Q3 OCTOBER 2024

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PUBLISHERS:

Neil Walker
Director of Marketing

Simon Barker
Sales Director

EDITORIAL CONTIBUTORS:

Ian Harbison
James Careless
Alex Preston
Mark Robins

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CONTENTS

Plane Talk in Plain English!

We are delighted to bring you the second edition of Aerospace Innovations magazine.

The aim of the publication is to analyse often complex technical subjects and present them in a clear and easy-to-read format, hence we borrowed the phrase "Plane Talk in Plain English!"

In our packed October (Q3) edition, Alex Preston speaks to some leading companies about DO-178C compliance standards for safety-critical software. In his next article, Alex examines the needs and uses for Air Data Testing Systems (ADTS), which are crucial for testing and verifying flight instruments when aircraft are on the ground. James Careless looks into the world of full flight simulators and the huge strides being made in computer-generated graphics over recent years, and how AR and VR are being incorporated into training programmes. In his next article, James looks at cybersecurity robustness and resiliency and talks to some leading experts about the rise of GPS jamming and spoofing, and what can be done to mitigate these and other threats to the commercial aviation sector. In his third article, James talks to some leading MRO software vendors about comparing and analysing data that has come from different IT systems and often disparate sources. In a related MRO IT topic, Cameron Byrd of AIXI and Barry Lott of Southwest Airlines, discuss the importance of clean data and how it can open the door to AI-Driven MRO operations. Next up, Mark Robins looks at Data Loading Systems (PDLS and ADLs) and talks to some leading providers of these systems and asks how they help operators improve aircraft operational readiness. Finally, we asked Matt Jackson of PACE Aerospace & IT to help demystify the ARINC 661 standards that relate to avionics displays.

We hope to meet those of you who are attending the High Integrity Software Conference (HISC) 2024, which is taking place at the ICC in Wales on October 22nd. Aerospace Innovations is proud to be an official media partner of this important annual gathering of engineers and software companies for a broad range of industries, including aerospace and defence. We are pleased to announce the launch of our own new event, called Avionics & Testing Innovations. The conference and exhibition is scheduled to take place on May 20th and 21st 2025 in London. It will deliver a great platform for avionics, testing and certification organisations to gather, learn, network and source new information, products, and services at one unique annual event.

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

Happy reading!

Simon Barker & Neil Walker
Publishers

simonb@aerospace-innovations.com
neilw@aerospace-innovations.com
www.aerospace-innovations.com

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Indonesian Air Force Orders Four Airbus H145 Helicopters

The Indonesian Air Force has placed an order for four Airbus H145 helicopters as part of its training modernisation programme. The order was announced during the Bali International Airshow taking place this week.

Under the agreement between the Indonesian Air Force and PT Dirgantara Indonesia (PTDI), Airbus will deliver the five-bladed H145s to PTDI, who will manage the reassembly and completion of the mission equipment and other customisation work at its facility in Bandung, Indonesia, for final delivery to the air force. These multi-mission helicopters will be deployed for military training and light search-and-rescue missions.

"We are honoured by Indonesia's selection of the country's first Airbus H145 for its new training fleet. We are fully confident that the highly versatile H145 will make a positive impact in enhancing its military pilot training and at the same time be a critical enabler for its search-and-rescue operations. With a trusted partner in PTDI, we look forward to working together in support of Indonesia's fleet," said Vincent Dubrule, Head of Asia-Pacific, Airbus Helicopters.

Dassault Falcon 8X Soars to New Heights with Honeywell's EASy IV Avionics

Honeywell Aerospace Technologies recently installed the Primus Epic for Dassault EASy IV integrated flight deck on our Dassault Falcon 8X aircraft.

This fourth-generation EASy (Enhanced Avionics System) flight deck comes equipped with state-of-the-art advancements that streamline operations, enhance situational awareness and improve operational safety.

Jim Currier, Aerospace Technologies (AT) CEO, flew on the aircraft and said, "The EASy IV upgrade is more than just an enhancement; it's a complete transformation of the flight experience. It's about flying smarter, with confidence and safety at the forefront. We're thrilled to have this featured on our 8X aircraft."

Chief Pilot Jonathan Maas said, "I was impressed by the user-friendly advanced situational awareness tools. The enhanced fidelity of the screens, combined with features like the 3D AMM and iNAV, make navigating complex airports at night or in bad weather significantly easier. EASy IV truly makes flying safer and more intuitive."

RTX's Collins Aerospace, Pratt & Whitney and TU Delft Enhance Collaboration on Commercial Aerospace Technology Research

Collins Aerospace, Pratt & Whitney and Delft University of Technology, have signed a master research agreement (MRA) enabling bilateral collaboration across a range of sustainable aviation research opportunities, including advanced materials, hydrogen propulsion, advanced manufacturing and industrial design. Through the strategic framework of the MRA, Collins Aerospace and Pratt & Whitney will initiate multiple research projects involving TU Delft graduate research facilities, students and staff over the next five years. Collins Aerospace and Pratt & Whitney are RTX businesses.

"Collaboration between RTX engineers and university research institutions plays an important role in developing our understanding of emerging technologies, while also supporting the next generation of talent that will drive our industry forward," said Michael Winter, RTX Chief Science Officer. "Our MRA with TU Delft – our first agreement of its kind with a European university institution – will focus on advancing technologies to support more sustainable aviation, which is key to the future of our industry."

Among the first projects initiated as part of the MRA, Collins and TU Delft are collaborating on a high speed intelligent inspection system to enhance manufacturing processes for lightweight and recyclable aircraft materials. Pratt & Whitney and TU Delft will develop novel engine configurations that utilize thermal energy recovery technologies in order to improve fuel efficiency and reduce CO_2 emissions for commercial aircraft.

Mayman Aerospace completes successful flight tests of its RAZOR™ VTOL aircraft

Mayman Aerospace has completed successful flight tests at a military base in the Southern California desert of its RAZOR test bed VTOL aircraft.

The RAZOR test bed is exactly the same dimensions and weight as the RAZOR P100 and uses the same propulsion, engine gimballing, thrust vectoring and flight control systems.

Supported by our Other Transaction Authority (OTA) contract with the US Department of Defence, the fully autonomous flight tests were designed to test avionics, thrust vectoring mechanisms, flight control laws, software, and command and control (C2). It also enables early verification of operating procedures. This series of tests focused on the transition of the engines moving out of hover mode, which is critical for high-speed winged flight. It also added to our history of successful autonomous take-off and landings.

The Mayman Aerospace RAZOR VTOL aircraft is designed with multi-role capabilities. Its proprietary control system enables swift, secure and efficient transportation of critical supplies, bolstering military readiness and resilience in challenging and austere environments. RAZOR aircraft can also be configured to extend the range of small Air-to-Air or Air-to-Surface missiles such as Brimstone or Hellfire, delivering them over 200 miles. The aircraft can then deploy the missile for final target acquisition, enhancing the reach and precision of the missile systems.

Launched vertically without the need of special launch system or infrastructure, RAZOR can act as an ISR, target designation and launch platform. Due to its extreme speed the RAZOR can quickly intercept drones. RAZOR also provides a cost-effective alternative to expensive cruise missiles. Its swift, agile, AI-guided C2/C3 enables precise payload or kinetic impact delivery. This versatile platform ensures efficient operations at a fraction of traditional costs.

Fokker Services Asia Appointed as an Embraer Authorized Service Center

Fokker Services Asia, a subsidiary of Fokker Services Group (FSG) has been appointed as an Embraer Authorized Service Center. This milestone was achieved with the signing of the final contract during the Aviation Week MRO Asia Pacific 2024 event held in Singapore.

Fokker Services Asia has now been awarded the official certification of Embraer Authorized Service Center to provide maintenance services for the E-Jets first-generation family, with a focus on E190 aircraft. This achievement not only marks a significant step forward in enhancing FSG's capabilities in the Asia Pacific region, but it also offers Embraer the opportunity to expand and strengthen their support network in this rapidly growing market.

Frank Stevens, Vice President of MRO Services at Embraer Services & Support, commented: "We are very happy to partner with Fokker Services Asia to offer a strategic additional location to our customers. This will potentially provide more capacity, capability and help us to keep expanding Embraer's Authorized Service Center footprint in Asia-Pacific".

Leon Kouters, Vice President Sales & Marketing at FSG, expressed his enthusiasm: "We are thrilled to have met all the stringent requirements set forth in the contract and to now be recognized as an Embraer Authorized Service Center".

Ramco Systems Unveils Aviation Software 6.0, Leveraging AI for Smarter Aircraft Management

Ramco Systems, a global enterprise software company offering next-generation SaaS-enabled platforms and products, announced today the release of its Aviation Maintenance Software 6.0, which leverages AI and machine learning for smarter, predictive aviation management. The latest product launch includes new AI-driven features that enable organizations to digitally transform their Maintenance, Repair, and Overhaul (MRO) and engineering operations. These features also streamline workflows from resource planning to purchase orders and improve management of flight safety and compliance.

"The latest version of Ramco Aviation Software 6.0 is a significant milestone in our journey of continuous innovation and commitment to excellence," said Sundar Subramanian, CEO of Ramco Systems. "Along with the advanced capabilities, our specialized Engine MRO solution is a key part of this release, addressing the critical challenges of engine maintenance. By harnessing advanced technology and our domain expertise, Ramco Aviation Software 6.0 will enable aviation organizations to meet their growing customer demands and stay competitive. We look forward to empowering organizations to drive transformation with this game-changing release."

Drayton Aerospace Selects EmpowerMX from IFS to Boost MRO Operations

Drayton Aerospace Porto Alegre (POA), a global leader in civil, freight aviation Maintenance, Repair, and Overhaul (MRO), has selected EmpowerMX from IFS to plan, execute, and optimize its operations. This collaboration aims to enhance return on investment (ROI) and deliver transformative efficiency gains by optimizing the utilization of resources. Key benefits include predictive control over maintenance turnaround times, improved management of risk factors, and heightened customer satisfaction.

EmpowerMX from IFS is a recognized asset and service management software solution for leading independent third-party MROs. It is a perfect fit with Drayton's vocation for providing value, quality work and world-class service to commercial airlines and freight operators.

The agreement will optimize software and technology to increase MRO efficiencies, turnaround times and the bottom line for the Brazilian-based company.

With a comprehensive roll-out plan over the next few months, the Drayton POA team will use IFS EmpowerMX to implement its vision of introducing proven MRO best practices to transform maintenance operations through cloud-based, mobile-first technology. It will play a key role in the efficiency of the business well into the future and be pivotal in their focus on becoming a world-class, third-party MRO centre of excellence.

Embraer to invest in new MRO Facilities for Commercial Jets in Texas

Embraer has announced the expansion of its maintenance, repair and overhaul (MRO) services network to support the growing fleet of E-Jets in the Unites States by opening a new Embraer owned service center at the Perot Field Alliance Airport, in Fort Worth, Texas.

In partnership with the City of Fort Worth, Denton County and the State of Texas, Embraer expects to begin operations in an existing hangar, in the first quarter of 2025, while building a second hangar that should be concluded by 2027. With the new facilities, Embraer's capacity to serve the E-Jets customers is expected to have a considerable increase in the U.S.

"This expansion will significantly increase the capacity, capability, and footprint of our services network by providing world-class support to our customers and the growing fleet of E-Jets in North America. Also, it is part of Embraer's growth strategy in the US", said Carlos Naufel, President and CEO of Embraer Services & Support.

Cebu Pacific Orders 70 Airbus A321neos

Cebu Pacific of the Philippines has placed a firm order with Airbus for 70 A321neo aircraft, finalising an MoU announced by the airline in July. The purchase agreement was signed in Manila by Mike Szucs, CEO of Cebu Pacific and Benoît de Saint-Exupéry, EVP Sales of the Commercial Aircraft business at Airbus.

Mike Szucs said: "The selection of Airbus A321neo underscores our focus on operational efficiency, sustainability, and innovation, ensuring that we continue to deliver the highest standards of service while significantly reducing our carbon footprint. This milestone signals our ongoing dedication to expanding air travel accessibility and affordability, while supporting the Philippine's broader economic growth and connectivity goals."

Benoît de Saint-Exupéry said: "The A320 Family has supported Cebu Pacific's domestic and short-haul international network growth over the last two decades. We're grateful to the airline for its continued endorsement of our best selling single-aisle product line. The A321neo is highly regarded for its unparalleled economics, performance and fuel efficiency. We're confident that these additional A321neo aircraft will contribute strongly to the all-Airbus operator's next phase of expansion as one of Asia-Pacific's leading low cost carriers."

Cebu Pacific operates 61 A320 Family aircraft on its extensive regional network. In addition it flies nine A330 widebodies on high density routes in the region, as well as to destinations in the Middle East. Following the latest order, the airline's backlog with Airbus now stands at 94 A320neo Family aircraft and seven A330neo.

The A321neo is the largest member of Airbus' best-selling A320neo Family, offering unparalleled range and performance. By incorporating new generation engines and Sharklets, the A321neo brings a 50% noise reduction and more than 20% fuel savings and CO2 reduction compared to previous generation single-aisle aircraft, while maximising passenger comfort in the widest single-aisle cabin in the sky.

To date more than 6,500 A321neo have been ordered by more than 90 customers across the globe.

FLYHT Celebrates Successful Edge Integration with Air North

FLYHT Aerospace Solutions Ltd. today announced the successful integration of the Company's industry leading 5G AFIRS EdgeTM solution with Air North, Yukon's Airline into their Boeing 737 NG operations bringing efficiencies such as automated post-flight data download for their flight safety program, Aircraft Interface Device (AID) functionality to connect the pilots to key aircraft data, and power over Ethernet to charge iPads to enhance cockpit crew operation. FLYHT's AFIRS 228 Iridium SatCom will power Air North's real-time access to FLYHTHealth™, FLYHTLog™, aircraft tracking, and voice services, while the Edge provides reports on aircraft system health and flight data downloads.

Per the agreement signed in October 2023, Air North has agreed to purchase FLYHT's innovative hardware and software services as part of the Yukon airline's fleet renewal plans. In June 2024, Air North was the STC partner on Boeing 737 NG aircraft for the AFIRS Edge.

"The commencement of Edge 5G data transfer operations at Air North validates the technology that we have pioneered with the flange version of the Edge," commented Derek Taylor, Vice President of Strategic Opportunities at FLYHT. "Air North has been our trusted STC partner, and we are excited to provide them with wireless access to their aircraft data."

Joe Sparling, Air North's President and CEO, said, "The next generation technology provided by the Edge allows us to meet our goals to improve connectivity and realize greater operational efficiencies. We look forward to installing the solution on additional aircraft as we modernize our B737 Classic fleet."

New Programmable Resistor Modules from Pickering Interfaces Address Functional Test, Verification and HIL Applications

Pickering Interfaces, the leading supplier of modular signal switching and simulation solutions for use in electronic test and verification, has announced a new family of PXI and PXIe programmable resistor modules, its first that can handle up to 2A and 200V (or as limited by max power). Part of the company's expanding range of medium to high power resistor modules, these PXI (model 40-254) and PXIe (model 42-254) products follow on from the 2.5 W (model 40-251), 5 W (model 40-252), and 10 W (model 40-253), providing a compact, simple solution for applications requiring 1 or 2 resistance channels, with up to 15 W of power handling capability per channel. The 42-254 range is also the first medium power module available in PXIe format.

Programmable resistors are designed to simulate resistive sensors and variable resistors in systems when testing devices such as electronic controllers. The 40/42-254 family is available in a variety of resistance ranges and resolution capabilities (from 0.125 Ω to 8 Ω resolution and from 1 Ω to 395 kΩ range) to meet the needs of most functional test systems. For added test coverage, each channel can simulate short or open circuit conditions that can be experienced in a system caused by faulty wiring or sensors.

Software control is simplified by using resistor value calls. The module calculates the resistance setting closest to the requested value and sets that value. The user can interrogate the module to find the actual setting used. To help ensure long-term accuracy, a calibration cable assembly can be attached to the module in place of the UUT (unit-under-test), enabling simple calibration using a DMM (digital multimeter) to verify the resistor channels.

Wind River Unveils Game-Changing Enterprise Linux Offering for AI and Critical Workloads

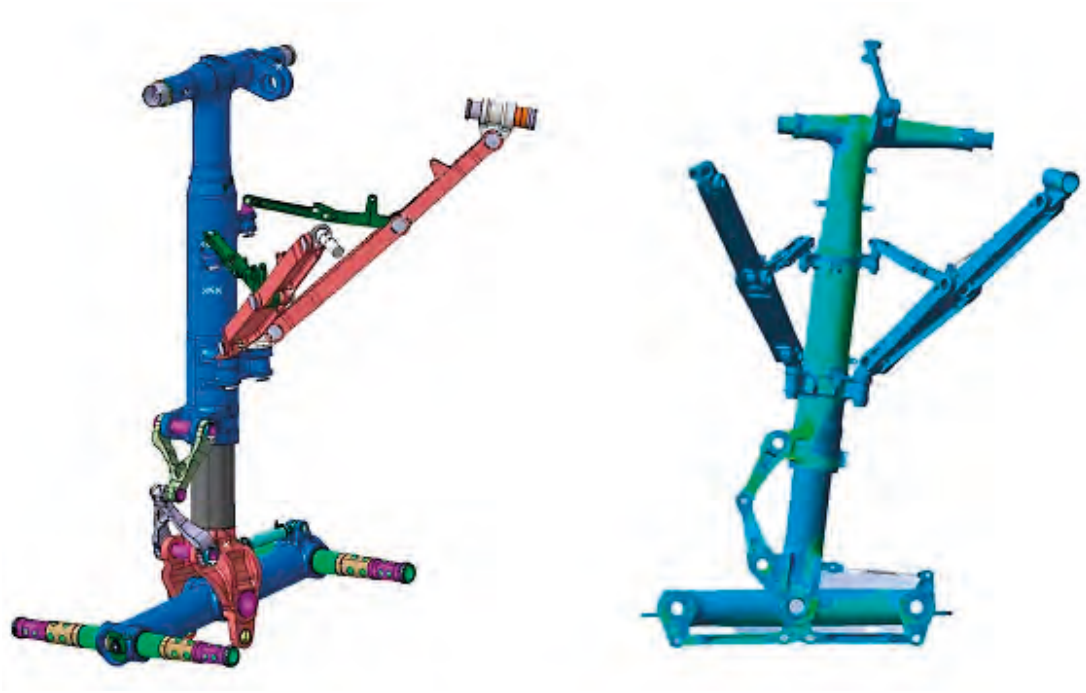
Wind River®, a global leader in delivering software for the intelligent edge, today introduced eLxr Pro, its commercial enterprise Linux offering to address the unique needs of cloud-to-edge deployments. Expanding the company's industry-leading Linux portfolio, eLxr Pro delivers long-term commercial support and services to the recently launched open source eLxr project distribution.

eLxr Pro enables organizations challenged with high-performance edge and enterprise needs to meet stringent performance and operational requirements for the next generation of commercial deployments across a wide range of emerging use cases for autonomous vehicles, aerospace, defense, energy, finance, medical, industrial automation, smart cities, and telecommunications. It addresses the challenges of optimizing and deploying near and far edge applications to process data closer to where it is generated, for workloads that involve remote automatic updates, containerized applications and orchestration, AI inference, machine learning, and autonomous operations. eLxr Pro is based on the open source Debian-based eLxr project, an enterprise-grade distribution powering deployments for intelligent edge, far edge device, near edge server, regional data center, and public cloud scenarios.

Enterprise supplier disruptions, such as the CentOS end-of-life in June 2024, have forced CIOs to reevaluate their Linux vendors. Current options are often either too limiting or overly complex, leading to implementations that do not meet the dynamic demands of this rapidly evolving segment. This trend is driving the demand for seamless cloud-to-edge solutions that efficiently manage complex workloads, such as rapid data processing, and AI and machine learning by reusing core operating system components and common code base and frameworks.

Liebherr, Ansys, and CADFEM Join Forces to Implement an Enterprise Simulation Strategy and Model-Based Engineering Approach

Strategic relationship signals long-term commitment to weave digital thread with Ansys technology



Ansys joins Liebherr in the implementation of the European manufacturer's simulation strategy and model-based enterprise approach. Liebherr's 35-year engagement with Ansys extends across the Ansys product portfolio, strengthening the digital thread and presenting a clear competitive advantage for Liebherr in developing products that exceed customer expectations.

Ansys simulation enables detailed virtual models that describe all physical and functional aspects of every Liebherr product. From mechanical, computational fluid dynamics, and electronics, to live simulation, acoustics, system simulation, safety analysis, and embedded software, Ansys' multiphysics capabilities reinforce the company's digital transformation and digital engineering initiatives through simulation process and data management (SPDM). Ansys Apex Channel Partner CADFEM Germany GmbH — which provides training, user support, and consulting services — supports all sites through a common resource-sharing strategy that reduces barriers to entry.

Liebherr-Aerospace and Transportation SAS is one of the largest Liebherr divisions with sites in Lindenberg, Germany and Toulouse, France, among others. Its product segment Aerospace has already launched a digital transformation program. The objective is to deploy an innovative model-based enterprise approach, become data/model-centric, and implement digital continuity across the entire development and product lifecycle, including efficient data exchange with customers and suppliers.

"Liebherr-Aerospace develops products consistently and completely digitally," said Elko Van Balen and Olivier Banessy, who together lead the model-based enterprise development at Liebherr-Aerospace and Transportation. "The implementation of the model-based approach behind this confirms that the right partners have been chosen."

"Access to Ansys software alleviates challenges related to delivering best-in-class solutions that specifically support our products and technologies in a timely manner," said Dr. Ling Li, PLM innovation services simulation consultant at Liebherr. "We recognize that expertise is being established at all locations and that new simulation topics are being tested as well. Even our designers can run live simulations using Ansys software, which frees up our dedicated simulation engineers and reduces our reliance on external resources."

In this project, Ansys and CADFEM are in close cooperation to jointly implement Liebherr's state-of-the-art and fully digitalized development infrastructure.

"Another important factor is the long-standing partnership with CADFEM, through which we are optimally exploiting the potential of Ansys in many respects," said Bertram Peer, Department Manager Simulation and Method Development Liebherr-MCCtec at the Liebherr plant in Nenzing.

"Virtual product design and development enables teams to work harmoniously across the product lifecycle to leverage critical data that leads to better products," said Walt Hearn, senior vice president of global sales and customer excellence at Ansys. "Through instantaneous data collection and sharing, digital models can simultaneously increase design capabilities and reduce product changes during the entire development process. The ability to transform business processes and applications to improve the customer experience makes the simulation software of Ansys integral to the digital transformation strategy."

Airbus and SESAR partners are taking Wake Energy Retrieval to the Next Level

Following Airbus' success with its recent "fello'fly" wake energy assisted A350 flight demonstrations, the EU's GEESE project within SESAR, led by Airbus, is now taking the concept big steps forward. By further developing the science, technology and processes, together with our industry partners, we could one day see airliners riding the buoyant wakes of others, reducing fuel and associated emissions.

Between 2019 and 2021 as part of its "fello'fly" experimental project, Airbus developed and flight-tested a concept known as "Wake Energy Retrieval". Abbreviated as "WER", the technique sees a pair of airliners flying in formation, allowing the trailing aircraft to benefit from the lift generated by the preceding aircraft's vortices, reducing the thrust required from its engines.

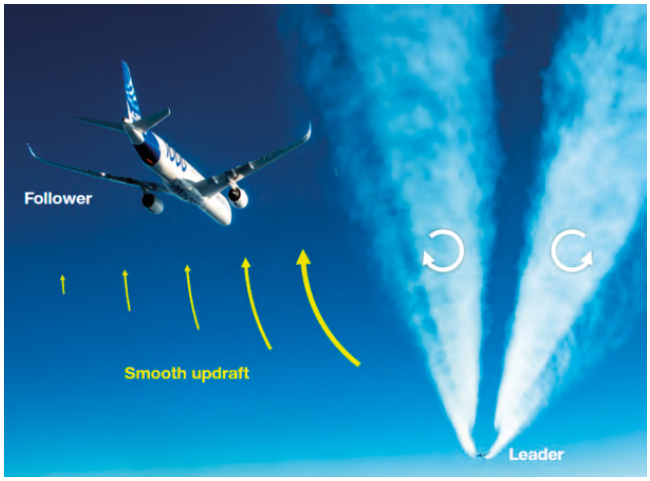
The campaign culminated on the 9th of November 2021, with the first long-haul demonstration of WER flights in transatlantic airspace. It involved two A350s separated by around 1.2 nm (2.2 km) from each other, flying as a pair from Toulouse, France to Montreal, Canada. The subsequent analyses suggested that airlines could save between five and 10 percent of fuel per trip.

The positive results caught the attention of the wider industry within Europe and also across the Atlantic. This has now led to the *SESAR-3 Joint Undertaking (SESAR JU) partners joining forces to further explore WER under a new dedicated industrial research project called GEESE. While this stands for: "Gain Environmental Efficiency by Saving Energy", it is also a nod to the fact that flocks of geese use a similar technique when they migrate in formation, flying over long distances, while benefiting from each other's wake energy.

International stakeholder collaboration

Led by Airbus, GEESE is a 10-million-euro project funded by the European Union's 'Horizon Europe' initiative and industry. This has brought together a range of stakeholders, including Eurocontrol, DSNA, Air France, ON, Indra, ENAC, DLR, AirNav, Bulatsa, CIRA, UAB, Frequentis, Boeing, French Bee, NATS, Virgin Atlantic and Delta Air Lines.

GEESE aims to map out how to enable and scale WER operations for both transatlantic and trans-continental flights throughout Europe. The project defines the necessary operational tasks for pilots adopting technology to automatically manage various WER positions – including flight management systems and new WER cockpit functions that capture and track the wake vortex. The campaign is also exploring a 'pairing assistance' system for dispatchers at airline operations control centres. Notably, airline partners will work together to update their flight plans to find suitable aircraft to pair, taking into account routing to rendezvous point and other considerations.



To this end, the project will run a series of simulations to validate the pairing procedures, involving Air France, French Bee, Delta and Virgin Atlantic airlines. It will also further investigate wake science, to advance the underlying concepts and consider the impact of formations. This includes defining the wake generated by the second aircraft in a pair, safe positioning behind the pair, and how to ensure the safety of surrounding traffic.

Three operational 'work packages' are being developed within GEESE:

"Enable Europe to North Atlantic WER Operations" will develop and refine the initial concept-of-operation (CONOPS), its safety assessment, analyse impacts on legacy systems, and develop simulations and trials to assess assumptions.

"Scaling-up the WER concept to continental Europe", will provide operational solutions for the extension of WER operations within European domestic airspace.

The third facet to GEESE, the Wake Science work package, – will investigate non-CO2 potential benefits of formations.

Current status and next steps

Following SESAR's project selection and funding grant preparation which took place towards the end of Q2 2023, GEESE was given the green light to commence its three-year execution phase.

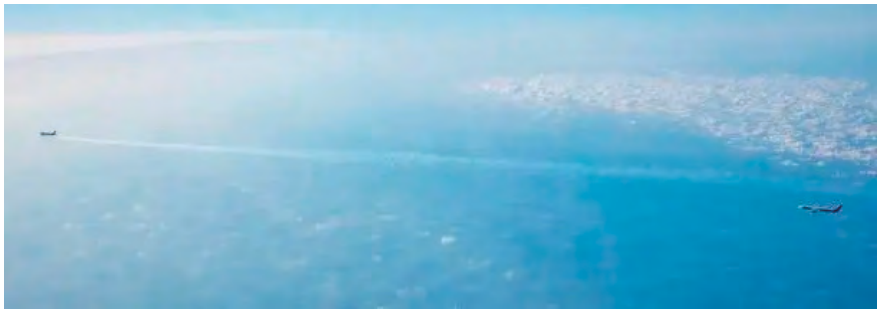
"Today, one year into the project we are mainly working on the definition of the operational processes which will be needed for preparing the WER operations," notes Laura Montironi, Vehicles Systems Architect, in Airbus Engineering.

"These processes will govern how the two aircraft will adapt their trajectories. We will develop these processes together with the airlines and the controllers, so they can perform the flight plan changes and any adaptations that will enable the aircraft to meet."

"We have made good progress to agree with stakeholders on the processes, paving the way for planning and detailing all the validation activities which we'll perform next year."

"This year we also launched the safety assessments," she adds. "So we are still currently in the paperwork phase, as the flights themselves are planned to start around the second half of 2025."

During the flight trials to be operated by Air France, French Bee, Delta and Virgin, the respective paired aircraft will be positioned at different altitudes – in accordance with today's normal ATM vertical separation minima requirements. This constraint is not an issue for the GEESE trials, since their aim is not to re-demonstrate the WER uplift flight-physics (which is already demonstrated under fello'fly), but rather to validate the processes needed for the aircraft to converge and meet as a pair, from a navigational perspective.



Regarding the aircraft types to perform the tests, Laura says: "We are still converging on defining these, and that depends on the airlines' respective flight planning. For the transatlantic flights it depends on which aircraft they will use on those sectors at the time of the trials. For Airbus, A350 will most likely be our platform of choice, especially given that it's a long-range aircraft whose avionics and navigation capabilities are of the very latest standard."

Flight plan uploading flexibility an advantage

Although not a prerequisite per se, it would nevertheless be advantageous if aircraft would enable the pilot to upload the flight plan directly into the aircraft's flight management system (FMS). This capability, which is already available in the A350, avoids the pilot having to make flight plan modifications by entering all information manually using the aircraft's MCDU keypad.

Once uploaded into the FMS the new flight plan will be selectable as a 'secondary flight plan' option, while the original flight plan would remain in the FMS as the primary flight plan.

Operational scenarios

For actual real airline operations it is envisaged that the new flight plan would only be released and sent by the airlines operations centre (AOC) to the pilot following a consultation and coordination between the AOC and the ATC controllers – who would be impacted by any flight plan change. Moreover, this would be done as part of a CDM workflow, during which the respective ATM controllers would confirm whether or not they could accept changes – for example taking into account sector loading or airspace constraints. Only once the new flight plan is approved would the pilot be authorised to activate the secondary flight plan in the FMS.

Moreover, the fuel load would actually remain exactly as per the original flight plan. "The fuel loaded would not be impacted, as it will be based on the 'no-WER' scenario," says Laura. "In fact, what we propose is that the respective airlines will not know if they will effectively constitute a pair. They will just declare their intention that their flight could be part of WER."

Aircraft agnostic requirements

While the WER trials will be essentially 'aircraft type agnostic', Laura nevertheless advises on some general requirements at 'aircraft level'. "For example, a function able to automatically position the 'follower' aircraft automatically behind the 'leader' aircraft and track its vortex. However, what we would not do is dictate how this capability or aircraft functionality should be implemented in a specific aircraft design and how the aircraft technology would accomplish it."

Laura adds: "For Airbus, this is done separately by our engineering colleagues in fello'fly. For other aircraft OEMs it would be up to them how they would want to implement the technical features."

"Nevertheless, in GEESE, we are discussing whether we can extend the scope of the trials to include the A330 and some Boeing aircraft. We don't have huge operational constraints on the aircraft itself – WER operation is mainly a flight plan change, so we are under discussion with airlines to evaluate the concept with a large set of aircraft types."

*SESAR = Single European Sky ATM Research

GEESE partnership linked to operational potential

Data is at the heart of modern aircraft maintenance. "You need it for compliance reasons, for documentation, and to unlock insights so that you can make the best decisions possible for your organisation," said Robert Mather, Vice President of Aerospace and Defense Industries at IFS, a maker of enterprise software.

In a perfect world, this data would be available in a consistent form from all sources, including different MRO IT systems. But we don't live in a perfect world, which is why analysing and comparing data from multiple sources is such a challenge for the aviation industry.

Why Discrepancies Exist

There's a lot of maintenance data systems in use today. Some are computerised, while others are still paper-based.

So why is this the case? "During the life cycle of an asset, be it an entire aeroplane or an assembly, its data is maintained in different systems," replied Matthias Wagenmann, Chief Technology Officer at Swiss Aviation Software (Swiss-AS), provider of the M&E/MRO software AMOS. "One reason for this may be that its owner uses several systems to manage it, which are not fully integrated. Another is that they are lent, sold, repaired, overhauled, or exchanged, thereby leaving the company's boundaries and thus the domain of their IT systems. By that token, relevant data about the specific aircraft may be distributed among multiple systems."

In fact, most aviation organisations — even with well-structured system architectures — have multiple data sources. So says Justin Daugherty, Senior Director, Aerospace Solutions

Credit: 2020 Juice Flair/Shutterstock

Analysing/ Comparing Data from Different MRO IT Systems and Sources

Justin Daugherty, Sr. Director of Aerospace Solutions. Credit: Maxa

"According to Gartner, 85% of data projects fail."

Justin Daugherty, Senior Director, Aerospace Solutions for Maxa

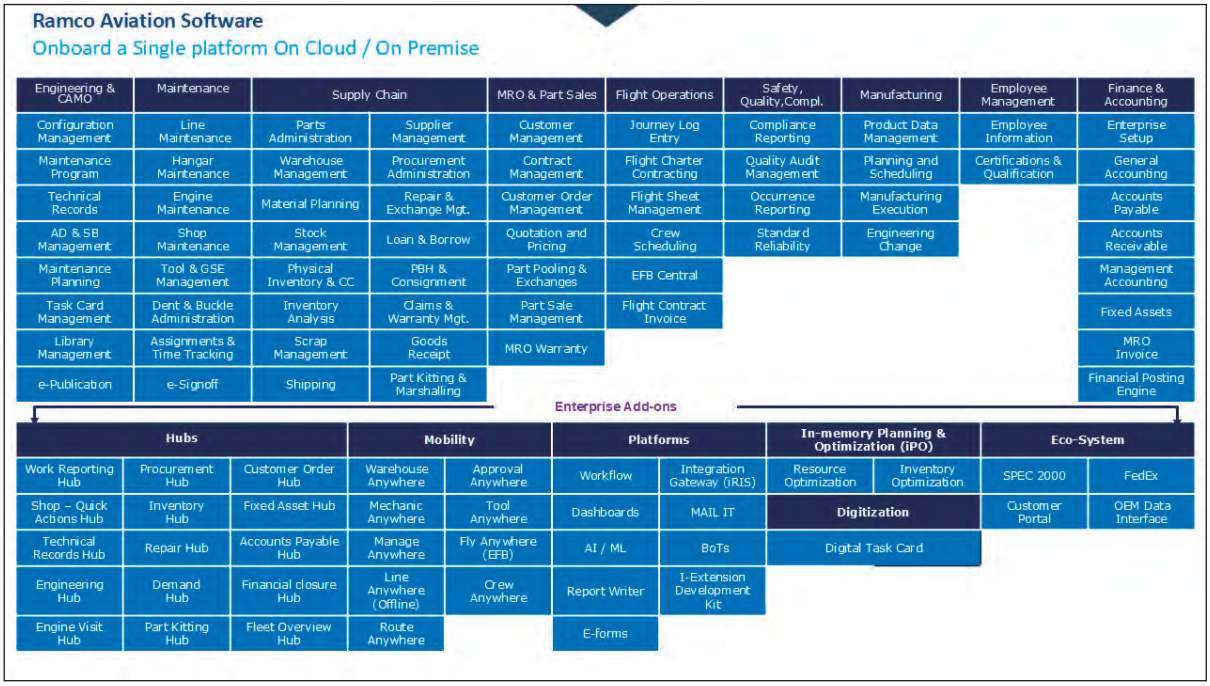
for Maxa, the ERP analysis software platform. As a result, "integrating multiple systems is crucial for more advanced analytics," he said. "Instead of 'reporting the news' within a single M&E/MRO system, the real value comes from combining data across various sources (M&E/MRO, HR, Scheduling, Finance) to gain a deeper understanding of operational complexities. For example, gaining accurate labour costing insights requires data from M&E/MRO for task assignments, HR for labour costs, scheduling for time worked, and Finance for invoicing details."

Unfortunately, this isn't as easy as it sounds. The reason: "Most of the documents exchanged between airline customers and MROs are in PDF format, for example, the Input Workscope for Aircraft Check," said Saravanan Rajarajan, Director of Aviation Solution Consulting with Ramco Systems, an enterprise aviation software provider. "It is quite likely that MROs receive the package of information one to two weeks before the aircraft's arrival. Once the package arrives, MRO planning teams have to grapple with the formats in order to extract data from the documents and put it into the system. Most of the time, the documents remain in an unstructured format like PDF, which makes it difficult to run the analysis of the data within."

This is just the thin edge of the wedge when it comes to integrating disparate data sources. In fact, "bringing this fragmented data back together across system boundaries can be a complex endeavour for several reasons," Wagenmann said. "For instance, the keys for identifying the data sets can be different and thus complicate correct mapping. The data entities and their lifecycle may be incompatible, making data delimitation and normalisation a fuzzy process."

"In the case of inconsistent or contradictory data, a decision must be made as to which data source is more trustworthy," he added. Such decisions are usually well-informed and thoughtful, but still — it's a bit of a coin toss.

When it comes to the trustworthiness of aircraft data, standards can vary widely from source to source. "Some systems like IFS are very rigid on data control and the business rules that allow you to enter data; plus aspects like



Screenshot of Ramco Aviation Software. Credit: Ramco

configuration management that enforce rules through the data entry process, which ensures that you have really robust detailed and accurate information," said Mather. "But all systems are not created equal. As well, the data isn't always labelled the same across multiple sources. So there can be a translation activity to ensure that all of the data points are aligned, so that you know you're talking about the same thing."

Bringing Disparate Data Sources Together

Whatever the challenges of bringing disparate data sources together, the fact is that it has been done for the sake of aircraft owners/operators and the MROs who support them.

It's not an easy task. "The basic prerequisite for analysing data from multiple sources is that it is available in a structured digital format," Wagenmann said. "If sub-processes are not adequately mapped in the IT system, the corresponding data is either not recorded at all or is recorded on paper/PDFs and is therefore only available for further processing in a roundabout way. Systems with sufficient production depth for the processes relevant to aircraft maintenance are therefore a mandatory requirement."

For different MRO data systems to interoperate with each, they need to have access to the right interfaces, he added. "This is why support for industry standards such as ATA-Spec simplify integration between different systems. A homogeneous system landscape also helps with integration: If the airline and MRO use the same M&E system, the data entities are defined equally and the integration effort is significantly lower, assuming the system has the appropriate interfaces."

According to Daugherty, bringing data together from disparate systems requires specialised skills in several areas. For instance, IT teams need to be able to manage data warehouses, govern that data, and ensure the selected tools are secure. "Then there's the complexity of understanding source system data structures, databases, and schemas that span across various platforms like M&E/MRO, HR, Finance, Flight Scheduling, and Payroll," he said. "This process often requires the expertise of Data Engineers and Architects to ensure proper data mapping, migration, and integration across these systems. Visualisation tools such as PowerBI, Tableau, or Streamlit are commonly used in the aviation sector, but these traditional methods often struggle with handling complex data across systems, especially when calculations occur at the visualisation layer."

In those cases where data from disparate data sources are integrated the traditional way — by mapping data and creating warehouses through human operator entries — errors can creep into the mix. "They do this through a highly intensive manual process of going through hundreds of pages of documents, converting the unstructured data into structured data, and thereby interpreting and processing it," said Saravanan. "This is why Ramco Aviation Software ensures data integrity with its access controls and processes, when a customer is moving from legacy to new systems or upgrading our own system to a newer version. Automated bots conduct regular scans on data to identify any inconsistencies." [Note: there are software applications that data-mine PDF documents that are not being discussed in this article.]

Even when the impact of human manual entry errors are minimal, the process "can often lead to outdated analytics once the project is complete," Daugherty observed. "As well, source systems, data structures, and schemas are continually updated

> **Integrating multiple systems is crucial for more advanced analytics."**
>
> Justin Daugherty, Senior Director, Aerospace Solutions for Maxa.

or changed, which can cause many analytics solutions to fail or require costly updates over time. This is why Maxa addresses these challenges by automating data integration processes and providing ongoing support for evolving data structures."

Making Analysis Work

All told, integrating data from disparate MRO IT systems for useful analysis can be an incredibly challenging task, and the risks of failure are real. This likely explains why "According to Gartner, 85% of data projects fail, often due to the complexities in standardising and unifying data from one or more data sources," said Daugherty. "While basic reporting may seem manageable, extracting valuable insights to drive profitability, efficiency, and safety in aviation requires leveraging data from all data sources. To succeed, MROs and airlines need advanced analytics that go beyond basic reporting."

"Near real-time data availability, consistent data quality and data depth are the cornerstones of modern data analysis," agreed Wagenmann. But this AI-driven analysis has its limits, because AI models can only be as good as the data they are trained with; optimization algorithms only work if the data used is consistent; and automation can only succeed if the data used is reliable and comprehensive," he said.

In this less-than-perfect world, developing 'workarounds' that allow data sharing and analysis to function despite system shortfalls is often the best that airline and MRO IT experts can do. "A popular workaround to bridge the digital gap if IT systems cannot exchange data in a structured manner is to rely on unstructured data like PDFs," said Wagenmann. "Of course, this approach relies on the receiving system being able to build structured data from it. Unfortunately, this is rarely achieved reliably, promptly and without loss."

Another way to support effective analysis across multiple data sources is to ensure that your core data management system is completely digitised, robust, and governed by rules that ensure high data quality. This core system should also act as "the aggregator for an integrated ecosystem," Mather said. "That

Credit: 2021 aappp/Shutterstock

Saravanan Rajarajan, Director of Aviation Solution Consulting with Ramco Systems. Credit: Ramco

"Most of the time, the documents remain in an unstructured format like PDF."

Saravanan Rajarajan, Director of Aviation Solution Consulting with Ramco Systems

means that if you do have solutions that are separate — for example, let's say you have electronic logbook that is different from your maintenance system — you have those interconnected and working together so that all of the data from the logbook comes into the maintenance system, which then becomes the system of record that you can do all of your analysis on."

Adopting standardised interfaces on multiple data sources can also aid analysis, by better enabling the sharing of data. "For example, Spec 2000 Chapter 18 [for Electronic Information Exchange between Operator Maintenance Systems and MRO Systems] will help streamline the data exchanges on work scope, work packages, work orders, related tasks, responses from the MRO on work accomplished, findings, new work orders raised, deferrals, and maintenance release," said Saravanan. "Adoption of these standards by airlines and MROs will automatically lead to IT MRO software providers adopting and complying with the standards."

Building for a Better Future

So far in this article, we have considered the challenges and solutions associated with multiple data sources in the aviation industry. Going forward, what steps should airlines and MROs be taking to minimise this problem, or to make it go away altogether?

Here's what the experts had to say:

"MROs and airlines should prioritise data governance and data-centric projects to improve margins and operational efficiency," said Daugherty. "Documenting procedures, data protection practices, and data governance methods is essential as companies move towards creating Data Products for advanced analytics across multiple systems."

"I think that, with the advent of modern technology over the past many years and the speed with which technology changes, it's imperative for organisations in the aviation maintenance realm to be on modern systems with a strategy for always keeping up to date on those modern systems," Mather said. "It's cost-effective in a lot of cases to consolidate down onto a single system with a lot of inbuilt simplicity, but that isn't necessarily the solution for everyone. Still, you should have modern systems; a single platform where possible, but definitely integrated where the ecosystem demands it."

According to Wagenmann, the best data analysis choices for airlines and MROs going forward include choosing comprehensive IT systems over specialised software offerings; making sure that their selected systems are designed to be open in terms of managing data flows and acting as data sources, and introducing clear data governance

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says SVP Technical Operations of airBaltic.

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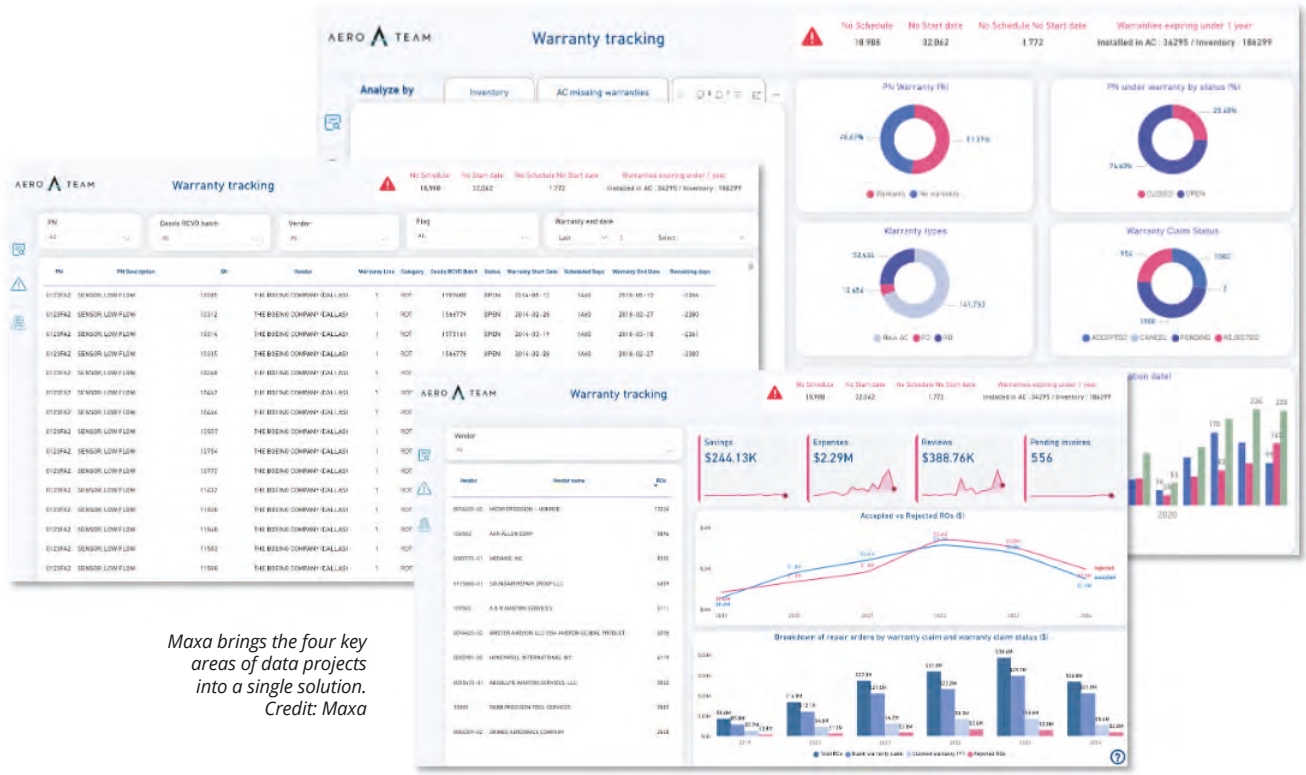

Maxa brings the four key areas of data projects into a single solution. Credit: Maxa

into the overall IT structure. "For each data entity, it should be defined which system is in the lead (single source of truth)," he said. "Divergent data must be avoided."

For his part, Saravanan believes that airlines and MROs should look at "a consolidation of platforms as a first step," he said. "For instance, MRO software should be able to cover key functional modules of engineering, maintenance, SCM, finance, publications, and contracting. However, organisations may adopt the strategy of adopting the best of breed software, where the core M&E is managed by one software and functions like HR and finance are managed by other software. In this case, a clear process, workflow and integration are to be laid out to collect the right data and manage its integrity." Whatever the case, "Data exchanges between Airlines and MROs need to be standardised, and IT MRO software providers must adopt these standards."

Daugherty shares Saravanan's sense of judicious caution. "While reducing the number of active systems can offer long-term value, and certainly is a recommended approach, such projects can be costly and time-consuming," he said in conclusion. "Alternatively, customers should consider utilising modern data cloud platforms, with solutions like Maxa, that can automate the process of consolidating data from disparate systems into a single source of truth. Regardless of the approach, moving towards consolidation and integrating advanced analytics into daily operations can help companies stay profitable and competitive."

By James Careless

Robert Mather, Vice President of Aerospace and Defense Industries at IFS. Credit: IFS

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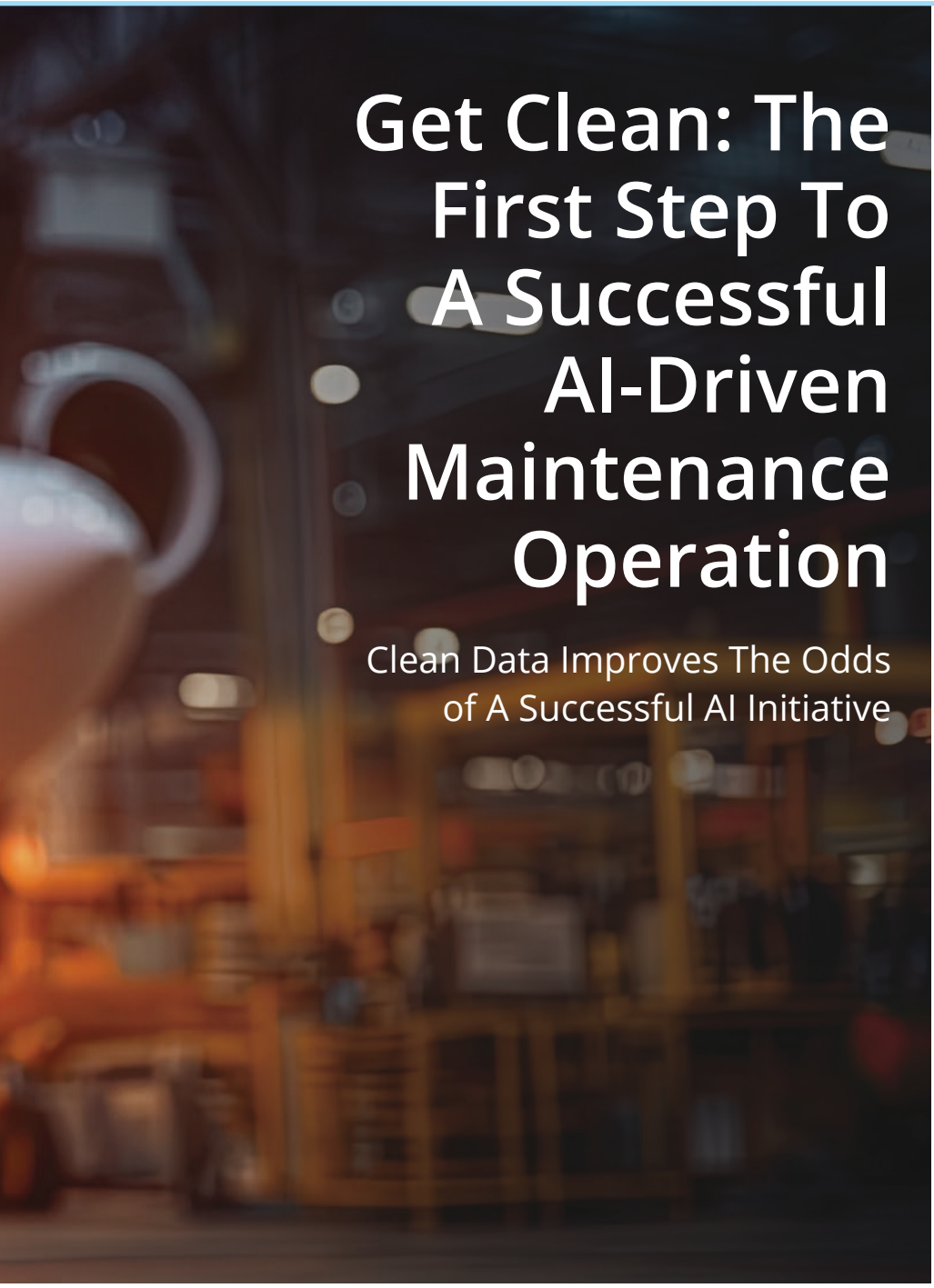
A comprehensive AI-driven maintenance operation is the logical next evolution for the airline industry. Tools such as chronic aircraft and rogue part identification, prescriptive maintenance, and predictive maintenance will be installed in every airline. But what does it really take – from beginning to end – to develop, implement, and see actionable results from an AI-enabled tool? And, if you buy into a tool or try to build one, will it actually work? What happens if you put effort into an AI project with data that's not AI friendly?

We Want AI: What Does That Mean?

The successful implementation and deployment of AI-enabled tools could be game-changing, launching an airline to industry leader status in operations, efficiencies, and customer satisfaction overnight. Conversely, failure will have cascading impacts: blown budgets, increased costs, lower efficiency, loss of brand reputation, and poor decision-making sinking an otherwise stable company.

Across all industries, not just in aviation, the odds of "getting AI right" are just barely above even, considering "54% of AI projects make it from pilot to production." Leadership knows they want AI, as "79% of leaders agree their company needs to adopt AI to stay competitive."

Some aviation maintenance leaders and even on-the-line team members are dabbling with unsecure, broad-access tools like ChatGPT that are not trained or focused on aviation maintenance to problem-solve on the fly. In contrast, a variety of moderately successful, enterprise-focused AI-based implementations are in the marketplace, but most



Get Clean: The First Step To A Successful AI-Driven Maintenance Operation

Clean Data Improves The Odds of A Successful AI Initiative

aren't living up to the hype.

Business questions swirl from "what AI do we need?" to more specific dilemmas like "how do we successfully select and then seamlessly implement a meaningful AI tool?" Business leaders and most engineering and IT teams have a general idea of how AI could be useful. Where they struggle is knowing which part of a project to tackle first, how much it will cost, what's required to maintain an AI model, how to evaluate buy vs. build options, and importantly, how to measure success. With huge budgets, unclear direction, high-stakes outcomes, and only 50/50 odds of success, it's easy to see why executives are hesitant to move forward. "60% of leaders worry their organization's leadership lacks a plan and vision to implement AI." Let's dig into the most important, most difficult, and often overlooked first steps to a successful AI-driven maintenance implementation along with information on proper execution.

> **Across all industries, not just in aviation, the odds of "getting AI right" are just barely above even, considering "54% of AI projects make it from pilot to production."**

Know Your Data

The first step in any AI implementation is understanding your data. This is not just a preliminary task. It's crucial and sets the foundation for the entire AI system – especially in how clean is your data. Your data foundation mirrors the maxim: "garbage in, garbage out."

Clean data holds powerful characteristics.

- It accurately represents the real-world constructs it models.
- It is complete without any missing information.
- It is valid and conforms to the data domain while maintaining relationships and hierarchies.
- It is consistent, without variation in how it is recorded.
- It must be uniform using the same format and units of measurement, so that it can be aggregated.
- Finally, it must be timely and available when needed which in today's world is usually close to real time.

The urgency and necessity of addressing clear, reliable data should be understood and prioritized by business leaders and tech teams. It's the first crucial, foundational step towards a successful AI implementation.

Clean Your Data

Many IT and engineering teams are quick to jump to an AI-tool without digging into what many consider "unglamorous" work. Teams should allocate time to thoroughly clean their data. Unclean data affects everything downstream. Using unclean data in analytics can adversely impact analysis outcomes, decision-making, and overall business operations. It

doesn't matter how sophisticated your AI-tools are. Feed them unclean data and you won't see meaningful, useful results.

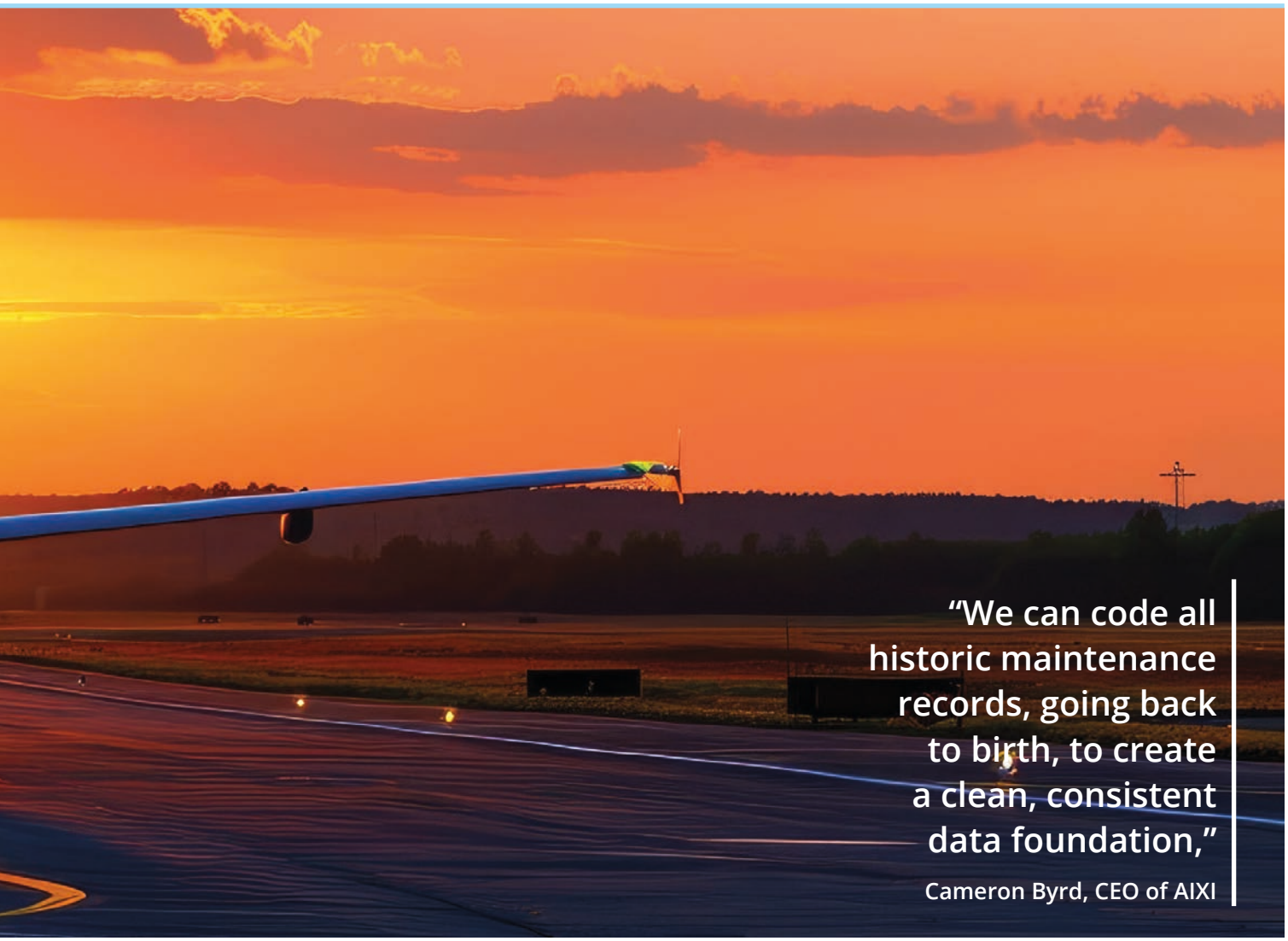
- **Inaccurate Results:** Unclean data can lead to incorrect conclusions and faulty analytics results. This might include errors in statistical calculations, misleading trends, and incorrect predictions or forecasts.
- **Loss of Credibility:** If stakeholders discover that data-driven decisions are based on flawed data, they will lose trust in the data analytics process and the teams involved. Rebuilding credibility can be costly and time-consuming.
- **Poor Decision-Making:** Decisions based on incorrect or incomplete data leads to ineffective strategies and actions, potentially causing financial losses or missed opportunities.
- **Increased Costs:** Identifying and correcting errors after data has already been used for decision-making can be resource-intensive and expensive. Additionally, operational inefficiencies driven by incorrect data can indirectly increase costs.
- **Reduced Efficiency:** Time and resources may be wasted on analyzing and making sense of poor-quality data, leading to delays and decreased productivity.
- **Compliance Risks:** In aviation, similar to finance, healthcare, and telecommunications, where data accuracy and handling are regulated, using unclean data can lead to compliance violations, resulting in fines and legal issues.
- **Damage to Brand Reputation:** If poor data quality leads to public errors or exposes customer data inaccurately, it can damage an organization's reputation and lead to loss of customer trust and loyalty.
- **Resource Drain:** Continuously correcting errors due to unclean data requires additional resources, which could be better spent on more strategic tasks.

Investments in data cleaning and proper data management are crucial for any data-intensive organization.

AI Use Case: Historical Maintenance Logs

Almost every airline today runs at least part of its maintenance program using historic maintenance logs. This data informs reliability programs, creates reports, and helps troubleshoot maintenance issues. The FAA uses this data from operators in order to identify safety issues. However, the current practice of assigning a single four-digit ATA code to each log entry, which is used throughout the industry and across all OEMs for congruency, has flaws.

Observe any technician doing a log history search. They only use the first two digits of the ATA code. When asked why, the paraphrased response is, "I only trust the first



> "We can code all historic maintenance records, going back to birth, to create a clean, consistent data foundation,"
>
> Cameron Byrd, CEO of AIXI

two digits, the rest is garbage." Looking deeper, we find that this maintenance data is around 80% accurate for the first two digits and at best 60% accurate using all four digits. The aviation industry is currently and knowingly running its maintenance programs with unclean data. This has created a mostly garbage in, definitely garbage out scenario for airline maintenance teams. But it doesn't have to be.

There is a rare opportunity to drastically increase efficiencies and outcomes for maintenance teams simply by cleaning the data. That's it... nothing more. ***Clean the data first, implement AI-tools second.*** By cleaning the data, the reliability and use of all downstream tools will improve. This sets the foundation for AI implementations.

> "Clean the data first, implement AI-tools second."

Maintenance Records Are Ripe for AI

Using the criteria above, it's clear that maintenance records already have clean-data characteristics. They only lack consistency and uniformity.

At a high level, the aviation industry is on the right track by assigning ATA codes to each log entry. This has and will continue to create consistency and uniformity. However, there's a disconnect. There's a lack of trust in the data that is captured. Some operations recognize the problem and have human experts manually re-coding log entries. Unfortunately, this process takes time – a lot of time – and reduces the timeliness of the data. In addition, humans are not inherently good at coding or large pattern matching. Plus, it is a boring, laborious task. Using people to hand-match ATA codes requires training, has a high turnover rate, and is inconsistent from human to human. This represents a perfect opportunity for an AI implementation.

One AI-focused software company is successfully using AI tools including a large language model (LLM) specifically developed around airline maintenance to solve this challenge. AIXI, a North Carolina based-company specializing in creating AI-enabled solutions for airline operations and MROs, uses their industry-specific LLM to automatically assign ATA codes to maintenance records in real-time using their ATA AutoCoder™. "We can code all historic maintenance records, going back to birth, to create a clean, consistent data foundation," said Cameron Byrd, CEO of AIXI. "This empowers technicians and optimizes MRO procedures because they can trust the data and pinpoint troubleshooting. It also sets the stage for true prescriptive maintenance tools."

Southwest Airlines has been using

RAW LOG TEXT

```
perf ifim task 31-30-00-810-801 omf
fault check, found fault cd 31-
14870 dfdau int fault; r/r dfdau
iaw amm 31-31-22
```

Difficult to analyze, not formatted, requires coder time and effort to read and comprehend. Inefficient.

AIXI ATA AUTOCODER OUTPUT

FAULT ATA	FIX ATA	OBJECT CODE	FAILURE MODE	ACTION CODE
3131	3131	fdr	fault light / flag / disagree	replaced

Clearly formatted, easy to combine, sort, and analyze. More efficient and more accurate.

AIXI's ATA AutoCoder™ cleans, standardizes, and normalizes maintenance records for use in AIXI's AI-enabled solutions.

AIXI's ATA AutoCoder™ since 2022 in an effort to "dramatically improve engineer access to defect trends, most likely fixes and more to support better maintenance," according to Barry Lott, Southwest's Director of Aircraft Records and Maintenance Reliability. The AIXI ATA AutoCoder™ has proven to be around 97% accurate and can execute in real-time. "When the person we had doing our ATA coding retired, it was a good time to explore an AI solution. ***AIXI's tool is faster, more accurate, and flexible for supporting other AI efforts we're exploring," said Lott.***

Cleaning, Coding, And Extending With AI

AIXI's ATA AutoCoder™ is able to assign five codes to each maintenance record instead of just one.

- One ATA code is associated with the discrepancy,
- Another code is associated with the fix, and
- Three human-readable codes represent the object, failure, and action taken to fix the problem.

Consider this example: a technician might enter 'NGS [nitrogen gas system] degraded' as the discrepancy and 'R/R L/H pack flow' as the fix.

> "The accuracy of AIXI's ATA AutoCoder™ can turn "garbage" maintenance records into a data goldmine."

The ATA AutoCoder™ converts this shorthand to 4741 for the Discrepancy ATA code and 2530 for the Fix ATA code. It would name the object as the NGS System, classify the failure as degraded and classify the fix as removed/replaced. The resulting entry is then much clearer for later retrieval and analysis – and it happens in a matter of seconds.

The accuracy of AIXI's ATA AutoCoder™ can turn "garbage" maintenance records into a data goldmine. The five fields add fidelity to the data that has never been there before, revealing insights about airline operations that were previously unobtainable. AIXI's prescriptive maintenance tools offer versatility based on the data accuracy that is used as its input. "Employing AIXI's ATA AutoCoder™ offered immediate and significant gain, but the real value comes from what we're set to do next," said Lott.

With AIXI handling the ATA coding, Southwest has been able to reallocate resources to focus elsewhere. All of the teams within the airline that rely on historical maintenance records for their operations and decisions now have access to clean, actionable data. ***The trickle-down impact of simply cleaning the data allows teams to work and make decisions more accurately and efficiently.***

- Technicians can now trust historical records using all four digits rather than just two. The extra code assigned to the discrepancy allows them to see the relationships between discrepancies and fixes. They can look up a particular discrepancy and find all fixes that have been applied to that problem, as well as how often a fix was applied to that problem.
- Reliability teams can complete reports and address new inquiries in hours instead of weeks and feel confident that the results are accurate.
- Finally, the human readable codes empower anyone in the organization to use the data for insights without training on ATA codes.

Get Clean Before Implementing AI Tools

A fully realized, AI-driven aircraft maintenance program consists of a multitude of tools that will require clean, consistent maintenance logs in order to work effectively. Future tools include algorithms for prescriptive maintenance, chronic aircraft identification, rogue part identification, long-term planning, and predictive maintenance. Internal teams, manufacturers, and airlines are working on implementations leveraging various mass-market tools and existing algorithms. However, they work off of the original maintenance logs and the ATA codes assigned by the mechanics. That puts us back into the "garbage in" situation. The best tools, including those with AI-supported intentions, are doomed to fail without clean data.

The "get clean" message cannot be stressed enough. Executives wanting AI, internal teams looking to build or buy AI tools, outside tools touting AI success – all have a high probability of failure unless the underpinning

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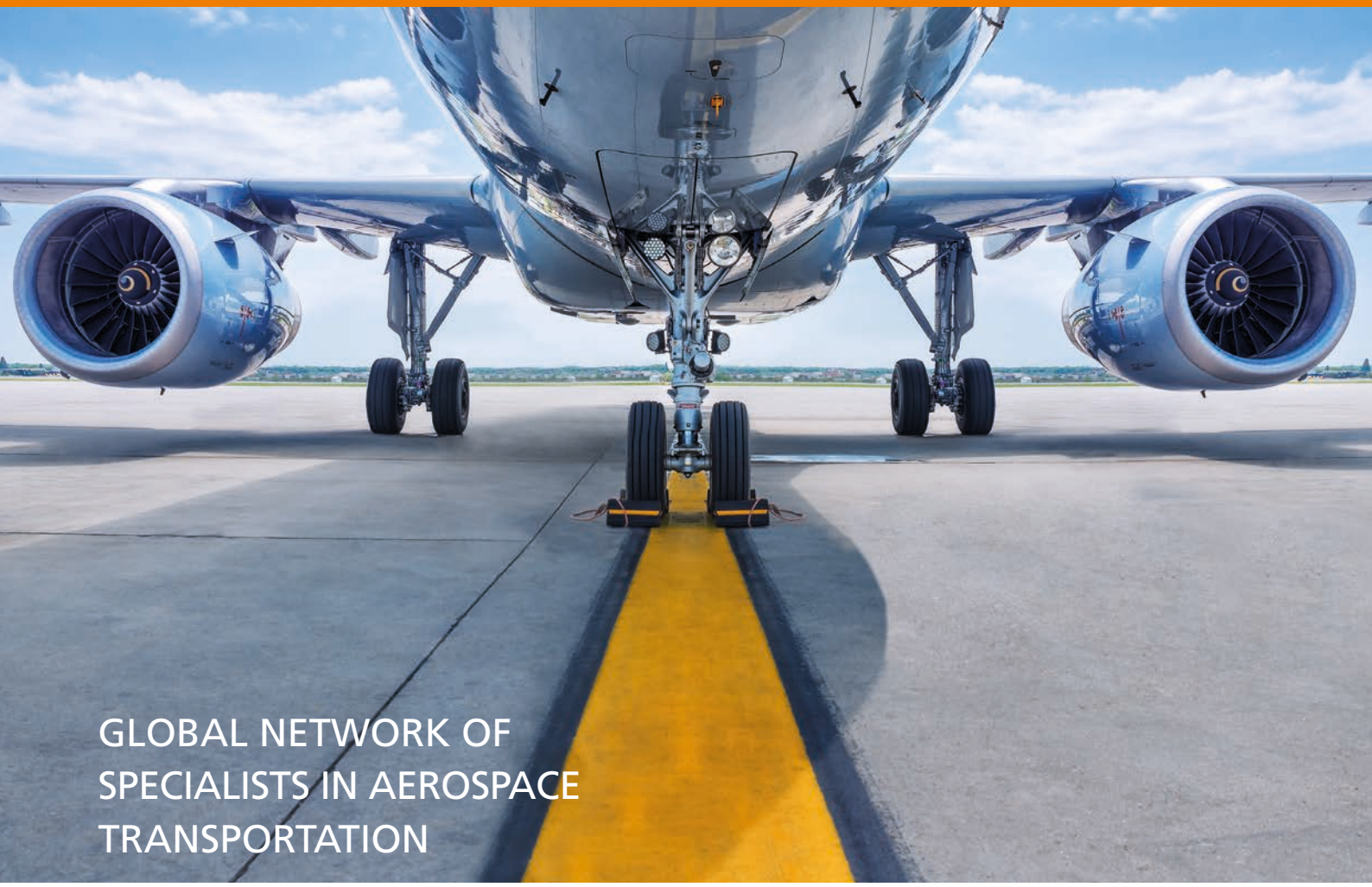

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maintenance data is clean.

Southwest Airlines is proving the power of clean data when coupled with targeted AI implementation and AIXI's ATA AutoCoder™ is providing their foundation. Southwest's Lott said that clean data is also opening new possibilities for his teams. "Accurate aircraft and fleet trending, prescriptive maintenance and, in the future, predictive maintenance would not be possible without AIXI's technology," according to Southwest Airlines.

Clean Data Opens Doors To AI Implementations

All current and future AI tools, large language models, machine learning, and analytical models heavily rely on data and their success is based on data cleanliness. Maintenance and reliability operations are no different and clean data stands to improve all operations that rely on that data.

Southwest is in an interesting position to leverage AIXI's data cleaning tools for AI implementations that have reaching impacts. They are poised to leverage the ATA AutoCoder™ data to streamline SDR reports in minutes, complete with FAA submission. There is a clear path to prescriptive maintenance that helps preserve the institutional knowledge of their long-time technicians and pass that to younger, less experienced mechanics using AI tools. Clean data sets the stage for chronic aircraft or rogue part identification, long-term planning and predictive maintenance. The reason - they invested the time and attention into cleaning the data. Before other airlines or MROs tackle AI projects, consider the risk and expense of starting without a solid, clean foundation. ***Getting and using clean data is the secret to unlocking AI-implementation success.***

Cameron Byrd, CEO, AIXI and Barry Lott, Director, Aircraft Records and Maintenance Reliability, Southwest Airlines

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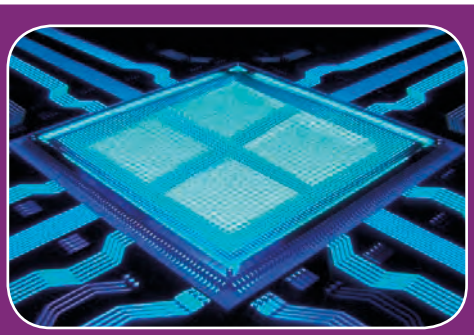
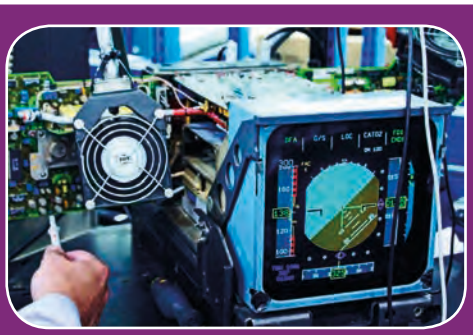
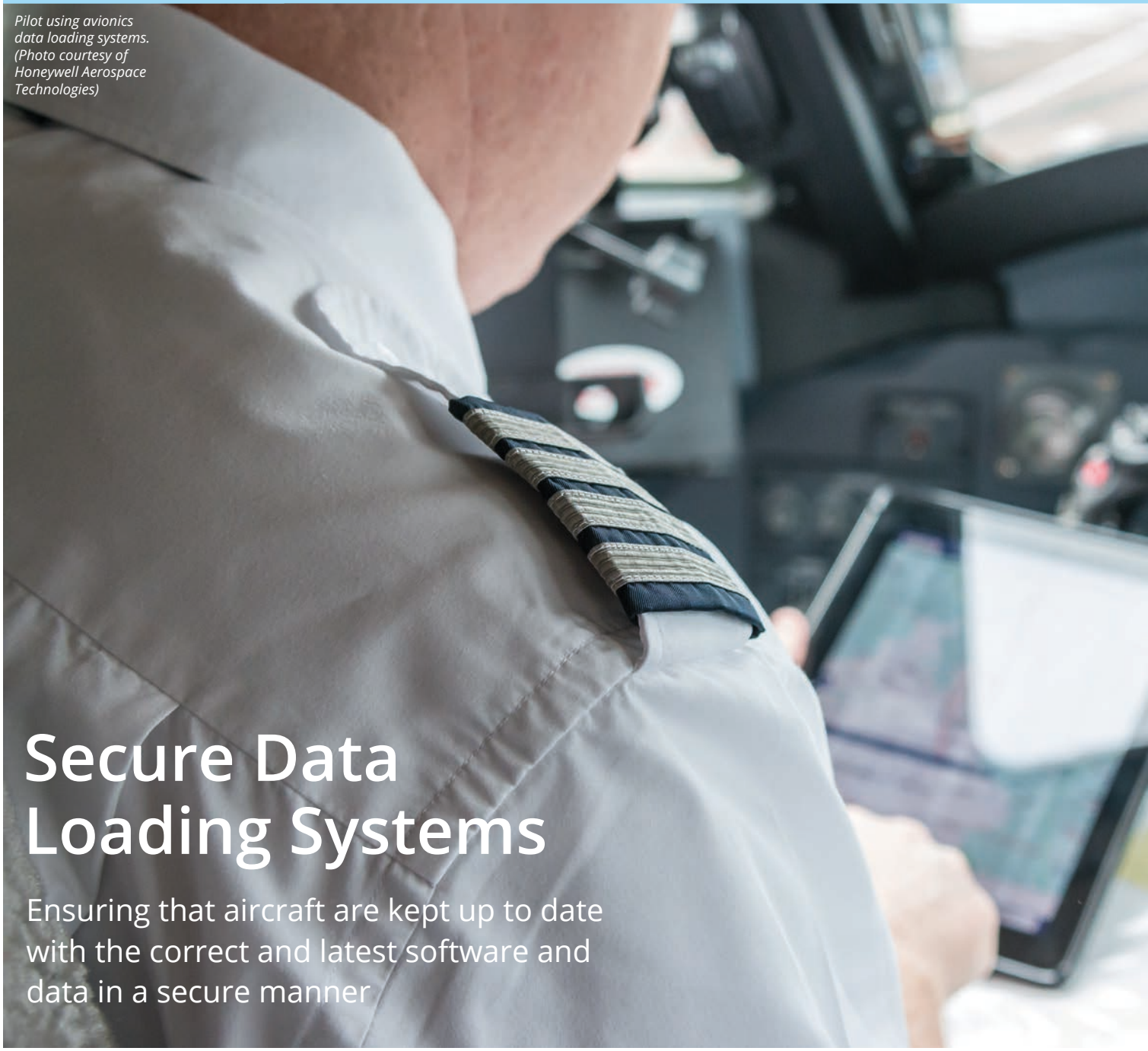
Sales Director
E: simonb@aerospace-innovations.com







Pilot using avionics data loading systems. (Photo courtesy of Honeywell Aerospace Technologies)

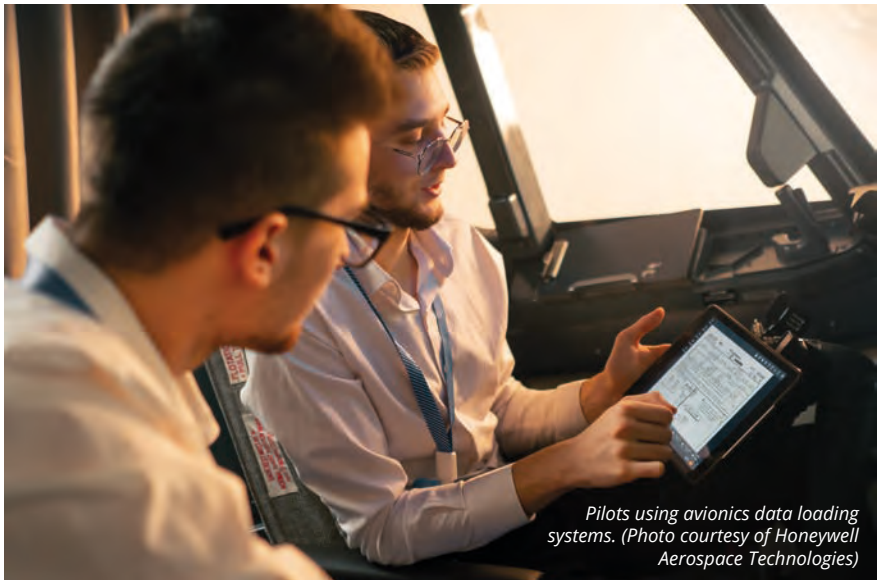
Secure Data Loading Systems

Ensuring that aircraft are kept up to date with the correct and latest software and data in a secure manner

Over the past decades aircraft have become more complex with advanced automation and avionics, and the need to keep their systems up to date with the latest software and data has grown. Avionics data loading systems—the primary method used to upload field-loadable software and data to aircraft onboard computers or retrieve data for further analysis—play a critical role in doing this. Data loading is how aircraft updates its various navigation databases at regular published intervals to provide airspace, airport, terrain and other data for the aircraft.

Not only can data loading systems ensure compliance with ever-evolving regulations via rapid updates and modifications to aircraft data systems, they can also provide increased operational efficiencies and enhanced safety. Streamlining this often-complex process helps improve operational efficiencies, reduces manual input errors and minimizes aircraft downtime. Data loaders can even perform integrity checks of the load, as well as validate authenticity by means of digital signatures.

The most common reason software and data is field loaded is for the mandatory navigation database update, which occurs every 28 days in accordance with the Aeronautical Information Regulation and Control (AIRAC) cycle. "This is required to meet continued airworthiness requirements by ensuring that all aircraft operate with a consistent set of data worldwide," says Thomas Nicholls, Systems Lead, MBS Electronic Systems GmbH & Co. KG Gilching, Germany. "Another reason is to implement service bulletins from original equipment manufacturers (OEMs) for updates for issues ranging from mandatory safety changes to advisory functional and efficiency improvements. Lastly, hardware



Pilots using avionics data loading systems. (Photo courtesy of Honeywell Aerospace Technologies)

replacements can also require the software on the new hardware to be updated, as it will not always match the approved configuration of the aircraft."

Loading Standards

In the commercial aviation sector, avionics data loading systems typically rely on industry standards, allowing vendors to develop interoperable tools. Scott Ridge, Vice President of Business Development, Avionica LLC, Miami, says this means mechanics can follow a consistent process for different aircraft, such as Airbus and Boeing, which simplifies maintenance and accelerates updates. "These standards also help address growing challenges like cybersecurity threats and the need for enhanced connectivity. However, on some modern aircraft, OEMs have introduced proprietary solutions that add complexity, requiring more training and slower response times to new challenges. The legacy of standards has consistently provided better solutions, streamlining maintenance and ensuring consistency across platforms."

Ridge cites the following benefits of standards-based data loading:

- Interoperability: Vendors provide tools that work across different aircraft, making maintenance processes consistent and efficient for mechanics.
- Enhanced cybersecurity and connectivity: Standards-based systems are better equipped

MBS Electronic Systems' products (Photo courtesy of MBS Electronic Systems)

to adapt to modern challenges, including cybersecurity risks and the increasing need for connectivity.

- Streamlined maintenance processes: Legacy standards enable faster software updates and more reliable workflows, reducing downtime and ensuring quicker responses to issues.

Older avionics systems data loading was (and is still) performed with physical media (e.g. PCMCIA data cards) inserted into the front of the unit or with a computer connected via a test connector on the front of avionics units. Today, Scott Chambers, Vice President of Sales and Marketing, FLYHT Aerospace, Calgary, Canada, says most systems are connected to a central data loading interface or system where most avionics units can be loaded centrally from the flight deck using physical or electronic switching architected in the aircraft by the aircraft manufacturer. "Thanks to industry standards like ARINC 615 that have evolved over the years, a multitude of onboard and portable data loaders are now in use in the airline industry that can be connected to aircraft systems via standard interfaces. Some data loading systems are also used to harvest data from the aircraft for example new generations of aircraft engines on A320neo, 737MAX, 787 and A350 generate large volumes of data that is harvested using data loading systems. Typically, portable data loaders are connected directly to engine avionics mounted on the engine itself for this task."

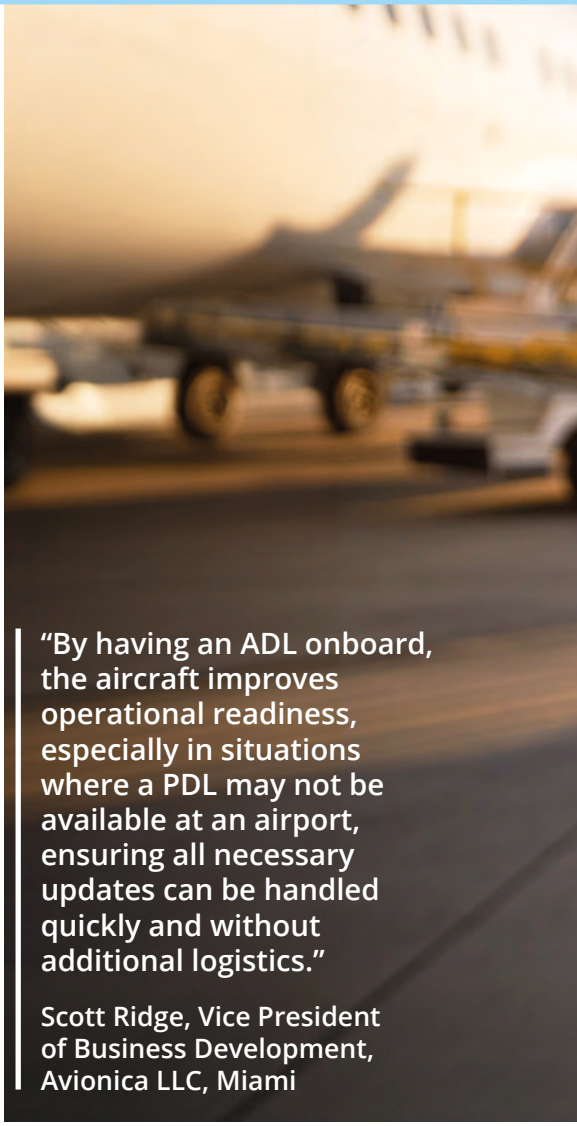
Phoenix, Ariz.-based Honeywell Aerospace Technologies follows the A835 software signing standard and A827 crating standard for secure deliveries of all loadable content on aircraft. Sarah Weinhardt Offering Management Director at Honeywell says in addition to this, Honeywell provides tools for end users (such as airlines) to verify the integrity and authenticity of our deliveries before they accept them within their ecosystem.

The revised ARINC standards are compelling operators to update their current data loading equipment to newer products that support these ARINC 645-1, 827, 835, and others. "The scope of security is extending from just the aircraft itself to tools that connect to the aircraft," says Chris Kuske, director of data loader engineering at Teledyne Controls, El Segundo, Calif. "More specifically, data loaders are now becoming part of operator's security picture. Some documents operators may be familiar with that may affect them are AC-119, the Boeing ANSOG, and DO-355A. These documents are changing the way airline operators deal with security in a big way."

Different Loading Systems

Avionics data loading systems come in two primary forms: portable data Loaders (PDLs) and airborne data loaders (ADLs). Ridge says PDLs can be purpose-built hardware or software installed on a laptop, whereas ADLs are permanently installed on the aircraft. "PDLs are cost-effective and versatile, as one unit can service multiple aircraft without the need for aircraft certification. On the other hand, ADLs, while more expensive and dedicated to a single aircraft, ensure that the necessary data sets are always available and can be wirelessly updated, which reduces operational strain and improves dispatch reliability. By having an ADL onboard, the aircraft improves operational readiness, especially in situations where a PDL may not be available at an airport, ensuring all necessary updates can be handled quickly and without additional logistics."

Jasmine Eggert, TechSAT GmbH, Business Line Manager Data Loading, Munich, Germany, notes that most modern aircraft use onboard data loaders to manage the configuration



> **"By having an ADL onboard, the aircraft improves operational readiness, especially in situations where a PDL may not be available at an airport, ensuring all necessary updates can be handled quickly and without additional logistics."**
>
> **Scott Ridge, Vice President of Business Development, Avionica LLC, Miami**

Engineer holding a portable data loader (Photo courtesy of TELEDYNE)

of airplane software configuration, and automatically synchronize with fleet repositories. "Legacy aircraft use PDLs and ADLs to configure individual onboard target computers. Onboard loaders and ADLs are installed on the aircraft, whereas PDLs can travel with the aircraft as a detached item or be kept at the operator's maintenance stations. Data loaders also allow for downloading logs and aircraft performance data for off-board analyses to improve aircraft performance."

Charlotte, N.C.-based Collins Aerospace uses self-contained avionics data loading solutions, simplifying the entire process for its customers while maintaining high levels of data security. "The system does not rely on carry-on devices and data loading can be completed anywhere the aircraft goes," says Collins Aerospace Director of Avionics Marketing Chip Gilkison. "Only in cases where the aircraft has to go to a service center would an external data loading solution be required. Many of those data loads require specialized software to load the avionics and service centers are trained in how to use them."

There is no standard data loading system for all aircraft. Weinhardt explains that every avionics system has its own protocols for this process— both for cyber security reasons and also to protect its IP. "But the process of data loading is pretty straight forward. There is usually a tablet application, which is approved to connect to the aircraft and transfer or receive data via a secure protocol. Some older systems use external storage devices or laptop temporarily wired to the aircraft versus a Wi-Fi or Bluetooth connection."

Physical media loading of onboard systems consists of physical media like USB sticks, memory cards, CD/DVD and even 3.5" floppy disks for loading. The logistical and security issues around the use of physical media can be a real issue. "Time constraints around reproduction and distribution of physical media are real issues," Nicholls cautions. "Consider the navigation data base but also other updates such as terrain data bases used with ground proximity warning systems that need to be updated across many aircraft in a timely manner. Administrating

FLYHT Aerospace Solutions' product (Photo courtesy of FLYHT Aerospace Solutions)

TechSAT portable data loaders (Photo courtesy of TechSAT)

these updates is also an issue as there is always a lag between the loads being performed meaning is very difficult to track updates and re-arrange update opportunities."

Security issues also exist in transferring the physical media and storing it, how do you ensure that media is not intercepted by a malevolent third party and modified? Nicholls explains "Many airborne systems do not support the PKI/ digital signature check technology required to ensure the integrity and authenticity of the loadable software. Physical media is used with some avionic systems such as Enhanced Ground Proximity Systems (EGPWS) but also for some airborne data loaders, some of which still use 3.5" Floppy Disks! Using a PDL that supports physical media emulation can overcome some of these issues by staging the loadable software/ data base to the PDL wirelessly, where it can perform a digital signature check prior to storage."

Chambers explains until around 2010, onboard floppy disk loaders were standard on Airbus A320 and A330 aircraft and used on Boeing 737, 747-400, 757 and 767 aircraft. "Many airlines still use floppy disks, and onboard data loading systems with floppy drives are still in use. Around 10 to 15 years ago most airlines began to address floppy disk obsolescence and they increasingly started adopting portable or onboard data loaders that had non-volatile storage where virtual electronic copies of all floppy disk software for the entire aircraft are stored onboard."

Advances and Innovations

In recent years, there has been an intense focus on security of all equipment (including data loaders) that interacts with aircraft. "New PDLs and ADLs that have been put into the marketplace have to support the latest security standards such as ARINC 645, 827, and 835," says Chris Kuske, Director of Data Loader Engineering at Teledyne Controls, El Segundo, Calif. "At Teledyne, our new generation data loaders have been designed from the ground up to integrate those security standards. The objective is to ultimately ensure the integrity and authenticity of software parts during transfers and protect against unauthorized access at every stage. Newer data loaders also provide expanded data bus capabilities, more computing bandwidth, as well as reduced weight and power consumption compared to their predecessors."

The new security standards (A645, A835, A827) are the foundation for the industry's transition to secure loaders and are driving innovation. "Newer aircraft systems come with an onboard loader which adheres to the security standard, whereas legacy systems have to transition to using secure PDLs and ADLs compliant with the standards," says Nicolas Lesellier, Product Manager Data Loading at TechSAT GmbH, Munich, Germany. "Difficulties in compliance with initial versions of the specifications are getting addressed by updates to mature and simplify the content, based on feedback from the initial rollout. TechSAT's PDLs MKII and MKIII implement A645, A835 and A827 and work with both Airbus and Boeing aircraft."

Nicholls agrees there has been progress in the domain of cybersecurity. "Many airlines have upgraded data loading systems to meet the latest requirements. This allows electronic distribution of loadable software parts in a secure manner ensuring the authenticity and integrity from the OEM to the installation on the aircraft." Ridge says that as the world becomes "smaller" and more connected, cybersecurity has become an even more vital aspect of avionics design, certification and maintenance. "Industry efforts on standards for the entire process are being reviewed and updated through the Airlines Electronic Engineering Committee (AEEC)," Ridge explains. "This includes the entire process, from LSAP creation, delivery, the data loading device and final delivery to the affected LRU; end to end."

Weinhardt explains that over-the-air or wireless loading continues to advance. "This seems simple when you consider how often our consumer home devices do this today but for the highly regulated aviation industry, there have been challenges with cyber and updating legacy aircraft with compatible gateways. In addition, the compression of data and the smarter use of that data to reduce the package size has allowed loading to take a fraction of the time it did just five years ago. But the same issue with industry regulations has caused delays in adoption of the wireless loading devices on older aircraft. New avionics systems are adopting these as standard."

These advanced data loading systems can support modern avionics high-speed buses, such as Ethernet, ARINC 664 and high-speed CAN, says Carsten Schweigert, TechSAT GmbH, North America Region, Seattle, to support higher data volumes and shorter load times. "The industry currently transitions to secure loading, to ensure each loadable software part (LSP) has a valid digital signature which is

Avionica's PocketPDL
(Photo courtesy of Avionica)

validated prior to each data upload (transfer of data to an aircraft computer). Secure loaders replace existing non-secure loaders by either upgrade or exchange."

Another innovation is wireless connectivity to automatically deliver or "stage" software parts on to the aircraft. With integration of a ground system like FLS-Desk and a secure wireless method to move software parts to onboard storage on the aircraft and a data loader function embedded in the aircraft Chambers explains it becomes possible to always have the right software and data loading capability on every aircraft all the time. "And, with global cellular connectivity software updates can be delivered very quickly to an airline's entire fleet ready for line maintenance to walk onboard and perform the software loading tasks such as the monthly navigation data base update."

Cloud-based data management advances data loading. Gilkison says this allows operators to upload and manage their software and databases remotely from a centralized system. "The ability to push updates to multiple aircraft and entire fleets from a singular location significantly reduces aircraft time spent on the ground and enhances security by ensuring only approved personnel are uploading verified data."

What's Unique about Avionics Loading?

Like all things in the aviation industry, Gilkison believes there is a heightened focus on safety, security and regulatory compliance within avionics data loading. "Aircraft systems, components and operations are highly regulated and require precision, appropriate checks to confirm data transmission and error mitigation."

The airline industry has aviation specific standards developed by the AEEC. Chambers says the purpose of these standards includes enabling interoperability of systems and as a part of that is enabling innovation and competition. "The standards cover all kinds of avionics systems and topics including guidelines and recommendations for field loadable software, data loading interfaces and protocols and security. In aviation, the safety criticality of avionics and regulations require tight configuration management and controls over aircraft software and avionics data loading."

Don't Overlook Data Loading

Data loading can be sometimes overlooked in the context of operating aircraft. "As aircraft designs continue to evolve, the amount of computing power on aircraft will continue to grow," Kuske says. "These new systems will require updates to continue to function properly, and data loading is critical to maintaining the authorized configuration of those systems and the aircraft as a whole. The security landscape around aircraft will continue to evolve as well, and today's data loaders are part of the solution to ensure safe and secure operation of an operator's aircraft."

By Mark Robins

Ensuring Robust, Resilience Cybersecurity for Civil Aircraft

Cyber-attacks against all aspects of civil aviation are on the rise, necessitating the implementation of robust, resilient cybersecurity measures in this vital industry.

There's no time to lose. "Cyber-attacks in general are escalating each year," said Vance Hilderman, CTO of AFuzion, which describes itself as being the world's largest aviation certification services company. "The 2024 estimated cost of cyber-attacks is US$8 Trillion."

Worse yet, "the world has been witnessing a steady increase in cyber-attacks against all sectors," warned the International Civil Aviation Organization (ICAO) on its Aviation Cybersecurity web page (*https://www.icao.int/aviationcybersecurity/Pages/default.aspx*). "Aviation has been no exception, being characterised by its extensive interconnectivity and complexity, its high level of media exposure, and its critical role in the socio-economic development of States."

"Cyber-attacks affect airlines, airports, and air transport managers," noted Waël Kanoun, Director of Cyber Defense Solutions at Thales Middle East, and International Aerospace Vertical Lead for Cybersecurity at Thales. "In 2023, the main target for attacks were airlines, accounting for over 60% of all cyber-attacks in the aviation sector. Certain patterns emerge, revealing that specific categories of stakeholders are more affected by particular attack vectors; for example, DDoS [Distributed Denial-of-Service] attacks on airports (64% of all DDoS attacks are on aviation), and ransomware attacks on the supply chain (63% of all ransomware attacks are on aviation)."

Why Aviation is at Risk

Before detailing the ways in which aviation is improving its cybersecurity, it is helpful to understand why this industry is in hackers' crosshairs to begin with.

The reason: "Since 9/11, aviation is increasingly seen as a 'target rich' cyber-attack area since aircraft incidents are among the highest profile incidents possible, with the exception of nuclear reactor incidents," Hilderman said. "Wealthy countries fly more and build more aircraft, so they are at a higher risk of cyber-attacks, which is increasingly known. As well, aircraft complexity is increasing along with usage of third-party commercial products and more-open communication protocols, thus increasing the number of potential aviation cyber-attack 'vectors' (areas of cyber vulnerability)."

As a result, aviation is increasingly being subjected to greater cyber-risks and more actual cyber-attacks. "To date, no commercial passenger aircraft has yet crashed due to a cyber-attack," said Hilderman. "However, many cyber incidents have been attempted and succeeded in impairing flight and supply chain operations."

A Wide Range of Cyber-Attack Options and Targets

When it comes to attacking aviation, hostile players have a wide range of options at their disposal. "The commercial aviation industry faces a range of cyber threats such as ransomware, phishing attacks, DDoS attacks, and advanced persistent threats (APTs)," said Roberto Valla, Senior Director of Aerospace & Defense at the security software firm Wind River. "These attacks can be perpetrated by nation-state actors, cybercriminals, or insiders with various motives. The industry's cybersecurity is becoming more robust, with increasing investments in technology and training, but challenges remain due to the complexity of interconnected systems."

Josh Lospinoso is CEO and co-founder of Shift5, whose onboard observability platform allows aviation, military, rail, and maritime operators to make smart, fast decisions about their aircraft through real-time data access, contextual insights, and actionable analytics. "There are a number of cyber risks that aviation defenders monitor, but the latest risk, requiring immediate action, is GPS jamming and GPS spoofing," he told Aerospace Innovations. "The rise in hybrid warfare globally — from the Ukraine to the Middle East — has led to the now-daily use of electronic warfare (EW) tactics. Forces can manipulate the electromagnetic spectrum to attack an enemy or impede operations, targeting GPS satellites to jam enemy radar, intercept communications, deceive enemy sensors, and spoof GPS signals. Its extensive use on the battlefield has bled into civilian life; according to OpsGroup, 900 daily flights are now encountering GPS spoofing. The International Air Transport Association (IATA) estimates GPS

"Since 9/11, aviation is increasingly seen as a 'target rich' cyber-attack area."

Vance Hilderman, CTO of AFuzion

Security-related photo. Credit BlackJack3D Getty Images/iStockphoto

Generic cockpit picture. Credit P. Darphin

disruption grounding aircraft could obstruct one million daily global passengers, incurring $60 billion lost in annual global GDP."

Although aircraft offer hackers the highest visibility targets, all aspects of aviation are under attack. According to Kanoun, "Attackers target airport systems to create backdoors, granting them prolonged undetected access. This allows the infiltration and potential disruption of key systems over an extended period, going from days to months. The longer the period of infiltration, the larger the amount of data collected. Such attacks can also be used to disrupt the operation of key systems such as luggage systems, announcements, CCTVs, and ticketing. The impact of such cyber-attacks can be substantial, as evidenced by the example of the Beirut airport cyber-attack in January 2024, where traveller information screens were hacked to display political messages for several days."

Meanwhile, the growing adoption of interconnected systems within civil aviation has spurred an increase in the number of possible cyber-targets. It's not just communication networks and flight management systems that are in danger. "As examples, the now-common availability of passenger Wi-Fi systems on aeroplanes, the use of credit card capture systems in-flight, the ubiquity of USB ports for device charging at the seat — all things consumers have come to expect during their travel — and digital flight bags (e.g. iPads loaded with vector routes, landing approaches, and runway maps) commonly brought onboard by pilots, are all opportunities for intentional unauthorised electronic interactions, or IUEI," said Valla. "The vulnerabilities are also heightened by the legacy systems still in use, which may not have been designed with modern cybersecurity threats in mind."

Stepping Up Cybersecurity: What The Experts Have to Say

Compared to the military sector, civil aviation has been slower to step up its cybersecurity practices "for simple monetary and apparent 'lack of urgency' reasons," Hilderman said. Nevertheless, this situation is now improving due to regulator pressure: "The FAA and EASA have recently mandated that all new commercial aircraft and avionics undergo required cyber-security evaluations and adherence to the new 'DO-326A' ('ED-202A' in Europe) requirements," he noted. "So, new aircraft will be increasingly protected. Now legacy aircraft and systems are much less protected. But fortunately, they are also much less vulnerable due to their near-exclusive use of custom-developed and fully verified dedicated software."

So, what is being done specifically to improve aviation cybersecurity? Quite a lot, according to the experts interviewed for this article. Quite a lot indeed.

A case in point: "Three main areas of work are enhancing the assurance of cybersecurity robustness," said Paul Butcher, UK Programme Manager and Head of Dynamic Analysis with AdaCore, which aids developers in the creation of safe, secure and reliable software. These three areas

are "the advocation of memory-safe programming languages, the advocation of memory-safe hardware, and the advocation of Refutation activities within airworthiness security standards," he said. [According to Wikipedia "memory-safe" is defined as the state of being protected from various software bugs and security vulnerabilities when dealing with memory access, such as buffer overflows and dangling pointers.]

Let's start with memory-safe programming languages. According to Butcher, trends within the aerospace industry have sometimes resulted in memory-safe programming languages falling out of favour, leading to the widespread use of memory-unsafe languages like C and C++. "The problem is that memory-unsafe programming languages are highly susceptible to unsafe memory instruction calls, which can result in undetected-through-testing software bugs, like buffer overflows," he explained. "If an attack can trigger these bugs, they become vulnerabilities that could lead to unauthorised electronic interaction with the air vehicle's avionics systems. For an operator, this can lead to costly fixes to deployed software and potentially life-threatening scenarios if the vulnerability is linked to a safety hazard. "

However, the tide is turning. In February 2024, the White House released a report titled 'Back to the Building Blocks: A Path Toward Secure and Measurable Software' *(https://www.whitehouse.gov/wp-content/uploads/2024/02/Final-ONCD-Technical-Report.pdf)*, which strongly advocates the use of memory-safe programming language and memory-safe hardware. "Since many cybersecurity issues start with a line of code, one of the most effective ways to address those issues is by examining the programming language itself," the report said. "Ensuring that a programming language includes certain properties, such as memory or type safety, means software built upon that foundation automatically inherits the security those features provide."

"This report recognizes that the risk of undiscovered vulnerabilities across the existing software ecosystem is unacceptably high and underscores the urgent need for a shift towards memory-safe solutions," said Butcher. "One promising solution to the prevalent use of memory-unsafe programming languages is to run the compiled application code on memory-safe hardware."

As for Refutation? "As stated within DO-356A/ED-203A, Refutation is an alternative to exhaustive testing that can provide evidence that unwanted behaviour has been precluded to an acceptable level of confidence," Butcher replied. "Therefore, refutation is the act of refuting claims that a system is secure by rigorously attempting to hack the system and identify attack paths."

Shift5's Josh Lospinoso has a different take on improving aviation cybersecurity. "The interconnected nature of modern aircraft and ground-based systems demands a layered defence strategy that can address the unique vulnerabilities of each environment," he said. "While many companies have developed robust solutions to secure ground-based OT systems, the critical need to protect the aircraft themselves cannot be overlooked."

At the same time, "the critical importance of securing onboard systems cannot be overstated.," said Lospinoso. "Today, aircraft are complex networks of interconnected systems, including avionics, in-flight entertainment, communication networks, and more. These systems are integral to the safe and efficient operation of the aircraft, but their connectivity also makes them vulnerable to cyber threats. A successful attack on these systems could have catastrophic consequences, ranging from operational disruptions to threats to passenger safety."

Working Together to Solve Problems

Fortunately, the cybersecurity industry is taking these concerns to heart, by developing products and services to address these vulnerabilities. "It has to be a team effort, because the future of aviation cybersecurity lies in collaboration," Lospinoso said. "No single company can claim to secure an airline's entire OT landscape, but together, specialised solutions can offer the comprehensive coverage that the industry requires. For instance, Shift5's expertise in securing onboard systems, combined with the strengths of other OT providers, forms a powerful alliance that can safeguard both the ground and the skies."

Thales' Waël Kanoun shares this belief in collaboration, which he extends to include airlines and regulatory agencies in addition to cybersecurity firms. "The aviation industry must continually assess and enhance its cybersecurity measures to effectively mitigate evolving cyber threats," he explained. "This is why Thales is active in sharing with other aviation stakeholders by being a member of Aviation ISAC (an international association

Portrait of Waël Kanoun. Credit:Thales

"Saying that AI systems are safe is not enough."

Waël Kanoun, Director of Cyber Defense Solutions at Thales Middle East, and International Aerospace Vertical Lead for Cybersecurity at Thales

of OEMs, airlines, airports, satellite manufacturers, aviation services, and their supply chains) and a founding member of the French Aviation CERT (Computer Emergency Response Team), which monitors cyber threats and responds to computer security incidents in aviation."

Thales is also providing cyber security training to the industry that integrates aviation and cybersecurity expertise, with a strong focus on practical applications. "One illustrative approach involves the utilisation of simulators in various locations such as the UK (NDEC in Wales), France, Belgium, and the Middle East (CyberNode in the UAE)," said Kanoun. "These simulators, referred to as 'CyberRange', are sophisticated simulation solutions enabling the execution of cyber attack scenarios. They facilitate accurate replication of systems, including airport and aviation systems, and offer a secure environment for testing and simulating attacks under conditions closely resembling real-world scenarios."

That's not all. According to Wind River's Roberto Valla, the aviation industry is adopting several more measures to boost cybersecurity. They include implementing advanced threat detection systems, conducting regular vulnerability assessments, and establishing comprehensive incident response plans.

Of course, for these measures to be effective, "it is important to work with proven, trusted technologies and technology partners who can help companies achieve their security objectives," Valla said. "And again, collaboration between industry stakeholders is also crucial, with information sharing initiatives and adherence to regulatory standards. Companies can also put additional focus on continuous employee training, upgrading legacy systems, and integrating AI-driven cybersecurity solutions."

Paul Butcher, UK Programme Manager and Head of Dynamic Analysis with AdaCore

"Three main areas of work are enhancing the assurance of cybersecurity robustness."

Paul Butcher, UK Programme Manager and Head of Dynamic Analysis with AdaCore

Protecting AI and Autonomous Flight

Speaking of AI, the notion of AI-managed autonomous aircraft being hacked to be repurposed for evil intent is the stuff of nightmares — and Hollywood. (Prediction: Such a scenario will likely turn up in a movie or TV show in the near future.) This begs the question:

As AI and autonomous flight make their way into aviation, what needs to be done to prevent them from being exploited by hackers and terrorists — and is this being done?

According to AFuzion's Vance Hilderman, the answer is yes. "The good news is that the FAA's DO-326A requires continuous reassessment of cyber-risks and that should include increased vulnerabilities caused by AI," he said. "Also, AI is currently disallowed onboard the aircraft to control any real time onboard safety function so onboard AI cannot be exploited for real time safety."

Having said this, Hilderman stressed that current FAA rules do not yet apply to legacy aircraft or onboard AI which is simply "monitoring" aircraft systems. "Frankly, the bad news is that it will likely take a major cyber incident to really force implementation of greatly enhanced cyber rigour, just as 9/11 triggered major airport/passenger scrutiny."

This is why the experts interviewed for this article want aviation AI to be properly regulated now, before a 9/11-style event ever takes place.

"Saying that AI systems are safe, is not enough: it is essential, particularly in such a critical environment, to prove it with strict controls," said Kanoun. "At Thales, we aim to keep humans at the centre of decision-making processes, meaning that the AI is only an aid. The AI technologies that we build into our systems have to meet stringent requirements and, just like the other stakeholders of the aviation industry, sometimes need to obtain certification before they can be used in real-world applications. Alongside academic and industrial partners, Thales anticipates the development of qualification methodologies to build trusted AI. This is particularly crucial for critical systems where infrastructure safety or human life is at stake."

One thing is certain: Regulating AI and autonomous flight should not be an industry afterthought. "As AI and autonomous flight technologies advance, it is essential to incorporate cybersecurity from the design phase, ensuring that these systems are resilient against potential exploitation, Valla said. "This involves adhering to design/development practices with security in mind as a top priority, implementing real-time monitoring, and creating fail-safe mechanisms. In general, aircraft manufacturers must show that they can either protect against unauthorised access, or if it occurs, isolate the access from propagating to other aircraft systems. They must also demonstrate how they prevent adverse impacts to aircraft systems. And in both cases, they must show how they can maintain these security protections for the transport's expected useful life as part of earning an airworthiness certificate. These requirements hold for both crewed and uncrewed aircraft."

Aeronautics factory office. Credit Gorodenkoff stock.adobe.com

What Aviation Operators and Others Can Do

For the aviation industry to truly create a robust and resilient cybersecurity environment, everyone has to do their part. This includes airlines, airports, and others associated with civil aircraft operations.

So what do aircraft operators and aviation businesses actually need to do? "They need to really read, understand, and adopt DO-326A/ED-202A for cybersecurity," Hilderman answered. "They need to do this not only for mandatory new aircraft/systems, but also for legacy aircraft and legacy systems, plus airports and air traffic management, supply chains, and infrastructure."

A case in point: "Avionics systems are the backbone of modern aircraft, responsible for critical functions that ensure safe and efficient flight," said Lospinoso. "The potential consequences of a successful cyber-attack on an aircraft's avionics systems can be catastrophic. Unauthorised access or malicious manipulation of these systems can lead to severe disruptions, compromising safety and operational efficiency. As a result, ensuring the cybersecurity of avionics systems is critical for maintaining the safety and integrity of modern aircraft operations."

Taking a Big Picture view of this problem, Waël Kanoun opined that, "to improve their cybersecurity and resilience, aircraft operators and aviation business need to adopt an approach that is both proactive and reactive. On one hand, the proactive part should rely on the 'cybersecured by design' principle, meaning that security must be placed at the centre of reflections from the outset. On the other hand, the reactive part should aim to constantly update the systems in place to be able to face evolving threats."

For Roberto Valla, the critical word in Kanoun's above statement is 'update'. "Once an airframe achieves safety certification, the thought is to lock it down and not make changes, to avoid triggering any recertification costs," he said. "But for security purposes, the threats are always evolving, and architectures need to both remain resilient and flexible to be able to thwart future, unanticipated threats. On a larger scale, aircraft operators and aviation businesses must prioritise cybersecurity by adopting a multi-layered defence strategy, which includes regular security audits, employee awareness programs, and the deployment of advanced security technologies. While progress is being made, there is always room for improvement and continued innovation, especially in areas such as threat intelligence sharing and proactive threat hunting."

The bottom line: Everyone has to work together to create and maintain a robust, resilient cybersecurity environment for the global aviation industry. Fortunately, "the aviation industry is in the process of developing a cohesive cybersecurity strategy," said Kanoun. "To implement this global strategy effectively, the participation of three key entities is vital: International organisations such as ICAO, IATA, EASA, and FAA, specialised expert working groups in aviation cybersecurity — for example, Aviation ISAC, EATM-CERT, and ECCSA — and national bodies responsible for securing critical instances and environments such as ANSSI in France, NCSC in the UK, and NCA in the US." Also required is the wholehearted support and participation of airlines, airports, and all aviation-associated businesses.

By James Careless

Making DO with Safety Standards

In the first of a two-part article, we look at the evolution of DO-178C and its influence on safety critical software

In 2023, Patrica Lustiq and Gill Ringland proposed the concept of Fractured Backbones. A backbone is an agreed set of rules which are shared and support the way that things work

In today's modern world, software is the digital backbone responsible for enabling a milieu of systems, from cash registers to satellites. Safety critical software is a class of software, often embedded in systems, where failures of the software can cause failures in systems that can result in damage to the system, environment, or property, as well as injury or loss of life of the people using these systems, or substantial financial and reputational damage.

As Gary Gilliland, Vice President of Marketing at DDC-I states, this type of software is developed and tested with the utmost care to prevent failures and manage or isolate failures in such a way as to protect the system.

Steve DiCamillo, Technical

Olivier Charrier, Principal Functional Safety Specialist at Wind River

Marketing and Business Development Manager at LDRA adds that, "In practice, most functional safety standards specify the use of hazard analyses and system safety assessments to arrive at a level of criticality – from non-critical to catastrophic. The higher the level of criticality, the greater the reduction in system safety resulting from a software failure."

Another dimension to the definition is added by Olivier Charrier, Principal Functional Safety Specialist at Wind River, who avers that software is just one component of the equation. "Usually, such equipment has been identified to have a risk of creating some aspect of harm, and as soon as an equipment is identified to be part of a harmful situation, then all the pieces of this equipment need to be reviewed against safety critical aspects," he says. He argues you need both safety critical hardware and safety critical software, and "you need to do a safety critical integration of all of them together."

According to Charrier two of the main reasons why there is a fracture in the digital backbone of software allowing accidents to occur are because either the wrong requirement was written into it or there is an integration issue.

"So, usually it's because it's not well written. So, if it's not well written, it's not well verified, and it can create a situation that can create an accident."

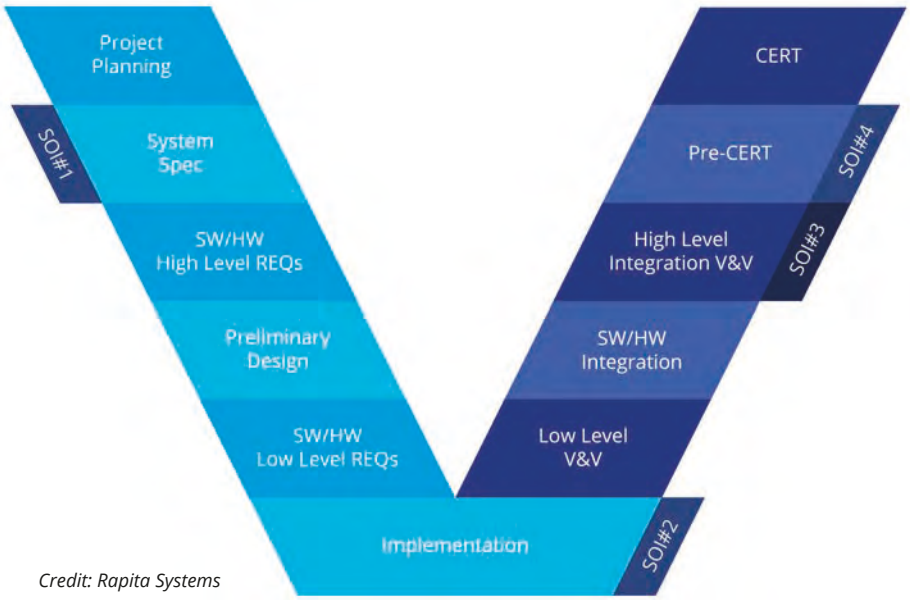
That's why safety standards keep improving, to try to help on this, he says.

Safety coded

"With increasing levels of criticality, functional safety standards generally require more rigorous processes, practices, activities, and engagement with regulatory agencies around the planning, development, and verification of software," says DiCamillo.

"Safety criticality influences software development by imposing stringent requirements on the entire software lifecycle," asserts Dr Benjamin Brosgol, a senior member of the technical staff at AdaCore. "This includes rigorous planning, meticulous design, comprehensive testing, and thorough verification and validation processes. Development methodologies for safety critical software often involve automated static analysis (including formal methods) and manual code reviews to ensure that the software behaves as intended under all circumstances."

This software must be developed to safety standards that are prescribed for the industry, explains Gilliland. "In the case of aircraft avionics, the software development standard utilised is DO-178C (FAA)



Credit: Rapita Systems

or ED-12C (EASA). These standards define a set of design assurance levels (DALs) from DAL-A for very critical safety requirements down to DAL-E systems which have no safety requirements. Additionally, for multi-core systems there sets of guidance in A(M)C 20-193 that systems must follow depending on the DAL requirements of the system. Depending on the safety criticality of the system there also may be redundancy in software as well as hardware."

What's in a name?

Rapita's technical writer, Dr Daniel Wright claims that for safety critical software, the bar for required verification and quality assurance is much higher than for non-safety critical software, commensurate to the huge risk should the software fail.

"In the context of DO-178C, the level of this bar depends on the DAL of the software. This has an impact on all aspects of development, from selection of hardware, software languages, standards and architectural models, and tools, including verification tools, to quality assurance processes and verification, and even organisational structure of departments involved in development, verification and quality assurance."

DO-178C, formally titled 'Software Considerations in Airborne Systems and Equipment Certification,' is a critical standard in the international aerospace industry. It provides guidelines for developing safety critical software in commercial airborne systems and is also being adopted for military systems. It defines the objectives, activities, and artefacts required to achieve

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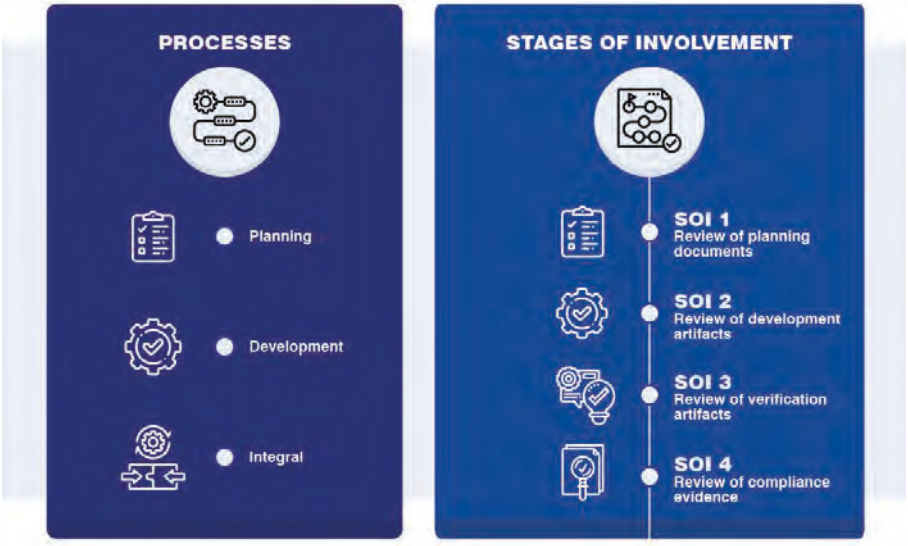
confidence that the software used in aircraft systems is safe and reliable. The standard categorises software into different levels of criticality, known as Design Assurance Levels (DALs), ranging from A (most critical) to E (least critical). DO-178C ensures that the software life cycle processes include sufficient rigour to meet the safety requirements associated with each DAL, thereby reducing the risk of software-related failures in aircraft.

Gilliland provides further elucidation. "DO-178C defines a process for creating and documenting the software development lifecycle for safety critical systems. It starts with creating a set of requirements for the software that states what needs to be done such that there is no ambiguity. The software is developed, using best practices and coding standards, to meet the requirements that have been documented. Developers must show traceability from the software to the requirements.

"Test software is developed by a different set of engineers to verify that software correctly implements the requirement as stated. Along the way there are code reviews to check that coding standards and best practices are followed by independent reviewers. In addition, the certification authority will conduct audits at various stages of the program to ensure processes and procedures are in place and being followed."



Credit: Rapita Systems

Credit: Rapita Systems

DO-178C includes a total of 114 objectives, and the objectives that should be met depend on the DAL of a software item, which is determined based on the level of risk should the software fail. While DO-178C prescribes objectives, it doesn't prescribe how they should be met, and a range of approaches are taken by DO-178C applicants, though many similarities exist across organisations. A collection of supplementary guidance documents has been introduced since the publication of DO-178C to cover the use of new technologies or specific aspects of design assurance, for example tool qualification.

Developing a fix

As Lustig and Ringland promote, when Backbones work well, they provide the resilience needed to adapt to disruptions and threats. A Backbone will have been designed for a set of circumstances, but it needs monitoring and maintaining. When a Backbone fractures, rather than evolving to fit the needs, it becomes a disruption they argue.

The increased use of software in airborne systems, and safety of that software, prompted the creation of DO-178.

DO-178() was originally published in 1982 by the Radio Technical Commission for Aeronautics organisation (now known as RTCA, Inc.) in collaboration with EUROCAE. It is the core document for defining both design assurance and product assurance for airborne software. The objective is to ensure that the software performs its intended function with a level of confidence in safety that complies with airworthiness requirements. The guidelines provided specify objectives for software life-cycle compliance, a description of activities and design considerations for achieving those objectives, and a description of the evidence indicating that the objectives have been satisfied.

As DiCamillo expounds, DO-178 has been revised several times since then and has been joined by a series of supplements and guidance documents (DO-330, DO-331, DO-332, DO-333). He says that ongoing work around the development of DO-178C has focused on maintaining the safety and reliability of airborne software systems in the wake of further technological advances. Examples of resulting guidance include "AC 20-193, Multi-core Processors" and "AC 20-170A,

Integrated Modular Avionics".

Gilliland augments the overview further. "DO-178C defines a process for creating and documenting the software development lifecycle for safety critical systems. It starts with creating a set of requirements for the software that states what needs to be done such that there is no ambiguity. The software is developed, using best practices and coding standards, to meet the requirements that have been documented. Developers must show traceability from the software to the requirements. Test software is developed by a different set of engineers to verify that software correctly implements the requirement as stated. Along the way there are code reviews to check that coding standards and best practices are followed by independent reviewers. In addition, the certification authority will conduct audits at various stages of the program to ensure processes and procedures are in place and being followed."

DiCamillo adds that the tables in DO-178C Annex A serve as a practical tool to summarise and clarify the objectives and activities described in the main body. These tables provide a structured way to ensure that all necessary steps are followed and documented – but they do not include the same level of detail.

DO-178C (and DO-278A) are part of a broader set of documents that provide a comprehensive avionics development and certification framework.

Keeping up with the times

In a paper presented to the 2012 American Institute of Aeronautics and Astronautics Infotech, Stephen A. Jacklin, an aerospace engineer at the NASA Ames Research Center, in Moffett Field, California, charted the background behind the release of DO-178C.

In 2005, the RTCA created special committee 205 (SC-205) to produce a revision of DO-178B to account for new software development and verification technologies that were deemed immature at the time DO178B was written. The new version, DO-178C "Software Considerations in Airborne Systems and Equipment Certification", was released in December 2011. Rather than placing all of the new guidance in DO-178C, the special committee decided to place the vast majority of the new guidance in six other documents. These documents were released together with DO-178C.

They are:

- RTCA DO-278A3: Software Integrity

Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems
- RTCA DO-248C4: Supporting Information for DO-178C and DO-278A
- RTCA DO-3305: Software Tool Qualification Considerations
- RTCA DO-3316: Model-Based Development and Verification Supplement to DO-178C and DO-278A
- RTCA DO-3327: Object-Oriented Technology and Related Techniques Supplement to DO-178C and DO-278A
- RTCA DO-3338: Formal Methods Supplement to DO-178C and DO-278A

As Amani Karchoud, Technical Product Marketing Manager at Sysgo summarises, DO-178C was developed to address advancements and lessons learned from applying DO-178B.

The differences fall into several categories noted in Appendix A of DO-178C. As well as describing the activities to perform towards the objectives throughout the sections, the major clarifications and improvements for Wright are planning content to cover outsourcing and supplier oversight; the impact of compiler, linker and hardware options on worst-case execution timing, considerations around deactivated or otherwise noncovered code; guidance for parameter data items; and tool qualification guidance including reference to DO-330.

On the latter point, Brosgol expands stating that, "The DO-330 companion standard to DO-178C introduces more rigorous guidelines for the use of software tools, expanding on the DO-178C distinction between verification and development tools. DO-330 is not specific to airborne systems and can be applied in other domains where code certification is required."

To these improvements, Brosgol adds incorporated supplemental guidance. "DO-178C is supplemented by several documents that provide guidance on using modern technologies during the software life cycle for airborne software: DO-331 (Model-Based Development and Verification), DO-332 (Object-Oriented Technology and Related Techniques), and DO-333 (Formal Methods)."

Additionally, DO-178C provides fixes for known errata and clarification for known inconsistencies, providing consistent terminology, improvements in wording and clarity, clarifying the importance of activities and their related objectives, and clarification and specification of 'hidden' objectives, along with other general clarifications.

All about the journey

As Wright stresses, avionics software must be approved before it can be used in the field. "Signoff is required by a Designated Engineering Representative or similar, who is authorised to approve the software on behalf of the FAA or another certification authority (e.g. EASA for ED- 12C). Signoff can be based on demonstration that the software meets the appropriate DO-178C objectives, or it can be through alternative means of compliance. No safety critical software would make it anywhere near operational use without the appropriate signoff."

The impetus to meet the objectives comes from regulatory requirements and industry best practices says Brosgol. Compliance is necessary to obtain certification from aviation authorities like the FAA in the US or EASA in Europe, without which an aircraft system cannot be legally operated in the airspace controlled by that authority. Additionally, adhering to these standards is a way for companies to demonstrate their commitment to safety and quality, thereby protecting their reputation and reducing liability.

"The main impetus for following these guidelines is to meet regulatory and certification requirements essential for market entry," says Karchoud. "While prescriptive, these standards are universally recognised as best practices."

The guidance in DO-178C provides a framework of processes, activities, and objectives to be met, but it does not specify the details of how those objectives are to be met – leaving that decision up to system and software development organisations, says DiCamillo.

Charrier picks up the point, stating that while at once DO-178C is mandatory in its perspective, ie, the objective, the way these objectives are realised is very agile and prospective. This agility can encourage the use of new techniques or the application of new technologies, but caveats Charrier, "there's nothing preventing the use of new technology, but you need to be aware that it will take time, because you need to educate and discuss it with the authority" and explain how you use that new technology in the context of the objective.

But as DiCamillo warns, while alternative means of compliance are in theory possible and acceptable, the cost to develop them and provide adequate proof of their viability could be prohibitive.

Brosgol deems "prescriptive" not to be the right word in this conversation. "Although it specifies a number of software life cycle processes, DO-178C does not mandate specific ways to develop the software, and indeed, its guidance is not called "requirements" but rather "objectives." So, in that sense, the standard is goal-based. In fact, it is possible (but not without some work) to take existing software and reverse engineer the artefacts that demonstrate compliance or to use alternative techniques to the ones documented in the standard"

But admits Brosgol, the guidelines have limitations. "They might not accommodate the latest technological innovations or specific project needs, or they might lead to processes that do not directly contribute to achieving safety objectives, potentially leading to inefficiencies or increased costs." To these limitations, Karchoud adds potential increased development time and cost. She stresses however, that they provide a framework that significantly mitigates risk of

> “Despite its limitations, the DO-178x series of standards has been successful in practice. It is strongly focused on the verification process, with the purpose of preventing the introduction of errors in airborne software.”
>
> **Benjamin Brosgol, senior member of the technical staff at AdaCore**

software failure.

Brosgol agrees. “Despite its limitations, the DO-178x series of standards has been successful in practice. It is strongly focused on the verification process, with the purpose of preventing the introduction of errors in airborne software. It achieves this by providing repeated opportunities to detect and eliminate defects before the software is fielded. There have been a very small number of aviation incidents where DO-178x-certified software has been identified as the cause.”

Alex Preston

Putting Data to the Test

Air Data Testing Systems are a crucial piece of aviation test equipment for use in testing and verifying aircraft flight instruments whilst the aircraft is firmly on the ground.

ADTS are used to test components such as pitot and static ports (pictured) to ensure the safe operation of flights. (Copyright Airbus SAS/ Jean-Vincent Reymondon)

Aviation is a very precision and safety-conscious focussed industry that has become increasingly dependent upon accurate and real-time data for safe and efficient operations of flight.

Today's modern aircraft rely on a plethora of air data components like the altimeter, airspeed indicator, vertical speed indicator (VSI), pitot tubes, static ports, and temperature probes, to generate navigation parameters such as pressure altitude, baro-corrected altitude, altitude rate of change, computed and true airspeeds (TAS), Mach number, total air temperature (TAT) and static air temperature (SAT).

The fidelity of these systems is tested and verified by Air Data Testing Systems (ADTS) or Pitot-Static Testers, an item of ground support equipment used to simulate airspeed, instantaneous vertical speed (IVSI) and altitude for aircraft line- and base-maintenance checks. Their versatility allows them to be used across different aviation sectors, making them suitable for a variety of airframes, including commercial airliners, business jets, general aviation aircraft and military aircraft and avionics systems.

As Chris Roberts, Product Leader - Test and Calibration at Druck, a Baker Hughes business describes, ADTS are available in two main configurations. The first is as a flightline product which has a built-in pump and is self-contained. This type of instrument can be directly connected to an aircraft. The second is as a workshop/ laboratory product for manufacturing or testing avionic instruments not installed in an aircraft.

Check-ups

According to Maria Quezada, Marketing Manager at Laversab, the primary functions of the ADTS are to simulate flight conditions by controlling pressure in the aircraft's pitot-static system, thereby allowing technicians to test these instruments in a controlled environment.

Paul Hart, Chief Technical Officer at DEA Specialised Airborne Operations expounds further. "An ADTS contains high-precision pressure and vacuum pumps within a portable ruggedised housing designed for flightline environments. The units connect to the pitot and static ports using special adaptors and colour coded tubing. The ADTS is typically controlled by a remote handheld unit by the maintenance engineer from the cockpit to cross-check that the airspeed, altitude and vertical speed indications on the electronic flight instrument system (EFIS (or "classic" round dial mechanical instruments)) correspond with the simulated pressures generated by the ADTS. The periodicity of this testing is stipulated by the aircraft manufacturer, who in turn are following guidance material from the regulations, such as FAA Advisory Circular AC43-60. Typically, this is a maximum of every two years or scheduled with routine maintenance inputs, such as a C-Check."

ADTS also addresses common issues such as instrument calibration errors, leaks in the pitot-static system,

The ADTS 552F pitot static tester provides a smarter way to perform aircraft maintenance, troubleshooting, fault-finding and emergency aircraft on ground instrumentation validation. (Copyright Druck, a Baker Hughes business)

ADTS' are extremely versatile, making them suitable for all types of aircraft. (Copyright Laversab)

and incorrect readings that could lead to unsafe flight operations.

"ADTS is also used when any defects are reported, either from the crew Tech Log or captured in the Central Maintenance Computer whenever a comparator mismatch has been detected between the Captain and First Officer EFIS displays, if discrepancies have been detected on airspeed, altitude or IVSI indications either side," explains Hart. "A common issue is whenever a pitot probe is blocked from icing, bird strike or damaged during ground handling."

In December 2021, an S7 Airlines A321neo suffered from reduced controllability after entering an area with severe icing after takeoff. It was subsequently determined that icing on three air data sensors caused a disturbed airflow to the pitot, static and angle-of-attack probes.

As a consequence the no. 1, 2 and 3 air data reference (ADR) used faulty airspeed and altitude data.

This would cause the system to underread and the combination of a visual check for the probe being misaligned, as well as a leak test using the ADTS would normally identify any fault rapidly," Hart says.

Hart believes that ADTS are an essential item of Ground Support equipment, given that they perform an essential test function on a primary aircraft system during routine checks and after repairs. Quezada agrees they have become integral to a maintenance team's avionics equipment portfolio. "Their role is crucial in ensuring that all air data instruments are functioning correctly before an aircraft is cleared for flight, making them indispensable for maintaining flight safety," she says.

Crucially, there are some regions whose regulatory requirements mandate periodic testing of aircraft air data systems. ADTS help ensure compliance with these regulations.

In fashion

Since their introduction, ADTS have evolved as technology and requirements have progressed.

"The main developments over the years have been in the size of the products," states Roberts. "In the early days they used to be built into trolleys and carts as they were so large. Nowadays they are about the size of carry-on luggage."

Early ADTS during the 1940s-1970s used manual pumps to pressurise a volume within the test set. Under these conditions says Hart, the user would refer to a look-up table of pressures (in PSI - pounds per square inch) that corresponded to different airspeeds. Subsequently, these were replaced with electro-pneumatic pumps and since the 1980s these have been

LEFT: The portability of today's ADTS units makes them convenient for a variety of environment, including hangars. (Copyright Druck, a Baker Hughes business)

ABOVE: Laversab's 6600 NG ADTS can perform specific checks for SmartProbe-equipped aircraft, including Embraer EJETS 1 & 2, Dassault Falcon 5X, 7X & 8X, and the Gulfstream G650. (Copyright Laversab)

computer controlled to meter very precise pressures to test a sequence of airspeed and altitude conditions.

Modern systems are now more automated, allowing for quicker and more accurate testing procedures. Most recently the remote controls used by the engineer in the cockpit use Wi-Fi or Bluetooth connections to replace the coiled cables that have been used for some decades, making them more versatile and user-friendly.

"These improvements have enhanced ground maintenance by reducing the time required for testing and calibration, increasing accuracy, and minimising the risk of human error," asserts Quezada.

Hart identifies essential features as being able to meet the airspeed, altitude and IVSI tolerances specified by the aircraft manufacturer.

Standout features of modern ADTS include Wi-Fi-enabled remote operation and Bluetooth connectivity, which according to Evolution Measurement, further enhances the efficiency of these devices. Technicians can connect wirelessly to the test sets, streamlining the testing process and eliminating the need for cables that can be cumbersome and prone to entanglement.

Other qualities embrace options for 2-, 3- or even 4-channel configurations. These systems also offer battery-powered operation, making them portable and convenient for use in various locations, from the hangar to the ramp, thanks to environmental ruggedisation - they are often exposed to bad weather on the flightline and need to tolerate "rough" handling, says Hart.

Roberts highlights the properties of Baker Hughes' Druck ADTS units, which in addition to their measurement accuracy and stability, control performance and operating environment capabilities, can be controlled from a remote hand-terminal so during the testing programme the technician does not need to leave the cockpit. These in conjunction with the pre-defined test sequence capabilities means that test programmes can be completed simply and efficiently.

While ADTS have evolved significantly with advancements in technology, manufacturers must be aware of and contend with obsolescence and updates. For example, as Quezada explains, Laversab offers hardware and software upgrades for their ADTS. These upgrades ensure that the equipment remains compatible with the latest aviation standards and technologies. Additionally, Laversab provides support services, including calibration and loaner units, to ensure that customers can maintain their equipment's performance over time.

Roberts says that Druck's ADTS are subject to regular lifecycle reviews and refreshes to ensure they can be relied upon in the harshest environments. Any software updates can be carried out quickly and efficiently by the end-user.

RVSM acceptance

Manufacturers must also manage RVSM (Reduced Vertical Separation Minima) compliance.

As ATEQ, whose entire range of air data test sets is RVSM compliant, explains RVSM is a vertical separation standard between aircraft that was phased between 1997 and 2005 in air traffic management. It is the reduction of the standard vertical separation required between aircraft flying between FL290 (29,000 feet) and FL410 (41,000 feet) inclusive, from 2,000 feet to 1,000 feet (or between 8,850 and 12,500 metres, from 600 metres to 300 metres). To be RVSM compliant, the aircraft must verify that it is flying within

these limits. Therefore, to achieve this accreditation, each aircraft must carry out a series of tests to confirm that all their pitot probes and flight indicators provide sufficiently accurate information.

RVSM compliance is thus essential for ADTS, remarks Quezada as it ensures that the aircraft can safely operate in airspace where reduced vertical separation standards are applied. "This compliance is critical for maintaining accurate altitude measurements, which is especially important in crowded airspaces where precise altitude data is necessary to prevent collisions," she says.

Hart agrees, although he makes the distinction that while it is vital for aircraft that are operated above 29,000ft / FL290 and are required to maintain 1,000ft vertical separation, for aircraft such as regional turboprops with ceilings significantly lower than 29,000ft, general aviation and helicopters, this level of altimetry accuracy is not needed.

To obtain RVSM approval, operators must ensure that the aircraft meets minimum monitoring requirements established by their respective state authority (determined by the country where the aircraft is registered), pilots and crews must be trained in appropriate RVSM flight procedures, and the integrity and accuracy of the aircraft's altitude-indicating systems must be closely monitored.

Monitoring flight checks must be completed every two years or 1,000 flight hours (whichever is greater) to maintain RVSM approval. When performing systems checks on aircraft equipped with RVSM-certified altimeters, it is imperative to use RVSM-compliant air data test sets and pitot-static test equipment.

The likes of ATEQ, DMA, Druck, Laversab, and Raptor Scientific amongst others offer ADTS that achieve this accreditation.

Calibration time

Maintaining the fidelity, integrity and accuracy of these systems requires regular testing and rigorous design and manufacturing processes,

BELOW: Calibration of Laversab's 6300 ADTS is required only once a year.(Copyright Laversab)

ABOVE: The 6580 Automated Air Data Calibrator from Laversab is an ADTS designed for laboratories. The high accuracy of the tester and NIST-traceable calibration make it fully RVSM-compliant. (Copyright Laversab)

including the use of high-precision sensors and components. ADTS manufacturers will typically calibrate pressure systems against a US National Institute of Standards and Technology (NIST)-certified reference.

"Druck specialises in pressure control and measurement. We manufacture and design our own sensors so are in control of the whole process," said Roberts. "By using our own unique design of sensor, TERPS, we can ensure the specification we state is adhered to with no degradation of performance over the specified interval. Unlike some of the sensing technology in the market, TERPS is not density sensitive for example. We have also spent many years developing our control technology and when coupled with our sensing capabilities customers can trust the accuracy and stability of our ADTS units."

Baker Hughes's Druck ADTS units are uniquely configurable and can be automated to complete pre-defined tests sequences for airspeed, altitude and angle of attack.

Laversab says it is systems can perform various test sequences, such as leak checks, accuracy checks for altimeters and airspeed indicators, and simulations of different flight conditions to test the performance of air data computers

For the ADTS to stay accurate, a calibration check should be carried out at chosen intervals. This is used to check the calibration, verifying the accuracy of the pressure sensors and ensuring that the system's readings are within specified tolerances, without adjusting it. It may be used either to see if the ADTS requires a calibration or to verify performance following a main calibration. If the accuracy of the ADTS is not within the specification, it is recommended to carry out a main calibration, which adjusts the accuracy of the main transducers.

"As the equipment manufacturer we cannot tell a customer how often to calibrate their equipment," says Roberts. "That is defined in their processes and procedures. We do however publish a specification for each unit, this can be as long as an 18 months specification due to the capabilities of our sensor technology, which can help reduce cost of ownership.

"Using PACE Tallis, our new transfer standard, calibration of the test sets is a simple and easy process and can potentially be completed just about anywhere. Customers may assess that they no longer need to perform calibration in an laboratory or workshop due to PACE

The DPI610E-Aero is a low cost yet flexible portable calibrator for precision leak testing of aircraft pitot static systems. (Copyright Druck, a Baker Hughes business)

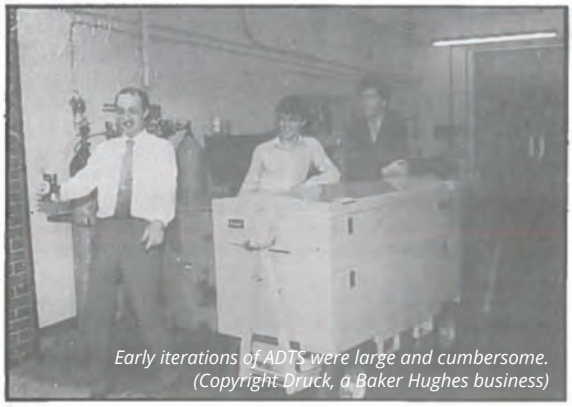
Tallis not being as susceptible to environmental effects as traditional calibration instruments."

The appropriate interval between recalibrations is generally recommended every 12 months, although as Hart says, intervals depend on specific aircraft and can range from monthly (when there is a specific airworthiness directive) to every two years. ATEQ Aviation, for example, recommends that its instruments be calibrated annually to maintain optimal accuracy.

Calibration of an ADTS can be performed at a manufacturer's facilities or by authorised service centres, ensuring that the equipment maintains its precision and reliability. Laversab offers two-day and four0-day options for instance.

Another key benefit is the multitude of test sequences these devices offer. These sequences are carefully designed to assess various parameters, ensuring that every crucial aspect of air data is thoroughly tested. From altitude and airspeed measurements, leak testing and EPR testing, modern air data test sets can accommodate a wide range of testing requirements.

In addition to the primary air data system tests, ADTS can perform a range of other testing requirements, says Quezada, such as verifying the performance of the aircraft's pitot-static system, testing the air data computer, and checking the functionality of altimeters and airspeed indicators under simulated flight conditions. These systems can also perform leak tests to ensure that the pitot-static system is airtight and free from defects that could impact flight safety.



Early iterations of ADTS were large and cumbersome. (Copyright Druck, a Baker Hughes business)

ADTS units can also be used to carry out cabin air pressure switch tests and have other applications such as checking altitude alerters, low airspeed warnings, outflow valves and cabin depressurisation sensors that would trigger oxygen mask deployment in an emergency.

Selection advise

With such an array of units available, what makes an ADTS a suitable candidate?

For Quezada, when selecting an ADTS, it is important to consider factors such as the type of aircraft you will be testing, the required level of accuracy, and whether RVSM compliance is needed. Additionally, consider the system's portability, ease of use, and available support services, such as calibration and software updates. "Opting for a versatile and upgradeable system like those offered by Laversab ensures that your ADTS will meet current and future needs."

Laversab offers both online and in-person training for users and free technical support for all customers. The company also provides loaner units to reduce downtime during maintenance, while all its ADTS units come with a three-year warranty, ensuring reliability and customer satisfaction.

Hart says that the ADTS must meet the accuracy and parameter range requirements specified by the aircraft OEM. "Manufacturers must provide a quick turnaround time when the ADTS is returned, typically annually, for sensor calibration." He also identifies portability and durability for flightline environments. Also on his shopping list are self-test on power-up, overpressure detection to prevent damage to aircraft sensors, and for airliners (Boeing, Airbus), that they can simulate ohmic resistance from total air temperature probe to simulate Mach number in combination with the pitot and static pressures.

For Roberts, the main areas to focus on is how efficient is the volume control. "Very often you will be trying to generate a vacuum or pressure up through a system of hoses and pipes which can have a sizeable volume associated with it, especially if the ADTS is being used through a line switching unit or on multiple pitot static systems simultaneously or independently. Baker Hughes Druck ADTS units are market leading when it comes to accurately controlling pressure into a large volume.

"Secondly but just as important is to understand what factors are included in the accuracy specification of the units this should include. A clear definition of what is meant by the accuracy specification, confirmation that all factors are included in the accuracy specification and a clear definition of what is meant by the precision specification.

"Lastly, how well shielded from environmental affects is the ADTS - such as fluid density, fluid humidity, temperature and EMC (Electromagnetic Compatibility)."

By Alex Preston

Advances in Flight Simulation

AXIS Flight Simulation, CAE, Collins Aerospace, and Indra Keep Pushing the Envelope

Rendering from Collins Arcus™ image generator. Credit - Collins Aerospace

During World War Two, countless allied pilots learned the basics of flight inside Link Trainers. Built to resemble a stubby-winged aircraft with realistic interactive instruments and flight motion inside, the Link trainer was state-of-the-art for its day.

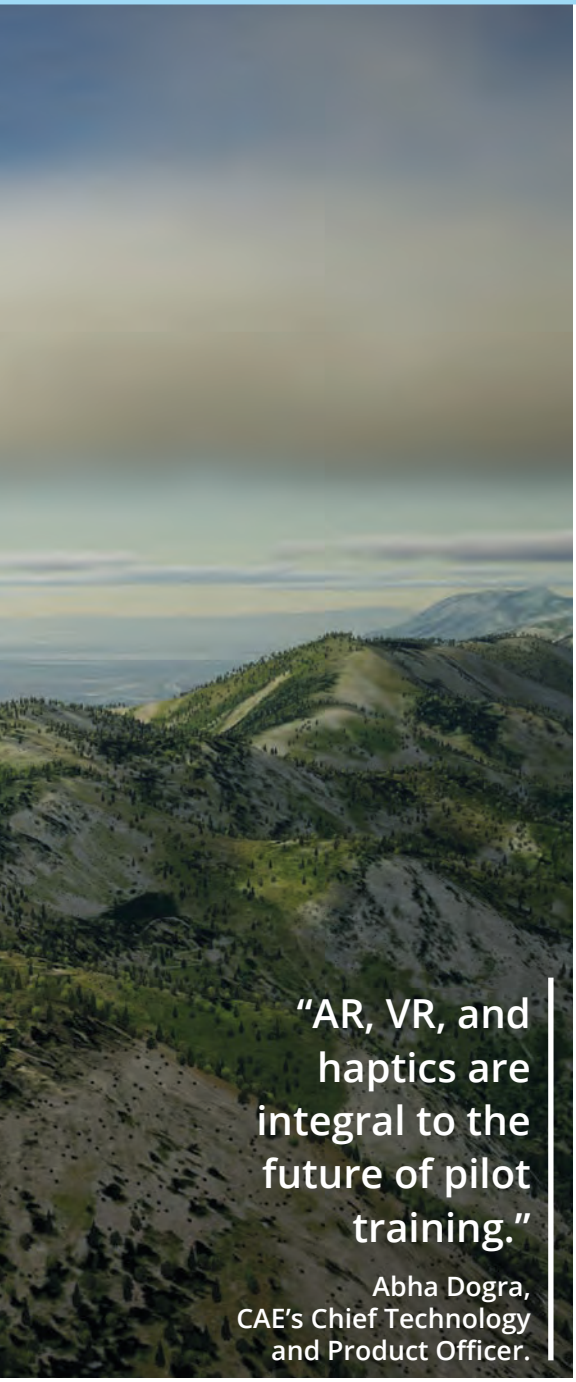
"Inside the 'cockpit,' the student relied on his instruments to 'fly' the Link through various manoeuvres while his navigational 'course' was traced on a map on the desk by the three-wheeled 'crab'," said the National Museum of the United States Air Force website (https://www.nationalmuseum.af.mil). "Slip stream simulators gave the controls the feeling of air passing over control surfaces and a rough air generator added additional realism during the 'flight'."

Not surprisingly, today's full-flight simulators (FFS) are light years ahead of the Link trainer, with companies such as AXIS Flight Simulation, CAE, Collins Aerospace, and Indra Sistemas pushing the envelope of what's possible. Here is what they are up to.

Advances Abound

To put it mildly, modern FFS provide training experiences that are stunningly close to actual flight. "High-fidelity graphics now provide an incredibly detailed and immersive environment, enabling pilots to experience real-world conditions with very high accuracy," said

Christian Theuermann, Member of AXIS Flight Simulation's Executive Board. "For example, enhanced terrain modelling, weather effects and dynamic lighting ensure that every aspect of simulated flight mirrors real-life scenarios. While detailed ground imagery captured using satellite data gathering and aerial imagery allows for more detailed and effective graphics. In regard to motion, our FFS' have



> **"AR, VR, and haptics are integral to the future of pilot training."**
>
> **Abha Dogra, CAE's Chief Technology and Product Officer.**

highly advanced, integrated motion cueing systems that replicate the feel of flight including turbulence, engine vibrations and manoeuvres. Nowadays, pilots training on a Level D FFS should not be able to tell the difference between flying the simulator or a real aircraft."

CAE has been similarly busy marrying advancing simulator-based flight training with innovative technologies. "Last year, we were the first to achieve Level D certification on a full-flight simulator equipped with a gaming engine-powered visual system," said Abha Dogra, the company's Chief Technology and Product Officer. "The CAE Prodigy Image Generator (IG) uses Epic Games' Unreal Engine to deliver high-fidelity graphics and physics-based simulation. This technology elevates training standards with photorealistic renderings, enhanced moving models, and a more immersive environment. It improves visual simulation fidelity, making training not only more realistic but also more effective."

Collins Aerospace, an RTX business, is also looking to video games to enhance their training experiences. "The more realistic and dynamic the image generator, the more closely aligned simulation training will be to live training," Dave Kanahele, Program Manager for Simulation & Training Services with Collins Aerospace, told Aerospace Innovations. This is why "Collins Aerospace developed a new training solution called Arcus ™ that combines Collins' advanced rendering and processing with gaming engine developer Epic Games' Unreal Engine technology for a higher fidelity training environment."

Indra Sistemas is so committed to constantly improving the realism of their simulators, that they invest 5%-9% of their annual sales revenues to pay for these advances. "While always improving graphics realism and motion effects, Indra simulators have reached a level of maturity that allows us to focus on more challenging developments," said Julián López, Indra Sistemas' Commercial Director for Simulation. "The focus of Indra simulators' evolution is now on the incorporation of Virtual and Augmented reality, and the use of AI to improve the behaviour of computer-generated forces, making them more human and realistic, and to deliver adaptive training, tailored in real time for each trainee."

AI Is A Natural Addition to Simulator Training

With its ability to process, and analyse vast amounts of data quickly and efficiently, AI (artificial intelligence) is a natural addition training — both in terms of providing the student pilot with 360 degree out-of-the-window views in real-time and responding to their control inputs in a realistic and accurate manner.

"The integration of AI and data collection ensures targeted and efficient training, made possible through performance analysis and data-analytics," Theuermann said. "AI can process large amounts of data in real-time and record pilots' immediate interactions, responses and decision-making processes during simulated flights. Using data collected from these algorithms, training programs can be tailored to pilot performance, identifying specific areas for improvement and allowing users to efficiently progress in their training." He added that AXIS Flight Simulation's AI-driven debriefing solution compares pilots' actions against optimal performance standards, for this very reason.

The CAE Rise platform also uses advanced analytics to assess pilot performance objectively, providing instant feedback and training

Christian Theuermann's Headshot. Credit AXIS Flight Simulation.

> **"High-fidelity graphics now provide an incredibly detailed and immersive environment."**
>
> **Christian Theuermann, Member of AXIS Flight Simulation's Executive Board**

Maintenance technician training can be enhanced by using VR. Credit CAE

CAE has integrated advanced virtual reality (VR) technology into their maintenance technician training programs, enabling technicians to engage with aircraft systems, components, and procedures in a fully immersive, simulated environment. Credit CAE

intelligence to instructors. “The platform also helps to calibrate instructors for more consistent training and grading,” said Dogra. “By offloading some tasks from instructors, it allows them to focus on evaluating more complex skills, making the training process both more efficient and effective. Upcoming CAE Rise releases integrate biometrics like gaze and pulse with telemetric data to further augment insights.”

CAE Rise™ will be used on all simulators at CAE’s new Savannah facility in Georgia, U.S., exclusive to Gulfstream, empowering instructors with technology that delivers insights and data to enrich simulator training for pilots. Credit CAE

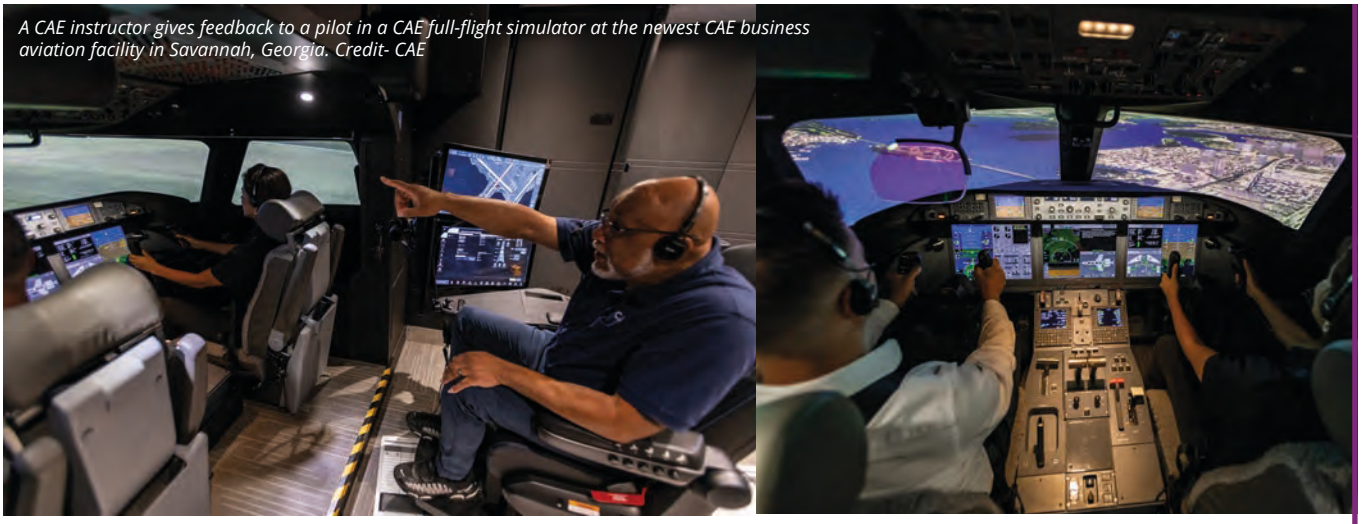
Indra is using AI in its simulators as well. According to López, AI helps to ensure

human-like behaviour in computer-generated elements such as airport ground control and air traffic in the civil sector, to Blue and Red forces in the military arena. It also drives the use of NLP (Natural Language Processing) for the creation of terrains, scenarios definition or modification of the exercise in real time based on the trainee’s current performance and adapts the exercises to their specific needs based on their past performance.

AR and VR Playing Their Parts

AR (Augmented Reality, aka Mixed Reality) combines computer-generated graphics on an immersive headset with views of the actual world. Imagine a training scenario where the student is sitting in a physical version of an aircraft cockpit, with the views outside the windows and the data on the displays being generated by computer. In contrast, VR (Virtual Reality) focuses the student solely on the computer-generated images; their physical setting is irrelevant. ‘Haptics’ refers to the physical equipment — like a control stick — that the student interacts with to respond to the simulation, and that provides real-time motion and touch sensations to make the experience convincing.

Not surprisingly, AR and VR are playing major parts in modern simulation-based training. “AR and VR technology adds another layer of immersion, providing an even more captivating experience of virtual flight and enhancing FFS training,” said Theuermann. “An AR system, for example, can project critical flight data, navigation information or checklists onto the pilot’s field of view. This aids real-time decision-making and situational awareness without obstructing the pilot’s view of their surroundings. VR, on the other hand, creates a completely immersive, computer-generated environment that users can interact with using a headset. In flight simulation, VR places the pilot inside



A CAE instructor gives feedback to a pilot in a CAE full-flight simulator at the newest CAE business aviation facility in Savannah, Georgia. Credit- CAE

a fully virtual cockpit, providing a 360-degree view and a sense of presence. This technology allows for realistic training scenarios, such as emergency procedures or navigating adverse weather conditions."

The real beauty of AR/VR simulation training is that it allows students to encounter various real-life situations without actually putting themselves or an aircraft at risk. "By using VR headsets, pilots can engage with immersive experiences that replicate pre-flight checks, emergency protocols and maintenance procedures without need for a physical aircraft or simulator," Theuermann said. Meanwhile, "Haptics enable pilots to experience the physical sensations of the controls and learn how difficult or easy they are to manoeuvre. This also ensures that pilots develop the necessary muscle memory for repeated flight procedures."

"AR, VR, and haptics are integral to the future of pilot training, offering new levels of immersion and realism," observed Dogra. "At CAE, we've been pioneers in integrating these technologies into our training solutions. Our XR solutions, including the CAE 700MXR simulator, combine mixed reality with haptics to create a highly immersive training experience. These technologies allow us to simulate a wide range of scenarios, making training more flexible and accessible. They complement traditional full-flight simulators, creating a comprehensive training ecosystem that enhances skill development."

The fact that AR, VR and haptics simulation devices can be used independently of full-flight simulators make them affordable training options for educators. "Flight training devices and headset VR and MR systems can reduce cost and increase opportunities for focussed training due to the immersive and portable nature of the simulators," Kanahele said. "Our Arcus Image Generator can take advantage of future commercial AR/VR technology as well as support Collins' unique real-time system performance optimizations to meet the most demanding training applications."

This being said, AR, VR and haptics — known collectively as XR (Extended Reality) — are not the end-all and be-all of flight training, said López. "AR and VR are definitely game changer technologies in many fields, and Indra has also incorporated it into our catalogue of display solutions," he explained. "However, Indra's view on XR in flight simulation is that although it provides a higher level of immersion for the trainee, it can be exhausting for the trainees, especially on long sessions."

The Power of Networking

Having one student in a modern simulator running realistic flight scenarios is impressive. Linking them with other students and instructors in real-time through networking: That's magic!

"Networking allows multiple trainees to participate in the same simulation from different locations, making joint exercises, like multi-crew coordination (MCC) or air traffic controller-pilot interactions, more seamless," said Theuermann. "This real-time collaboration improves communication skills, teamwork and the ability to manage complex, multi-faceted flight scenarios. Today, MCC courses form part of airline pilot training (APT) and help trainees learn how to fly in a multi-crew environment. The objectives are optimum decision-making, task sharing, checklists and support throughout all phases of flight under normal, abnormal and emergency conditions."

"System networking has become a cornerstone of modern training solutions where instructors, pilots, and simulators can digitally interact with each other, leveraging the courseware and practising complex

> **"The more realistic and dynamic the image generator, the more closely aligned simulation training will be to live training."**
>
> **Dave Kanahele, Program Manager for Simulation & Training Services with Collins Aerospace**

A B737 Full Flight Simulator developed by Indra and currently used by Global Training Aviation (GTA), a fully owned Indra company. Credit - Indra

manoeuvres," Dogra agreed. "By enabling simulators to connect across different locations or to connect with an actual aircraft's data, we are able to provide shared, synchronised training experiences that bring teams together in real time. This connectivity ensures that training is consistent and collaborative, regardless of where participants are located. It also allows for more complex and realistic training scenarios, where multiple trainees can interact just as they would in actual operations. This approach not only improves training outcomes but also fosters better teamwork and communication among crews."

Networked simulator training has become particularly important for military student pilots, allowing them to experience the kinds of mass deployments they will undertake on active service. "It supports large-scale operations and tactical training, such as formation flying, air combat or combat search and rescue (CSAR) and allows cross-disciplinary training with roles like air traffic control or maintenance staff," said López. "An example of this implementation is the interconnection of Indra simulators between the three Spanish Army Bases of CESIHEL (Helicopter Simulation Center) in the centre of Spain, Agoncillo in the north and Almagro in the south of Spain. In total, 12 helicopter simulators, including Chinook, EC135, Cougar, Tigre, and NH90 interact regularly, sharing communications, visual and tactical scenarios, providing significant operational and training advantages in the context of military and helicopter training."

Awesome Advances to Come

As awe-inspiring as modern simulation-based flight training is today, the future holds even more exciting possibilities.

For example, Indra is working on combining AR training with Full-Body Haptic Suits that provide immersive feedback to the pilot and could simulate the forces of acceleration, vibration, and even G-forces during manoeuvres. "Also advanced touch-based interfaces might replace physical controls, allowing pilots to interact with virtual cockpits using touch-sensitive gloves or panels, creating a more modular and flexible training system," López said. "This technology cannot yet be applied to Level D Simulators (the highest fidelity flight simulators certified), but with the development of wearable haptics and AR glasses to be more unnoticeable, this can be a reality in the near future."

Then there's Brain-Computer Interfaces (BCIs): Yes, you read that correctly. "Neural interfaces could permit better monitoring of the reaction of the pilots in stress situations, facilitating the selection of roles and profiles for specific missions," said López. "BCIs could even be used for direct interaction with the simulator through thought commands, significantly increasing the speed and precision of control inputs."

If that isn't enough, quantum computing could be used to create ultra-realistic physics models for flight simulators. "As quantum computing technology matures, it could revolutionise flight

simulation by enabling far more complex aerodynamic and weather models, offering simulations with unprecedented accuracy in real-time," López said. "Quantum computing could also support far larger, more complex simulated environments with realistic interactions between multiple aircraft, real-time weather, and air traffic."

These are just some of the envelope-pushing ideas being developed by the simulation-based training industry. "We're continuously pushing the boundaries of what's possible to help our customers," said CAE's Dogra. "Looking ahead, we're focused on developing more modular and scalable training systems that can be tailored to the specific needs of our clients. We're also exploring adaptive learning technologies that adjust in real time to a trainee's performance, offering a more personalised and effective training experience."

"The simulator market is constantly evolving, and we are dedicated to delivering cutting-edge, innovative training solutions," AXIS Flight Simulation's Theuermann agreed. "Earlier this year, we launched the first front-loading roll-on/roll-off solution, AX-D Flex, which was designed to train on multiple aircraft types in the same hardware. The equipment consists of a core simulator structure with motion and visual display components that can be integrated with cockpit modules. This unique solution optimises pilot training, while providing new levels of cost-efficiency. We're also working on some exciting new innovations which we'll be launching later this year."

As for Collins Aerospace? According to Kanahele, "Collins is looking ahead at making training simulators even more flexible and more deployable. Operational security requirements have increased as potential adversaries have increased land, air, space, cyber, surface, and subsurface ISR/monitoring capabilities. These restrictions make it challenging for warfighters to train as they will fight. Additionally, the cost to travel continues to increase to the point where it is not worth the flight/drive time to accomplish low-end tasks or training."

All told, the simulation-based training industry has evolved so far past the original Link trainer, that it is giving actual flight training a run for its money. Obviously, there will always be a need to put pilots into aircraft for real-life training, but the amount of this that has to be done is constantly on the decrease. "In some defence scenarios, pilots are going solo on advanced aircraft without ever having flown with an instructor in the air," said Dogra. "The capabilities of today's simulators are so advanced that they can replicate nearly every aspect of real flight, making it possible to minimise the time and resources spent on flight training in an actual aircraft while still ensuring pilots are fully prepared."

By James Careless

Rendering from Collins Arcus™ image generator. Credit - Collins Aerospace

Making sense of the ARINC 661 Standard

Shared Screen Example with PFD and Engine Subsystem on Same Display

Example of Additional Data Changes Triggering Display Code changes on Display

The ARINC 661 Standards for Avionics Cockpit Display development have been in use by the industry for over 23 years, with the first release dating back to 2001. From its initial usage with the Airbus A380 it has grown to be used across most new commercial aircraft and many military projects globally. It has been proven in the real world and allowed developers and integrators to develop complex and interactive systems using a non-proprietary method.

However, even with the success of ARINC 661 internationally there has been confusion when people start to implement a system or perform integration with existing environments. There are implementation details that are outside the scope of the standard or need to be agreed when working with different suppliers to allow successful integration. With the introduction of the new ARINC 661 Part 2 standard the level of confusion for casual or new users has increased across the industry. To understand what the purpose of and usage of ARINC 661 it helps to understand the reasons why ARINC 661 was introduced, and the history of the cockpit displays.

Avionics display background:

Glass Cockpits started to appear in service with military aircraft in late 1960s and early 1970s which replaced the "steam powered" dials and gauges. These digital displays were often just a digital replication of existing instruments, but this then moved to more electronic flight instruments and systems which allowed the removal of many other existing gauges and the need for additional people in the cockpit (flight deck engineers) The evolution of commercial flight deck introduced multiple large display systems with the need to interact with these systems by use of keyboards, pointing devices such as trackpads and even touchscreens which added another layer of complexity for development of systems.

The need for standards:

The complexity and number of the systems that pilots must interact with has grown greatly over the years. Originally sub-systems that needed to present data to pilot and be interacted with were tightly coupled via proprietary interfaces or definitions. Any change to a display layout or information presented required the display computer to have code modified and additional data added to the display interface message protocols.

This lack of a standards-based approach led to the proliferation of monolithic applications, either developed internally or via suppliers. These applications always need to be recertified as a whole, no matter which type of change was made. Exchanging data between suppliers was difficult, making it a challenge for aircraft manufacturers to think about switching providers for a system during the life cycle of an aircraft – or to reuse display elements between projects that are built using different software architectures.

The challenge of sharing a screen would often make this set of proprietary message structures complex and unique to the aircraft. Any supplier or subsystem that interfaced to the display would need clearly defined interfaces. For the simple example shown this would mean defining all parameters that are required to be updated on the display by each subsystem. This leads to a detailed set of specification documents with information relating to the display such as structures, sequencing byte order etc . An alternative approach to proprietary messaging was to allow systems to take over parts of the display and issue graphics commands directly. This introduced additional overheads for development and could mean the graphics looked inconsistent without everybody using the same graphics components. This would then require additional checks, control software, requirements and guidelines to be undertaken as part of development which added to the cost and possible error.

Introducing the ARINC 661 Standards

The ARINC 661 Standard original need and intention can be summarized as: Reduce cost of updates and new features, Support managing hardware obsolescence, introduce interactivity to cockpit in a standardized Human Machine Interface (HMI).

To achieve this the original architecture defined three major parts.

- Cockpit Display System that renders

EVOLUTION OF THE FLIGHT DECK:

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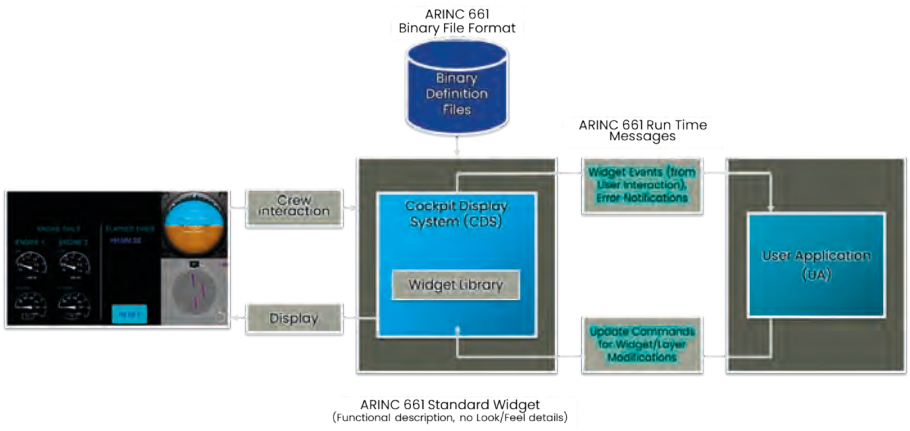
graphics and allows user interaction.

- A Binary file that defines what graphics are shown and the layout of screen.
- User Application that sends and receives data from the CDS controlling information being displayed on screen and what user interaction.

In addition to the architecture separation of graphics from systems the standard defines a set of widgets (push button, check button, touch area, graphic primitives etc.) The widgets are not described how they look & feel (colours, font type, shape, modes etc) but what events they generate and what data they can receive from external systems. ARINC 661 describes how widgets should function and what their parameters are, not defining their visual appearance. This gives full freedom to the display manufacturers to implement their own look and feel for a given project. There is a provision in the standard to allow developers to create custom widgets with tailored functionality and parameters that still follow general widget creation patterns.

In the first release of the standard, there were 42 widgets that could be used to create displays. This number went up to 50 with the first update to the standard, 57 with supplement 2, increasing to 65 in supplement 3 and continued to grow with each update. As of Supplement 9 there are now 120 Widgets including 3D Maps, Touch and Gesture Management along with the more traditional Push Buttons and Text Labels.

The graphics system does not have any knowledge of the meaning of the data that is sent but only what needs to change on the display. For example, instead of sending a proprietary message that defined “Airspeed” the User Application sends a generic ARINC 661 Message which controls the widget on the screen that is responsible for showing the Airspeed data. The benefit this brings is that if more information or items need to be added there is no need to change the message structures or update code

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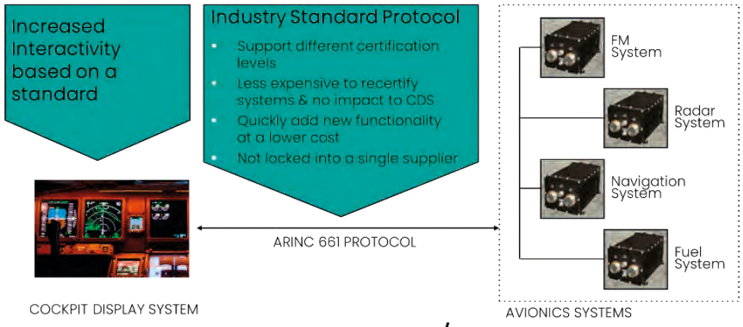
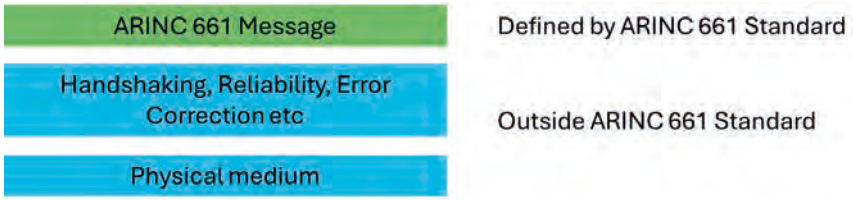


ARINC 661 Objectives / Advantages



on the Display System.

The standard clearly defines the message protocol how to control the widgets on the screen but does not define how the messages are transmitted from the systems that want to control graphics. Many new users assume that the standard mandates a transmission medium, but this is not the case as this would reduce the flexibility of developers to build systems using different technology and architectures. What the standard is clear on is that whatever transmission mechanism is used must be reliable and all messages received in correct order. This means that developers when integrating need to use transmission methods to ensure that this requirement is met. For an ARINC 653 system using APEX channels between partitions this requirement is met without additional management, however if a developer wishes to use UDP Messages they would need to implement methods that ensure messages are not lost and are in correct sequence.

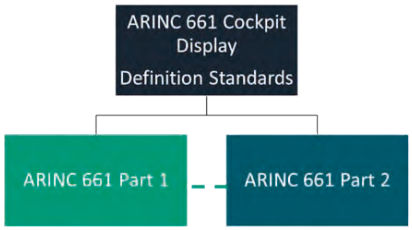
Originally the ARINC 661 standard focused on the communication protocol and the layout of the graphics on screen with a predefined appearance. In 2015 a requirement to have a standard way to define the physical look and feel of graphics was brought to the ARINC standards committee by avionics vendors and airframers. This was wanted to manage specifications, define new widgets and to be able to re-use from one aircraft to another. The request for having this as a standard was approved and work on a new ARINC 661 Standard began. The existing ARINC 661 Specification was relabeled as Part 1 and the new complementary standard labeled Part 2. Both standards sit under the generic ARINC 661 Cockpit Display Standard and are separate documents with parallel development and evolution life cycle. The first formal release of new Part

ARINC 661 Part 1	ARINC 661 Part 2	Publication Date
Specification 661-1		June 2003
Specification 661-2		June 2005
Specification 661-3		November 2007
Specification 661-4		May 2010
Specification 661-5		July 2013
Specification 661-6		September 2016
Specification 661-7		June 2019
Specification 661-8	Specification 661-0	September 2020
Specification 661-9	Specification 661-1	Jan 2024

2 standard appeared in 2020 and coincided with the Part 1 supplement 8 release.

There has been a level of confusion due to the shared name. Both the Part 1 and Part 2 standards have continued to develop and evolve with the committee releasing both specifications in parallel.

The need for Part 2 Standard was



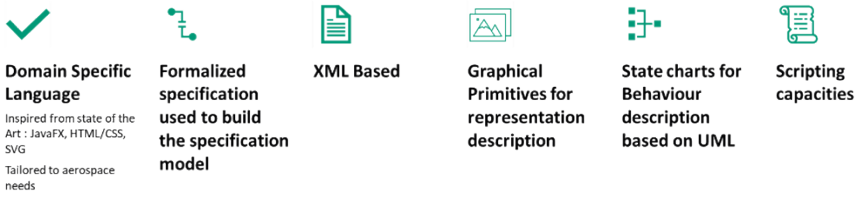
driven by a need for clearly defining the appearance of the widget appearance without textual descriptions. Often textual documents can be ambiguous with the assumptions on what is meant. The simple request and description of asking for a picture of a "football" to be shown would be recognized differently by a person in Europe and in North America. New input control devices and the want to define user centric natural interaction means that more complex modeling of logic also meant that textual was no longer suitable. As a result, of these needs the Part 2 standard defined a formal language to define the Look and Behaviour of UI Objects.

Part 2 Standard Language for modelling Avionics HMI

The semantics of the modelling language defines 3 key areas.

- Interfaces
- Representation
- Behaviour

The User Interface (UI) markup



language syntax is expressed as an XML notation model. This model is designed to be executed in a standard way so that all users of the model see the same behavior and appearance. One of the major benefits of using Part 2 to define graphics is that a single definition model can be used through the lifecycle without need to re-express in multiple documents, tools or code. A model that starts as a prototype can be evolved to become a formal specification and transcoded to a DO178C Design model. This allows fast iterations and try out new user experience. Currently unlike Part 1 which has Binary and XML syntax the Part 2 standard does not define how this model would be deployed to an embedded platform.

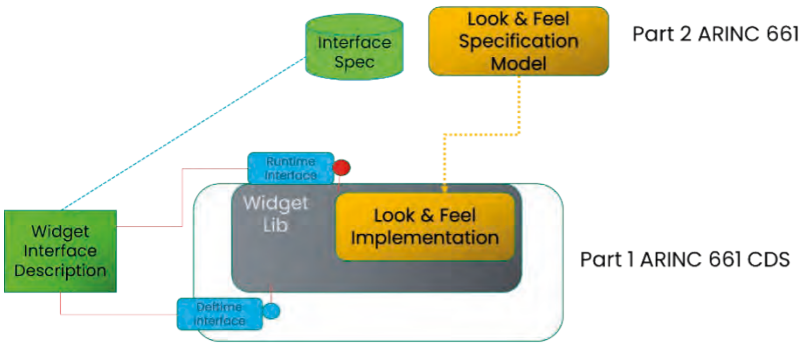
The future of ARINC 661

ARINC 661 is still being developed and extended with both Part 1 and Part 2. The standards committee has very active membership and involvement from industry supporting and is not showing any slowdown to the updates and improvements. With Part 1 generally supporting backwards compatibility of data files the evolution and improvements in standard are designed to ensure that integration with newer versions does not impact all systems on aircraft.

With recent inclusion of 3D widgets in Part 1 and the formalisation of scripting language in Part 2 the ARINC 661 standard is keeping pace with the technical and usage needs of the industry. Currently the ARINC 661 Committee are on target to provide new functionality in Part 1 and Part 2 in 2026. Key areas of the standard under development at present is management of screens and flight decks, along with formally providing mappings of Part 2 definitions for Part 1 widgets.

While the implementation of ARINC 661 architecture in systems did originally look complicated the benefits of easier upgrades and an open standards-based approach are driving more projects to adopt it. With its inclusion in the FACE standard as part of safety critical profile for graphics the number of aircraft with an ARINC 661 system on board is growing rapidly especially in non-commercial aircraft. ARINC 661 looks like it has a healthy future with at present no other standard providing the depth and flexibility for HMI development in the aerospace domain.

By Matt Jackson
Technical Product Manager HMI and Embedded Systems
PACE Aerospace & IT
Member of ARINC 661 Committee



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- Cyber threats and security in Avionics and Air to Ground
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- Complex Systems (Hardware and Software) Testing and Certification
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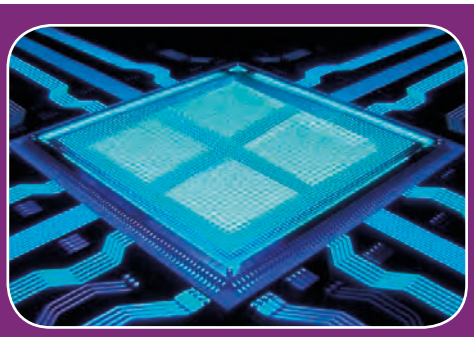
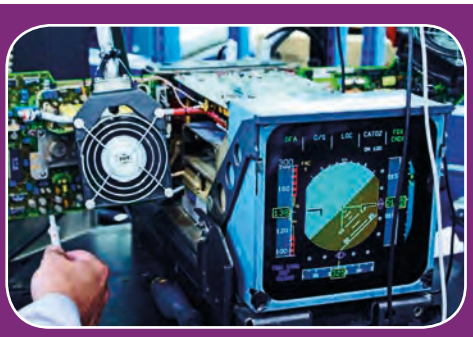
Neil Walker
Director of Conferences
E: neilw@aerospace-innovations.com

Simon Barker
Sales Director
E: simonb@aerospace-innovations.com





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