around times (TATs) and control costs. Some MROs even take vertical integration to the point of fabricating their own extended DER [Designated Engineering Representatives] repair capabilities with extended repair detail parts in lieu of purchasing OEM parts as part of DER repairs."

As a result of their supply chain challenges during and after COVID-19, OEMs are now more sympathetic to the idea of vertical integration. In fact, "Vertical integration is becoming more prevalent in the aerospace OEM supply chain," said Simon Merriott, AJW Group's SVP of Customer

Simon Merriott - Senior Vice President Customer Service, AJW Group - Copyright: AJW

"Vertical integration is becoming more prevalent in the aerospace OEM supply chain."

Simon Merriott, AJW Group's SVP of Customer Service.

Daniel Adamski Headshot. Copyright: Kellstrom Aerospace

"Best in class aerospace OEMs have benefitted over the years from borrowed concepts from the automotive industry."

Daniel Adamski, Executive Vice President – Distribution with Kellstrom Commercial Aerospace.

Service. "Major OEMs like Boeing, Airbus, GE Aviation, and Rolls-Royce are increasingly integrating upstream by acquiring suppliers or forming long-term partnerships to secure access to critical components and raw materials. They are also integrating downstream by entering the MRO space, offering extended service agreements, and controlling aftermarket services. This strategy enables OEMs to not only manage production but also maintain control over the lifecycle of their products, ensuring a steady revenue stream from aftermarket services."

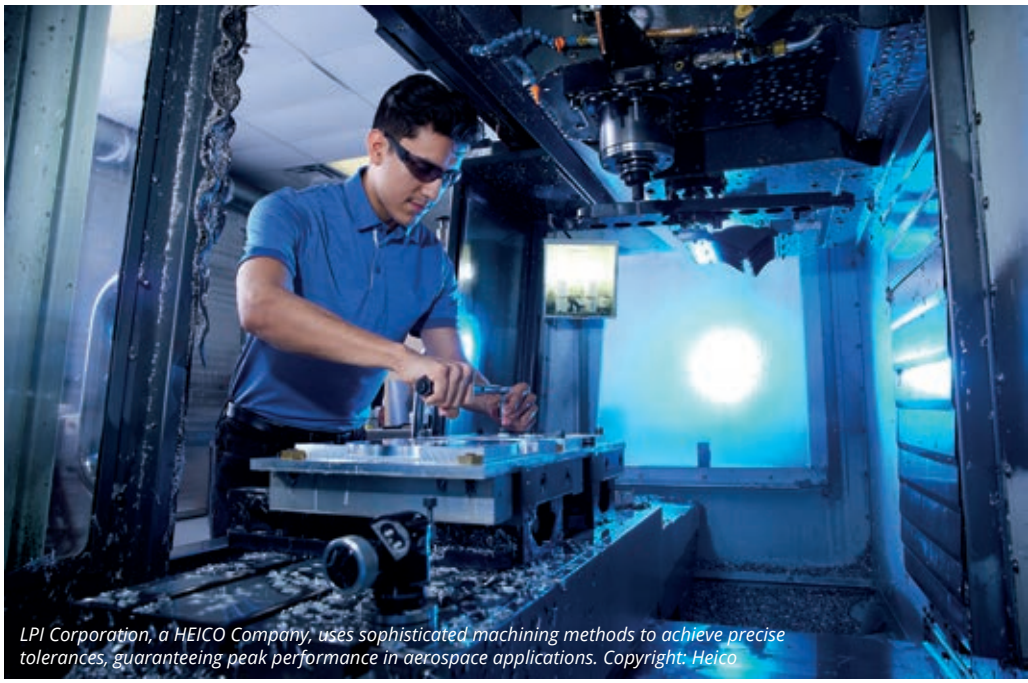
According to Merriott, the aerospace MRO supply chain is more fragmented, but vertical integration is on the rise here as well. The reason: "OEMs are increasingly entering the MRO market, either by establishing their own service centres or acquiring independent MRO companies," he said. "This is a shift from the past, where MROs operated independently from OEMs. OEMs are now aiming to capture more of the aftermarket business, particularly for maintenance, repairs, and spare parts, thus tightening their control over the entire product lifecycle."

Still an incomplete process

There is no doubt that COVID-19 shook many aerospace companies' faith in using third party sources and relying mainly on parts that were purchased for their price, rather than their proximity. Nevertheless, "achieving full vertical integration is a significant challenge," said Loycano. This is why, "vertical integration exists in pockets," in the aerospace industry, he said. "Naturally, companies want to control their own destiny, which motivates them to manage more aspects and increasing levels of their supply chain. However, doing so comes with considerable obstacles."

A case in point: "If we look at hardware as an example — just a small part of the overall aerospace supply chain — even something as simple as making a nut or bolt includes critical steps like applying a plating or coating," said Loycano. "Many companies don't have the ability to fully integrate that process in-house, sometimes because of evolving environmental regulations, and some companies were grandfathered in and still maintain those capabilities, giving them a competitive edge. For newer entrants, however, it's a barrier — they have to rely on existing providers."

Another obstacle to vertical integration in the aerospace industry is the OEMs' reluctance to make information public, for fear of providing advantage to competitors. As a result, "there is not enough data sharing in the ecosystem which prevents efficiencies across the supply chain," said Monica Badra. She is the founder of Aero NextGen, a digital solution brokerage in MRO that matches clients to solutions that solve specific pain points. "This reluctance is shared by all of the OEMs, from airframers to part manufacturers: visibility into new aircraft, flight schedules, and production of parts is very limited," Badra said. "When it comes to the actual fleet that's in service, the airlines' reluctance to share data makes it difficult for MROs and OEMs to prepare for the level of work inflow they're going to receive in their shops. As such, knowing when to order parts beforehand — instead of after the unit or aircraft



LPI Corporation, a HEICO Company, uses sophisticated machining methods to achieve precise tolerances, guaranteeing peak performance in aerospace applications. Copyright: Heico

AJW HQ, Slinfold, West Sussex
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has been received and inspected — and having the manpower in place to fulfil all of that work becomes very difficult to achieve."

Despite the obstacles associated with achieving vertical integration, the trend is catching on. "The aerospace industry tends to watch the major OEMs very closely to see how they react and respond to the market," Loycano observed. "Therefore, OEMs often set the trends, prompting others to consider similar strategies. For example, we are starting to see others follow in the footsteps of one of the top OEM's 10-plus-year strategy of consolidating their sub-tier hardware spend. This strategy ensures their sub-tiers have access to the products they need to put their assemblies together, and by mirroring this approach, competitors hope to gain similar success."

The downside? As aerospace companies that work in a similar space combine, either through joint venture or an actual acquisition, there's fewer of them out there to serve the rest of the market." As a result, when a large OEM comes in and acquires a supplier that serves everyone, it risks alienating that supplier's remaining customer base, because organisations tend to not want to work with a company that's now aligned with a competitor," said Loycano. "This reality of industry consolidation has created some challenges with respect to certain products.

Gaps in the supply system

A supply chain works much like a set of dominoes set out in a line. so that triggering one can cause the rest to fall down in sequence. If one element in that supply chain is missing — if there's a gap — then the process won't work as planned.

So where are the gaps in the OEM and MRO supply chains, and why do they exist? "Well, at the airframe level there is not much more vertical integration today than in the recent past," said Patrick Markham, VP of Technical Services with HEICO Corporation. "This is because the airframers still have high concentrations of Tier 2 (T2) OEM suppliers with little to no competition once the T2 OEMs 'get onto the aircraft'. As a result, the airframers are much more like assembly facilities than manufacturing facilities. Even when Boeing re-integrates Spirit AeroSystems [Boeing's former Wichita plant that the company sold off in 2005], they will still have most of their subsystems being manufactured by a small number of big T2 OEMs."

Irony #1: Because of the power

FDH worker at the COE – handling parts

of Airbus and Boeing in the aircraft OEM market, "major subsystem suppliers typically compete to have a foot in each airframer's supply base," Markham said. "This is the primary reason for gaps in vertical integration: The big T2 OEMs whose umbrella covers many subsystems will typically keep the manufacturing of the various subsystems in separate facilities or divisions."

Irony #2: "On the MRO side, the MROs either owned or controlled by the major OEMs will be vertically integrated, since they are manufacturing the parts that the MRO side of the business is consuming," said Markham. "This tends to leave the independent MROs at a natural disadvantage."

Another cause of gaps in aerospace vertical integration is money. "When evaluating gap areas in supply chain vertical integration strategies, at times the largest challenges are capabilities with extraordinarily large capital expenditure (CAPEX) and non-recurring engineering (NRE) requirements like casting and forging manufacturing, advanced new generation computer chip manufacturing, patented materials and processes including patented surface treatments," Adamski said. That's not all: "Some supply chain integration constraints go beyond cost to intellectual property constraints that are harder to overcome," he noted. "These must be dealt with by contractual guarantees and redundancy strategies."

Then there's just the problem of how many parts it takes to build and maintain an airplane. "OEMs rely on a vast network of specialised suppliers, often involving thousands of components sourced globally. Integrating all tiers of this supply chain is highly complex and cost prohibitive," said Merriott. "Meanwhile, independent MROs may rely on multiple suppliers for spare parts, which can lead to bottlenecks and inefficiencies in the supply chain. So vertical integration in MRO is limited by the fact that MROs cannot control the production of parts, creating logistical challenges."

When it comes to this last gap, OEMs fare worse than MROs. The reason: "OEMs operate with a well-defined bill of material, so when a part is missing it becomes a real challenge to fill it because you don't have a lot of other options," said Loycano. "On the MRO side, flexibility is greater because the FAA has stepped in and allowed for PMAs (Parts Manufacturer Approvals) and other ways to satisfy the requirements of an original part, giving them a bit more flexibility to get an aircraft back into service."

The impact of gaps

The gaps noted above don't just impede vertical integration in the aviation industry. They also create distinct and different problems for OEMs, MROs, and their airline customers. "For OEMs, especially at the lower tiers of the supply chain, these gaps can create vulnerabilities in production schedules and delivery

times," said Merriott. "The complexity of the supplier network means they are often exposed to risks from supply chain disruptions, which can delay aircraft production and increase costs."

Next, independent MROs face gap-related challenges due to their reliance on third-party suppliers for critical parts. "Delays in parts procurement can lead to longer aircraft downtimes, higher operational costs, and a reduced ability to meet customer expectations," Merriott said. "This lack of control over the parts supply chain may reduce efficiency and competitiveness in the market."

Finally, there's the impact on the airlines who fly the aircraft. "These gaps can result in longer lead times for aircraft maintenance, increased costs for parts and services, and ultimately, operational inefficiencies," said Merriott. "Airlines may experience extended aircraft downtime, which impacts their ability to generate revenue and maintain reliable schedules."

Bob Loycano, Vice President of Supply Chain with FDH Aero

All of these gaps caused supply chain delays for the aerospace industry prior to COVID-19. The pandemic made these delays much worse, and many of them have yet to return to pre-pandemic levels.

"Both OEMs and MROs are grappling with extended lead times," Loycano said. "Parts that once took a few months to source can now take over a year to manufacture and get in the door, creating a significant challenge, whether you're an OEM or MRO."

"Gaps in vertical integration can amplify supply chain challenges," added Markham. "Since aircraft are a sum of all of their many parts, a disruption, unforeseen demand, or a manufacturing hiccup can ripple up the supply chain and impact the MROs' and the airlines' ability to maintain airworthy aircraft for their planned needs. Some recent examples include having aircraft built, but waiting on engines. It's hard to deliver an aircraft without its engines."

Filling the gaps

If vertical integration is the key to resolving the aerospace Industry's supply chain issues — both on the

OEM and MRO sides of the coin -– then the question that must be answered is this: How do we fill the gaps?

One way is by creating partnerships with third party suppliers that mimic the seamless smoothness of true vertical integration. "OEMs and MROs can establish stronger, long-term partnerships with key suppliers, as AJW Group has done over its 92 year legacy," Merriott explained. "By working closely with our partners and suppliers, we reduce bottlenecks and improve parts availability and logistics."

"Alternative Parts, FAA-PMA approved parts & DER repaired parts, help to fill the demand for spare parts," Markham added. "These FAA approved alternatives are natural gap fillers. Some of the OEMs have even bought FAA-PMA parts to include in their new build when their supply chain could not keep up. Likewise, OEM (or OEM controlled) MROs will often use the PMA and DER alternatives when their OEM parts are unavailable. On the independent MRO side, some MROs develop relationships with PMA part producers to develop supply chain redundancy. This is especially true for the HEICO companies: The HEICO repair stations collaborate effectively with the HEICO PMA divisions to develop completely independent Bills of Material to break the reliance on the OEM supply chain."

A second solution is to use advanced technology such as artificial intelligence (AI) to improve the monitoring, purchasing, and warehousing/distribution of needed parts, so that true just-in-time delivery can be executed without delay. "We have implemented advanced data analytics, real-time tracking, and predictive maintenance systems within our Group operations to improve visibility and efficiency across the supply chain," said Merriott. "Our digital transformation efforts allow for more streamlined processes, better inventory management, and quicker responses to supply chain disruptions we may encounter."

A third way to fill the gaps is by using the combination of onboard aircraft systems' monitoring and real-time AI analysis of those results to support preventive maintenance of aircraft. According to Badra, "AI can also support predictive maintenance by going through the historical records of aircraft maintenance events and unit repairs, to identify the intervals in flight cycles between part removals, using those rates to detect when parts will be removed, to order the parts needed based on historical bill of materials and plan the manpower to manage the repairs on time and potentially avoiding an Aircraft On Ground [AOG] situation from taking place."

Another way to fill the gaps is by working closely with suppliers, alerting them to both OEM and MRO needs as far into the future as possible. "The more we can understand what our customers require, the more we can buffer those requirements," said Loycano. "That's what we do as a distributor: We go out ahead of that demand to get the parts and put them on the shelf, alleviating the OEM or aftermarket company's inability to understand what their requirements are. Essentially, we have the parts they need, whenever they need them."

Lessons learned from the automotive sector

At the outset of this article, we talked about the automotive industry and its success with vertical integration. This success is something that the experts interviewed for this article are well aware of. So what lessons do they believe can be learned from the automotive industry and applied to aerospace?

"Standardising certain aircraft components, where possible, could help reduce complexity and improve supply chain efficiency," Merriott replied. "This would enable easier sourcing and manufacturing of parts across different platforms. As well, automotive companies often use just-in-time (JIT) production to minimise inventory costs and reduce lead times. While more challenging in the aviation industry due to safety and regulatory requirements, elements of JIT could improve efficiency in the aviation MRO supply chain."

This is just one example: "Best in class aerospace OEMs have benefitted over the years from borrowed concepts from the automotive industry," said Adamski. "Lean, 6 sigma practices, kaizen and many of the Shingo masters principles originally championed in the automotive industry by Toyota and others. In fact, continuous improvement through kaizen have been applied effectively not just to aerospace production facilities but also to aerospace supply chains through kaizen activity, along with data-driven management informed by control towers at the production cell level, management by walking around (gemba), daily risk management and mitigation strategies, and a variety of other strategies with the objective of managing all risk areas including those in the supply chain, which can include an effective vertical integration strategy including built-in redundancies."

The bottom line: Although the aerospace industry may not be able to apply all elements of vertical integration to the same extent that the automotive industry has, there is much that can be done to make aerospace supply chains work better and more rationally for OEMs, MROs and the customers they serve. What it will take to get there will be a mix of determination, innovation, and the motivation to do things better. Given some of the results described by the experts quoted for this article, this push is already underway.

By James Careless

Your parts have a destination

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Maintaining Predictive Maintenance with Today's MRO Software

An essential role in modern aviation that enhances safety, reduces costs, minimizes unexpected component failures and improves overall fleet availability

Predictive maintenance with aviation MRO software is a key tool for MRO teams and airline operators. It plays an essential role in modern aviation by enhancing safety, reducing costs and improving operational efficiency. Transforming how airlines and MROs operate, it addresses key challenges such as unplanned downtime, data management and spare parts optimization, making it a vital tool for the industry.

Because aircraft systems are so complex, even minor issues can lead to significant operational disruptions. Forecasting maintenance shifts the focus from routine, time-based

Graph below: Copyright: Maxa

checks to data-driven, need-based interventions, which helps to reduce unplanned downtime.

The industry is acknowledging the positive benefits of predictive aviation maintenance software and its usage is growing. According to a market report by Hamburg, Germany-based IoT Analytics titled "Predictive Maintenance and Asset Performance Market Report 2023–2028," the global predictive maintenance market grew to $5.5 billion in 2022—a growth of 11% from 2021—with an estimated CAGR of 17% until 2028.

Using predictive maintenance with aviation MRO software solves challenges. "As aircraft are using more advanced avionics platforms with large volumes of data collected from nearly all aspects, gaining access and utilizing this data is integral to safe and smooth operations," says Justin Daugherty, Sr. Director of Aerospace Solutions at Maxa, Montreal, Quebec, Canada.

"Predictive maintenance in aircraft requires leveraging real-time data. [This includes] sensor data or performance data and can include real-time connectivity utilized by AI-driven analytics to predict potential failures before they occur, allowing maintenance teams to address issues proactively."

Monica Badra, Founder of Aero NextGen, Montreal, believes solutions for aircraft predictive maintenance, "address challenges by automating complex data analysis to identify potential failures early, helping manage component wear through optimal replacement timing, reducing costly aircraft on ground (AOG) events

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Decision Assist for Mechanics by Leveraging Machine Learning. Copyright: RAMCO

by scheduling repairs proactively, and optimizing inventory levels to avoid both shortages and excess stock. This improves overall maintenance efficiency, minimizes operational disruptions and reduces costs."

What's Unique about Aviation?

Predictive maintenance in the aircraft industry is unique, according to Jason Cordoba, Managing Director of CordobaQ, London, because of the critical nature of the systems involved, the strict regulatory environment and the extreme precision required in forecasting. "By accounting for factors such as system complexity, operational stress and regulatory compliance, predictive maintenance ensures the safety, reliability and efficiency of aircraft. Its importance in aviation lies in enhancing safety, minimizing costs, reducing downtime and extending equipment life—all of which are essential in an industry where precision and reliability are non-negotiable."

Yes, unique because of the high complexity and safety-critical nature of its systems; however, AI is helping with that. "Aircraft components must function flawlessly, making predictive maintenance crucial for avoiding in-flight failures and ensuring regulatory compliance," says Simon Miles, Head of AI, Aerogility, London. "AI-driven solutions such as Aerogility support this by analyzing large volumes of data created from aircraft operations. This proactive approach ensures that maintenance is done at the optimal time, reducing risks and ensuring system reliability."

Because the aviation industry is so highly regulated for safety and reliability, Saravanan Rajarajan, Director of Aviation Solution Consulting at Ramco Systems, Chennai, India, explains that predictive maintenance solutions must align with data collection and validation regulations. "Data processing and insights are validated. Aircraft systems in the areas of navigation, communication and control systems are critical for flight safety, which means the predictive insights should be highly accurate and tolerances for minor malfunctions should be exceptionally low or zero. Aircraft data are sensitive and proprietary, which adds an extra layer of uniqueness to predictive maintenance. The system should comply with data privacy and cybersecurity requirements to protect data integrity."

Miles believes many AI systems act as a "black box," where users cannot see or understand how decisions are made. In contrast, Aerogility's model-based AI provides clear, explainable outputs, allowing maintenance teams to trust the predictions and make better-informed decisions. A trusted, explainable approach gives airlines confidence in the recommendations. "By reviewing various factors, such as usage patterns and the availability of parts, model-based AI enhances

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A Crucial Aspect and Success

A crucial aspect often overlooked is that implementing powerful predictive maintenance software, while necessary, is only part of the solution. The real challenge lies in managing situations where components showing normal operation are predicted to fail. This creates complex decision-making scenarios involving maintenance action selection, repair cycle management and return-to-service protocols. Success in aviation predictive maintenance demands a well-orchestrated ecosystem of collaboration. This includes seamless coordination between airlines, MRO service providers, OEMs, technology providers and aviation authorities. This interconnected network ensures effective implementation, regulatory compliance and optimal operational benefits.

Vikram Singh,
New Services Program Director,
Revima, Rives-en-Seine, France

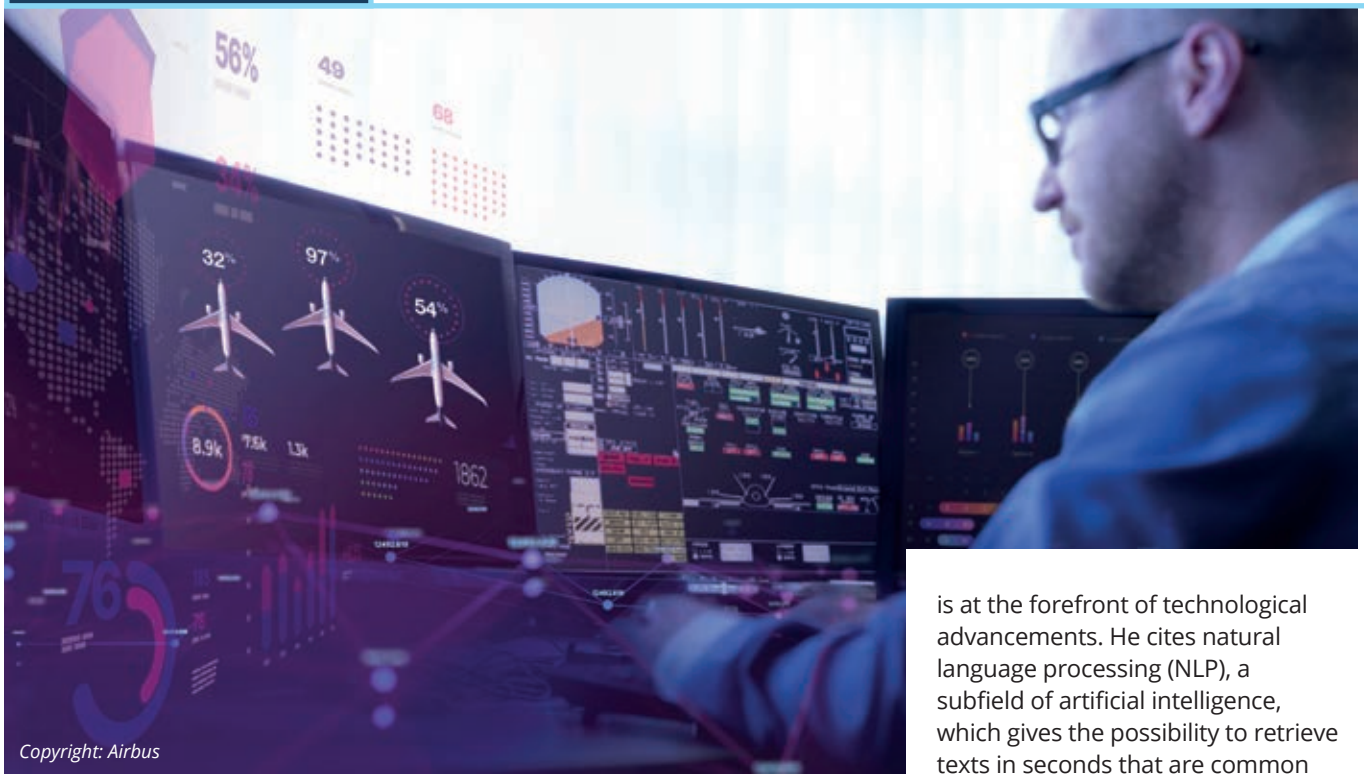
forecasting and planning, solving the challenge of balancing operational demands with maintenance needs. The great thing about model-based AI is that, from experience, maintenance teams can consider a series of what-if options and understand the behavior of different trade-offs. The impact of a particular part failure may, for example, result in bringing in the aircraft for maintenance earlier than expected."

David Marty, Head of Digital Solutions Marketing at Airbus, Leiden, Netherlands, agrees that as the latest generation of aircraft enters the market, the more the industry must deal with aircraft producing a high level of data. But, he contends the challenge is to turn this data into intelligence. "Often data tells us what happened and not immediately why a weak signal was triggered. With the information, we are able to prioritize, focus on key issues and find an approach to best implement a solution. All in all, data is becoming more and more powerful as a tool and together with our customers, we're committed to use this tool correctly to make flying safe and ensure stable operations. Predictive maintenance is the first step to optimize technical operations and eradicate technical cancellations and delays. The next step would be to leverage data analytics and digital capabilities to reduce direct maintenance costs and increase aircraft availability."

Furthermore, Marty contends that predictive maintenance is at its early stage in the aviation industry, "While in contrast to that, already well developed in industries like retail, oil and gas and many others. "Predictive maintenance implementation is a real digital transformation project implying organization change, change management, etc. All Airbus customers having already engaged in predictive maintenance have confirmed the value in terms of reduction of technical operational interruptions."

Predictive Innovations

Recent advancements in MRO software for aircraft predictive maintenance focus on integrating AI, IoT and digital twin technologies. AI and machine learning analyze historical and real-time data from aircraft systems, predicting failures more accurately than traditional time-based or reactive



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approaches. "IoT-enabled sensors offer continuous, real-time data monitoring, reducing the need for periodic manual inspections and lowering the risk of unexpected failures or AOG events," Badra says. "Digital twins simulate aircraft system performance under various scenarios, allowing maintenance teams to forecast potential issues without physical testing, saving both time and resources. Additionally, cloud-based platforms and collaborative dashboards centralize data and improve decision-making by providing stakeholders with a unified view of aircraft health and maintenance status."

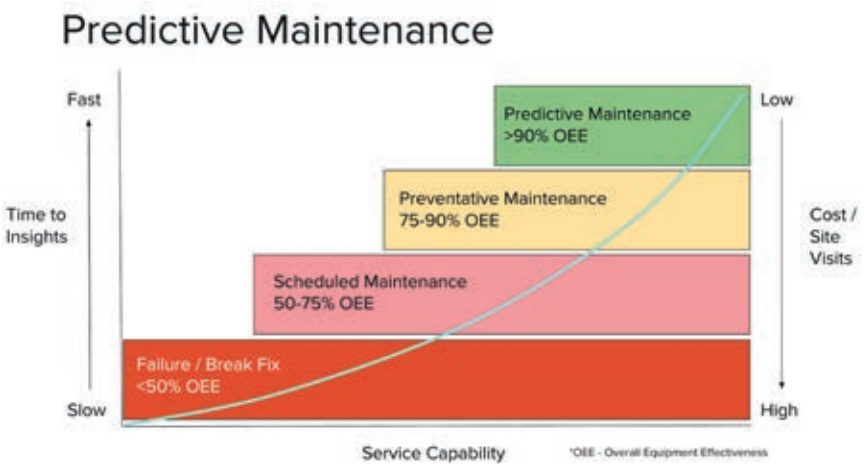
Cordoba agrees that AI-powered dashboards, machine learning algorithms, digital twins, IoT integration, cloud-based platforms, and advanced analytics—have revolutionized how maintenance is conducted. "These technologies help by enabling more accurate predictions, reducing human error, enhancing collaboration and ensuring more efficient use of resources. By replacing outdated manual processes and static data models, they optimize aircraft maintenance, reduce costs and increase operational reliability."

These innovations replace manual processes, scattered data sources and reactive maintenance methods with proactive, data-driven approaches. Badra adds that enhanced analytics for inventory management also optimize stock levels for aircraft components, reducing costs associated with excess or shortage of parts and making aircraft maintenance more efficient and cost-effective.

By integrating AI and machine learning into its MRO software, Maxa enables more accurate failure predictions based on historical and real-time data from aircraft systems. Maxa's platform continuously monitors aircraft health through IoT-enabled sensors, providing real-time insights that reduce the need for manual inspections and help prevent unexpected failures and costly AOG situations. "Through a centralized, cloud-based platform, Maxa offers collaborative dashboards that give stakeholders a shared view of maintenance activities and system health, enhancing decision-making and coordination," Daugherty says. "This suite of tools replaces outdated, reactive maintenance methods with a proactive, data-driven approach, ultimately reducing costs, improving operational reliability and streamlining inventory management for aircraft components."

Marty agrees that AI integration is at the forefront of technological advancements. He cites natural language processing (NLP), a subfield of artificial intelligence, which gives the possibility to retrieve texts in seconds that are common (logbook entries) and finally get recommendations based on airline fleets. Furthermore, he says there are increased capabilities to manage extended sensor data. "Time series through FOMAX — co-developed with Collins Aerospace — is an on-board connectivity solution that enables airlines to collect aircraft maintenance and performance data on-board the aircraft and automatically transmit it to ground-based operations, at a higher speed than previously possible, and in near-real-time.

Enhanced and next-generation predictive maintenance capabilities are forcing operators to revisit data platforms and data quality. Rajarajan explains the first step in implementing predictive maintenance is assessing the data capabilities and quality of the source systems. "Existing infrastructure should have a clear process and workflow to collect the right data, and collected data should be governed by the right workflow controls. The second step is training the AI systems in different data types, the context of data and the relationships between structured and unstructured data sets, which has to be correlated meaningfully through training. Accuracy issues require constant intervention from the data engineers and business until the AI systems bring in real value."



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Capitalizing the Cloud

Cloud-based software enables real-time data collection and manages the volume and velocity of the data needed for predictive maintenance. "The cloud enables centralized data storage, scalable analytics and real-time collaboration across global fleets, which are essential for the Industry 4.0 revolution," says Suyash Joshi, Senior Developer Advocate, InfluxData, San Francisco. "It integrates advanced tools like AI/ML and digital twins, transforming MRO operations into more agile and proactive processes."

"Cloud technology has been a fundamental enabler for predictive maintenance in aviation, revolutionizing data sharing capabilities among collaborators in a secure environment," says Vikram Singh, New Services Program Director, Revima, Rives-en-Seine, France. "This technology has created an effective platform for cross-organizational collaboration while providing robust frameworks to manage intellectual property rights and data ownership concerns."

Cloud-based systems provide the scalability and flexibility to run advanced AI/ML programs for faster processing and scaling of data over time. "Cloud-based systems also provide the foundational block to connect to the external ecosystems and leverage the data along with in-house data for prediction," Rajarajan says. "The API-based protocol is essential for ensuring seamless software collaboration for the organization. Thereby, the key data are received and shared."

The cloud has transformed MRO software for aircraft predictive maintenance by providing scalable, centralized platforms that enhance data access, collaboration and storage. With cloud-based systems, real-time aircraft data from multiple aircraft can be seamlessly collected, processed and analyzed in a single, secure environment.

Daugherty believes "This enables MRO providers and airlines to access predictive maintenance insights from anywhere, improving responsiveness and allowing for quicker, data-driven decision-making. Additionally, cloud-based storage reduces dependency on on-premise servers, offering greater scalability and reducing IT infrastructure costs. By simplifying data management and enhancing accessibility, the cloud enables a more proactive and efficient approach to aircraft predictive maintenance, minimizing downtimes and improving fleet reliability."

The cloud has significantly impacted MRO software for aircraft predictive maintenance by improving data accessibility, enhancing collaboration and offering scalability for processing vast amounts of data. "It reduces costs, strengthens data security and accelerates innovation in predictive maintenance capabilities," Cordoba says. "By moving from traditional, on-premise systems to cloud-based platforms, MRO providers and airlines benefit from faster decision-making, more accurate predictions, and a more efficient and cost-effective approach to managing aircraft maintenance."

By Mark Robins

Advances in Predictive Maintenance for MRO Software

In recent years, the field of predictive maintenance for MRO software in aerospace has witnessed several advancements:

- **AI/ML Algorithms:** Advanced machine learning models are now capable of analyzing vast amounts of historical and real-time data from aircraft systems to detect patterns indicative of potential failures, helping operators address issues before they escalate.
- **IoT Sensor Integration:** Aircraft are increasingly equipped with IoT sensors that continuously monitor critical systems, such as engines, avionics and hydraulic systems. The integration of this sensor data into MRO software allows for real-time insights and more precise maintenance schedules.
- **Time Series Data Analytics Platforms:** Tools like InfluxDB provide the ability to ingest, store, and query high-resolution time-stamped data. This is crucial for monitoring trends, identifying anomalies, and correlating events across systems over time. By leveraging time series databases, MRO solutions can transition from rigid, schedule-based maintenance to dynamic, condition-based approaches.

Suyash Joshi,
Senior Developer Advocate,
InfluxData, San Francisco

AI takes flight: Growing use cases for AI in aviation MRO and its regulatory future

Since the release of ChatGPT, it seems as if all anyone can talk about is Artificial Intelligence (AI). However, beyond some of the over-hyped usage of ChatGPT and Generative AI in the public domain, applications for AI genuinely do offer vast opportunities for increased efficiency and productivity in many industries, and its adoption in Aerospace will be high.

So, how can and where can we apply AI in aviation, an industry that is, for good reason, extremely cautious and safety-conscious, and also requires complete visibility and traceability? Well, AI constitutes way more than just generative AI and Large Language Models (LLM). Incorporating AI into aviation maintenance, in particular, presents a unique opportunity to enhance safety, efficiency, and accuracy by employing a wide range of tools and technologies.

Here we'll explore the here and now applications for AI in aviation maintenance, plus a glimpse of the regulatory future surrounding industry AI adoption:

1. Maintenance Scheduling & Supply Chain Optimization – I think we might be able to plan that a little more efficiently, don't you?
AI-powered optimization engines aren't as prominent in the zeitgeist as Generative AI, but it is one of the most suited applications of AI, and there are a multitude of applications for optimization in aviation. Since we're talking aviation maintenance, maintenance scheduling optimization is the obvious standout.

Giving up maintenance yield means performing more maintenance over time—which means additional costs – but also, having the aircraft out of service for longer means lost revenue. An optimization engine that can schedule maintenance at the best possible time at the best possible location has the potential to greatly reduce maintenance costs and improve maintenance yield fleet wide.

At the same time, to ensure cost-effective and timely completion of a given maintenance visit, optimizing the order in which tasks are performed and how they are assigned yields numerous benefits. Doing so can significantly enhance the efficiency of the process, reduce costs, and improve turnaround time (TAT). In turn, this will help get the aircraft back in the air faster, leading to increased revenue generation. The direct benefits from optimizing maintenance scheduling are making the most effective use of maintenance technicians a limited resource, amid skills shortages and workforce availability issues. AI can schedule tasks dependent on the technician's skills, availability of parts and tools, and even the physical location on the aircraft.

Furthermore, by applying optimization to the maintenance supply chain, you can minimize material delays by ensuring that the right parts are always where you need them when you need them to get your aircraft back in the air as quickly as possible.

2. Error Detection & Reclassification – are you sure that's what you meant?
AI can also assist in identifying data entry errors and reclassifying data to improve accuracy and the overall

quality of datasets.

When raising faults, misclassification of the failed ATA systems is a common issue in the airline industry. Sometimes it is the result of human error, but often the fault first gets classified when it is raised, based on the symptoms. Then, when the fault is eventually resolved, it is found that the original fault classification was not the actual culprit system—that there was another root cause. These misclassifications can have a significant impact on data quality. Airlines may assign their technical records team or reliability engineers to review records, identify errors, and perform reclassifications to address the issue. However, this process can be time-consuming, costly, and requires painstaking attention to detail.

IFS customer Southwest Airlines, has recently launched an AI-based solution that can detect misclassified faults by leveraging an aviation-specific language model to identify patterns in text. This approach allows for improved data quality by detecting and presenting potential errors to a reliability engineer, who still has the final decision-making authority, resulting in a more efficient process that maintains human oversight.

3. Automated Failure, Troubleshooting, and Repair Identification – How about you try this?

When a fault occurs, a technician usually needs to spend significant time examining the fault-isolation manual, researching the correct origin of the fault, and determining the appropriate troubleshooting steps and repairs.

On top of fault classification, an aviation-specific language model could, in real-time, when a fault is being raised, identify potential sources of the failure, suggest troubleshooting activities, and propose repairs. By presenting these options to the technician, the model reduces unnecessary noise and enables them to use their time more efficiently. By including the past success rate for each option, the technician can select options that save time and resolve the issue more quickly.

This can help the aircraft to get back in the air sooner and even prevent recurrences in the future. Avoiding or reducing delays has real value to airlines. According to Airlines for America, in 2023, delays had a direct cost of $101.18 for every minute a flight is delayed.

4. Predictive Maintenance & Anomaly Detection – Heads up, it's about to break!

The concept of predictive maintenance is about to get an overhaul. The application of newer types of AI, namely Anomaly Detection and Pattern Recognition, is making predictive maintenance much more accessible.

Unsupervised learning models are lowering the barrier to entry even further for the use of AI in predictive maintenance applications. Although to a lay person, the concept of "unsupervised" learning models for AI might seem scary, it's just a name for a mode of learning that allows you to plug the AI into a set of data, and it can essentially figure out its own algorithm. Add in the fact that these AI models are comparatively cost effective—in terms of the technology itself but more importantly, in terms of reducing or eliminating the need for a team of data scientists to analyze data, train models and recalibrate—and AI usage for predictive maintenance is more democratized, not just something available for tier 1 OEMs or the largest airlines and MROs.

Not only do unsupervised models reduce the time and cost of implementing a solution, but it also has the power to strip out bias from the process, particularly when dealing with large amounts of unlabeled data like the flood of sensor data generated from a modern aircraft or jet engine—management consulting firm Oliver Wyman expects the newest generation aircraft will be generating between five and eight terabytes of data per flight by 2026.

Key to these models is anomaly detection, which enables the integration of AI with your sensor data. By identifying what is considered "normal" it can alert you when deviations from that normal state occur. This serves as an early warning system. When combined with pattern recognition, AI can learn to detect patterns in the sensor data that indicate certain events are likely to occur. This results in an accurate and reliable early warning system that can predict upcoming events.

Future waves of AI in aviation – on regulatory maturity path

We can think of AI adoption in terms of three waves. The first is what we can do now with existing regulatory frameworks, largely in a supporting role. The second is what we can do in the relatively near future, and involves a more proactive approach from the AI, but this still involves humans being the ultimate decision maker. The third wave is much further in the future and involves some significant regulatory changes in terms of how we do things in MRO which ultimately results in much more AI-driven automation.

We can consider the core tenet of aviation maintenance today the principle of a highly-trained and certified person performing maintenance in accordance with the rules, regulations, and procedures approved by the OEM and the regulator. At the stage of AI adoption we're in today, we can safely deploy AI as long as it doesn't mess with that core tenet. This means that AI must be in a supporting capacity only with final decision making always resting with a human.

Bringing it back to predictive maintenance, the only way to unlock the true potential of AI-driven predictive maintenance, though, is to fundamentally change our approach to maintenance, moving from an inspection-based model to a truly predictive model. Right now, predictive maintenance is in addition to the prescribed maintenance program—in the future it will be used instead of it. Organizations and regulators such as IATA and the FAA are working to move in this direction, but it is a massive shift and it's not happening overnight.

Data quality is of critical importance to the ascent of AI in aviation

However, the application of AI is only as good as the data streams airlines and MROs are able to feed it. AI models by their very nature are data-hungry and rely on accurate data to make accurate decisions—and bad data can seriously skew these results.

There are many organizations in the industry still relying on paper. When working on paper, there is always a time lag between things happening and information getting into the system which means that decision makers are faced with information lag. Or even worse, if organizations are working with paper or even simplistic systems, there is no validation that the data they are generating is actually correct. Digital maintenance platforms help address this data issue from the outset They start by setting up a solid data structure—all the rules the data needs to follow. Then, as transactions are processed in real time, such as a technician recording maintenance on a mobile device, they are validated against the rules and prevent poor data from being entered at source.

With the right digital foundation at the data level, airlines and MROs can begin to build AI into their maintenance operations. These improvements can represent real value to airlines & air operators and, ultimately, their customers. AI is here to stay, and the aviation industry is taking notice. Early adopters have the chance to get in on one of the great technological leaps of our age. Companies that can quickly integrate AI will be the ones that come out on top. They'll streamline operations, make smarter decisions, and stay ahead of the curve as AI continues to evolve.

By Rob Mather at IFS

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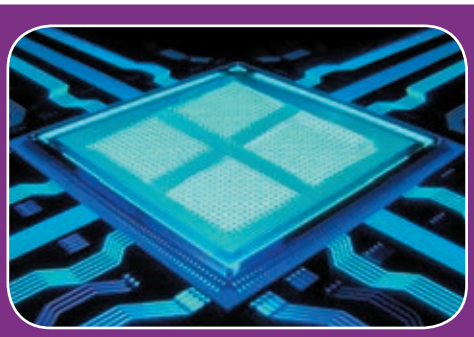

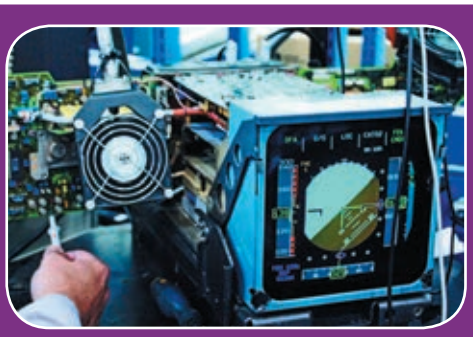

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