Q3 OCTOBER 2026

AEROSPACE INNOVATIONS

News, views and analysis of the commercial and defence sectors



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

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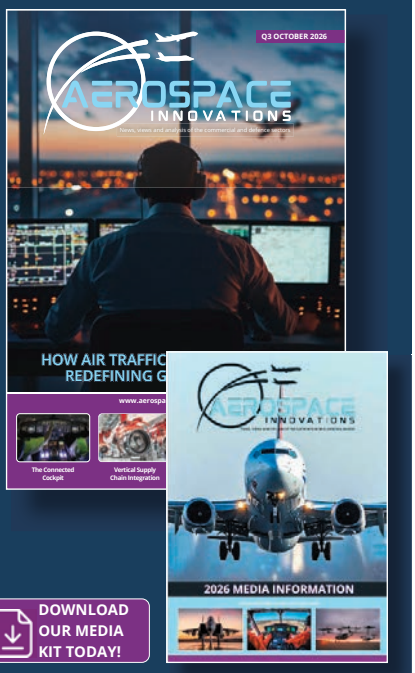
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How ATM Modernisation is Redefining Global Airspace

In our cover story, James Careless spoke with several leading air traffic management (ATM) stakeholders about ATM digital transformation programmes, and how they will fit more aircraft into the same airspace safely, efficiently, and sustainably.

In his second article, James interviewed Klaus Olsen, CEO of EFB Admin Services Int. and asked him how Aircraft Interface Devices (AIDs) are reshaping EFB data governance. In his third article, James spoke with Boeing, Leonardo and some simulation and software companies to find out how digital twins are speeding up the path to aircraft certification.

In his first article in this edition, Alex Preston interviewed leading aircraft connectivity providers about the connected cockpit, and how high-speed connectivity is moving information more efficiently between aircraft, pilots, and airline operations. In his second article, Alex spoke with several leading MRO software providers about Agentic AI, and it offers a remedy to the inherently reactive architecture of traditional MRO practises. In his third article, Alex talks about predicative engine maintenance and finds out from some leading experts how analysing data turns into better informed maintenance decisions.

In his first article for Aerospace Innovations, Michael Bryan writes about the promises being made for eVTOLs and drones to be integrated into airspace, UTM with ATM, and the missing civic layer that Metrops was created to address. Next, in another first article for this magazine, Markus Gilges, spoke with some leading industry players about Remote Visual Inspection (RVI) tooling, and finds out how it has evolved over recent years, especially for the use in engine maintenance.

Our first guest feature in this issue is written by Azita Hajihassani, Founder of consultancy company, Leading Disruption. Azita talks about vertical supply chain integration and discusses some of the biggest challenges for aerospace and defence companies to overcome. Our second guest article in this issue is supplied by dSPACE and is about how digital twins are transforming simulation and validation in aerospace.

Aerospace Innovations is proud to be an official media partner of the High Integrity Software Conference (HISC), which is taking place on October 13th. We hope to see many of you there who will be attending it. The 'Call for Papers' for our own Avionics & Testing Innovations Conference 2027 is now open.

Please submit your speech topics and abstracts by October 23rd online at: www.avionicsandtesting-innovations.com/call-for-papers

We are grateful to our expert journalists, to our contributors, to our readers, and of course to our loyal advertisers – without whom publications like ours would not be possible. As always, we hope you enjoy reading this edition of Aerospace Innovations magazine, and we would be delighted to hear from you if you have any comments to suggest to us for the improvement of this publication.

Best regards,

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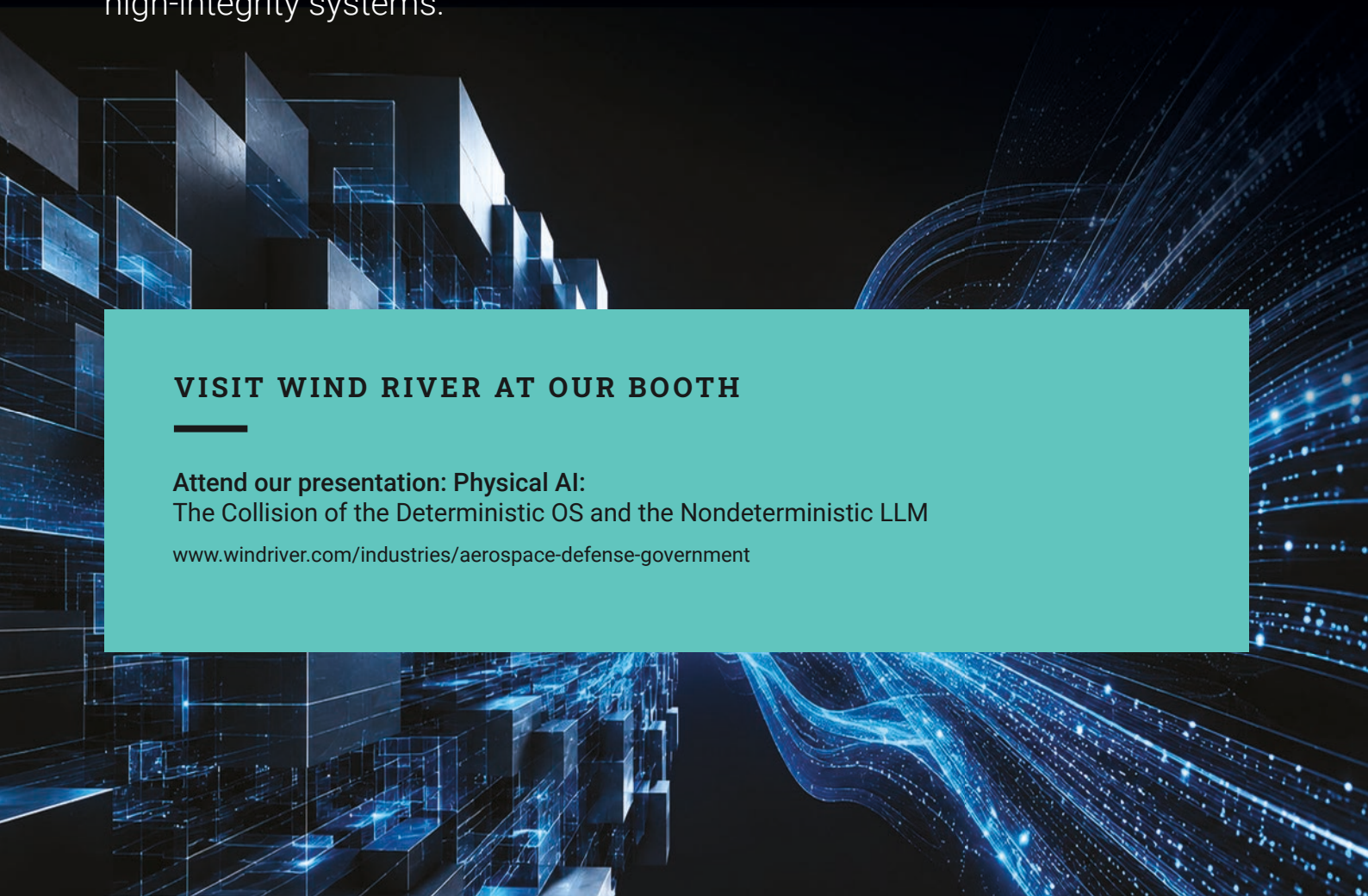
WNDRVR

Mission-Critical Assurance for the Age of Physical AI

How do you combine a deterministic real-time performance with nondeterministic AI?

As intelligent systems evolve from embedded control to physical AI, the challenge is no longer just safety certification. It is ensuring that AI-driven applications, heterogeneous compute architectures, and mission-critical software operate together without compromising reliability.

Join Wind River at HISC 2026 to explore how deterministic foundations, open architectures, and intelligent applications are shaping the future of high-integrity systems.



VISIT WIND RIVER AT OUR BOOTH

Attend our presentation: Physical AI:
The Collision of the Deterministic OS and the Nondeterministic LLM

www.windriver.com/industries/aerospace-defense-government

Ramco Systems Signs MoU with Safran Helicopter Engines

Global aviation software provider, Ramco Systems, has announced that it has signed a Memorandum of Understanding (MoU) with Safran Helicopter Engines, world's leading manufacturer of rotorcraft turbines, to collaborate on enabling seamless integration of Safran's engine data with Ramco Aviation Software.

Through this MoU, Ramco and Safran Helicopter Engines will work together to enable engine information post shop visits to flow directly from Safran into the Maintenance Information System (MIS) within Ramco Aviation Software, reducing manual data entry for helicopter operators and allowing them to focus more on keeping aircraft in service. The outcome of this collaboration will be the award by Safran Helicopter Engines of the EngineLife® Connect label, which identifies the best connectivity solutions compatible with its range of products and services.

As part of the MoU, the companies will work on enabling engine configuration, usage metrics, and maintenance events to be automatically ingested into Ramco Aviation Software, improving data accuracy and consistency across maintenance operations.

The collaboration will also include joint evaluation of data exchange formats and establishment of operational processes to ensure ongoing compatibility.





World's first human-crewed Seaglider flight!

REGENT has completed the world's first flight of the Viceroy Seaglider prototype, the largest-ever all-electric wing-in-ground effect (WIG) craft to fly with people on board. The flight marks the first time a wing-in-ground effect vessel has been engineered and readied for commercial and defense operation at scale — solidifying America's leadership in ground effect flight and positioning REGENT as the pioneer of this transformative transportation technology.

"This is the moment we have been envisioning and tirelessly pursuing for the past five and a half years: REGENT has successfully proven safe, efficient ground-effect flight," said Billy Thalheimer, co-founder and CEO at REGENT. "The Viceroy Seaglider flight marks the start of a new era in mobility, unlocking opportunities across passenger travel, defense missions, and cargo transport. I'm so grateful to the amazing team who made history today. We're now moving quickly toward production to deliver Seagliders to coastlines around the world."

"Completing this flight test validates years of rigorous engineering and operational work and gives us the confidence to move into full-rate production," said Mike Klinker, co-founder and CTO at REGENT. "We showed today that flying a Seaglider is every bit as smooth and safe as we designed it to be. I can't wait to get onboard and to share the experience with others as we make our vision for the future of maritime mobility a reality."

Icelandair Selects Ultramain Systems' Electronic Logbook Solution to Advance Digital Operations

Ultramain Systems has announced that Icelandair has selected ULTRAMAIN® ELB (Electronic Logbook) to replace paper technical logs across its entire fleet to support ongoing digital transformation initiatives aimed at enhancing operational efficiency.

With ULTRAMAIN ELB, Icelandair's flight crews, maintenance personnel, and operational teams will be able to collaborate in real time, replacing the delays of a paper-based process with immediate visibility into aircraft status. The transition supports improved data accuracy, faster defect reporting and resolution, streamlined compliance processes, and enhanced aircraft availability across Icelandair's operations.

"The transition to an electronic logbook will provide our flight and maintenance teams with a more efficient way to share and access operational information," said Leifur Gudmundsson, SVP Technical Operations at Icelandair. "We look forward to working with Ultramain as we implement this solution across the fleet."

Icelandair is Iceland's premiere airline connecting North America and Europe through its Reykjavik hub and is modernizing its operation with technologies that give employees clearer information, deliver a more reliable experience for customers, and strengthen efficiency across the airline.



Pem-Air Selects Ramco Aviation



Enterprise aviation software provider Ramco Systems Corporation, USA (RSC), a subsidiary of Ramco Systems Limited, has announced that Pem-Air, an FAA and EASA-certified engine MRO services and accessory repair provider, has selected Ramco Aviation Software as the technological foundation for its engine MRO operations.

Pem-Air has been rapidly growing, adding support for larger engine platforms such as the GE90 and Trent 700, as well as next-generation engines, including CFM LEAP. Ramco Aviation Software will power operations across this expanded engine portfolio as Pem-Air meets the demands of tomorrow's fleets.

With modules for Maintenance Planning, Engine Maintenance, Supply Chain, Quality & Compliance, Engineering, and Finance, Ramco Aviation Software will provide Pem-Air with a single integrated system that connects every stage of a shop visit. In addition, Ramco Anywhere mobile applications will support technicians with digital task cards and electronic sign-offs, enabling Pem-Air's move toward paperless operations.

Ramco Aviation Software's capabilities extend deep into the engine MRO workflow, covering Contracting and Configuration Management, Work Scoping and Production Planning, Marshalling and Kitting, and Technical Publications, with Resource Optimization supporting smarter staffing and workload planning across every shop visit.

KEYVAN Aviation Awarded Contract as ICAO's Data Provider

KEYVAN Aviation has been awarded the tender for the provision of ARINC 424 data issued by the International Civil Aviation Organization (ICAO), a specialized agency of the United Nations. Under which announcement in April 2026, KEYVAN Aviation is supplying worldwide ARINC 424 data to ICAO, covering 195 countries.

By securing the tender issued by ICAO, KEYVAN Aviation has further demonstrated the reliability of its data, its technical capabilities, its commitment to quality and its compliance with international standards.

Final, up-to-date, high-quality datasets have been made available for online purchase through the ICAO Store, providing access to users across the global aviation industry. Official records relating to the tender and contract award are also available through the United Nations Global Marketplace (UNGM).

AdaCore Releases Demonstrator for Trustworthy Development with AI

AdaCore has released GNAT Foundry: Intersection, an open-source demonstrator of how human engineers can collaborate with AI to deliver high-integrity software. The demo shows how formal methods and trusted tools can guide AI in a high-integrity software development workflow.

AI serves as a powerful tool, enabling human engineers to work more efficiently and effectively. Rather than replacing human engineers, AI can automate many of the steps required to produce high-integrity software.

But AI brings two key challenges to high-integrity software development: firstly, AI fails in ways that are different from humans and are therefore difficult to predict, and secondly, AI generates artifacts so quickly that this can easily overwhelm human reviewers. GNAT Foundry demonstrates a workflow that addresses this by leveraging deterministic trust furnished by non-AI tools as guardrails around AI-generated artifacts, so that humans can focus their attention where it is required. AI drives Ada SPARK-based tools; the tools produce the evidence. The evidence is backed by formal proof, requirements-based test results, structural coverage measurements, and traceability data generated by qualified, established tooling.

AdaCore provides support for the Ada SPARK tooling to software projects that build high-integrity software through their GNAT Pro, SPARK Pro, and GNAT DAS offerings.

GNAT Foundry: Intersection demonstrates how to use AI in a trustworthy way to both open-source and proprietary projects and demonstrates AdaCore's thought leadership in high-integrity software development.



Nick Lester appointed Head of Airworthiness for the Morson Praxis DOA



Nick Lester has been appointed Head of Airworthiness for the Morson Praxis UK CAA DOA, taking on the safety-critical remit alongside his existing role as Chief Engineer Structures & Certification within the Aerospace & Defence division of the engineering consultancy.

A former Chief Stress Engineer at MBDA, Nick has held senior engineering positions supporting major aerospace programmes during his 21-year aviation engineering career, including development of the CAMM-ER missile and the Landceptor defence system, design of the Airbus A350 Wing Fixed Leading and Trailing Edges, Type Certification and subsequent modifications to the AW189 helicopter, and development of the Bloodhound supersonic car.

In his current role as Chief Engineer Structures & Certification at Morson Praxis, Nick is responsible for technical quality across a range of aerospace programmes, supporting organisations including Vertical Aerospace, Leonardo Helicopters, DRAKEN Europe and Marshall Aerospace.

As Head of Airworthiness within the DOA, Nick will play an important role in helping ensure aircraft design, modification and certification activities continue to meet the UK CAA's rigorous safety and regulatory requirements. The position provides technical oversight of airworthiness compliance, engineering assurance and regulatory alignment, while acting as a key interface with the Civil Aviation Authority on matters relating to airworthiness and aviation safety.

Eve Air Mobility and RV Connex Sign MoU to Advance Urban Air Mobility Regulatory Framework in Thailand

Eve Air Mobility and RV Connex Co., Ltd., a leading Thai engineering and aerospace company, are signing a Memorandum of Understanding (MoU) to work together on regulatory development that will help shape Thailand's Advanced Air Mobility (AAM) industry.

Under the terms of the MoU, RV Connex and Eve will jointly collaborate on long term industry and regulatory engagement in Thailand. Bringing together interested public and private stakeholders to establish safe, efficient, and scalable advanced air mobility operations.



This collaboration seeks to evaluate future operational scenarios, safety requirements, airspace rules, and infrastructure needs that are specific to Thailand's aviation system. Learning from global AAM standards while also meeting the needs of the Thai market. RV Connex will collaborate closely with partners from government, academia, and industry to make sure the process is thorough and inclusive.

BAE Systems And NMITE Partner To Develop The Next Generation Of Radio Frequency And Wireless Systems Engineers

BAE Systems and the New Model Institute for Technology and Engineering (NMITE) have partnered to launch a new Master of Science (MSc) degree programme in Radio Frequency (RF) and Wireless Systems Engineering, aimed at addressing the critical shortage of specialist engineering skills in the UK.

Demand for engineers with expertise in this area continues to outstrip supply, posing a risk to national security, industrial resilience and economic growth. This is because RF technologies underpin many of the systems people rely on, from wireless communications, radar and satellite navigation to medical imaging and critical infrastructure such as power grids and water systems.

That's why BAE Systems' Digital Intelligence business is teaming up with NMITE to train the next generation of experts by providing the initial investment required to launch the MSc and helping to fund the first two years of the programme.

Andrea Thompson, Group Managing Director of BAE Systems' Digital Intelligence business, said, "Radio frequency engineering underpins both our national security and our modern way of life – from secure communications and advanced sensing to healthcare, transport and next-generation wireless networks. But the demand for highly skilled radio frequency engineers continues to exceed supply."



"This new programme addresses that shortage – helping to develop the next generation of engineers by combining academic teaching with practical industry experience to support the long-term capability and resilience of the UK's engineering ecosystem."

TASKING and WITTENSTEIN high integrity systems Enable OS-Aware Timing Analysis Without Hardware-Based Trace

By combining TASKING's embedded development tools with WITTENSTEIN high integrity systems (WHIS)'s SAFERTOS®, engineering teams gain a complete, OS-aware toolchain for debugging, testing, and certifying safety-critical applications to IEC 61508, ISO 26262, DO-178C and other industry standards.

Engineers developing safety-critical embedded systems like these can now ensure the precise timing that is so critical for these applications thanks to a new integration between TASKING's compile, debug and test toolchain and WITTENSTIEN high integrity systems' SAFERTOS.

This announcement demonstrates a tighter integration between TASKING's high-performance embedded software development tools, and its unified toolchain, with WITTENSTEIN high integrity systems (WHIS)'s pre-certified safety real-time operating system SAFERTOS®. By using TASKING's embedded software trace tool (SWAT), developers can perform comprehensive OS-aware timing analysis without requiring dedicated on-chip hardware trace support.

In safety-critical embedded systems, precise timing is unquestionably critical. In a flight control system, for example, missing the response window by even a fraction of a millisecond can be the difference between a controlled manoeuvre and a loss of aircraft control. The TASKING and WHIS integration bridges this hardware gap to provide access to crucial timing data as well as to enable engineers to leverage TASKING's extensive range of debug and test tools to support and accelerate the development and verification of applications running on SAFERTOS.



Horizon Aircraft Secures LOI with V-Star Powered Lift Aviation for the Purchase of Up to 100 Hybrid eVTOLs For $600 Million



New Horizon Aircraft Ltd. ("Horizon Aircraft"), an advanced aerospace company developing one of the first hybrid-electric Vertical Take-off and Landing (VTOL) aircraft, has announced it has signed a Letter of Intent ("LOI") with V-Star Powered Lift Aviation Pty Ltd. ("V-Star"), an Australian-based aircraft operator specializing in advanced power-lift aircraft, to purchase 5 Cavorite X7 hybrid-electric VTOL aircraft with options to purchase up to an additional 95 aircraft. V-Star intends to secure the delivery slots for these 5 aircraft with a firm deposit upon execution of the definitive agreement.

V-Star provides innovative, cost-effective aviation solutions with particular expertise in critical emergency services. The addition of Cavorite X7s into V-Star's fleet will significantly reduce medevac response times and patient transfers, and search and rescue missions can be executed faster and more cost-efficiently.

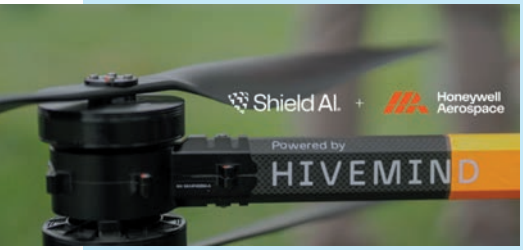
V-Star CEO Tony Laws commented, "Flying at nearly twice the speed of helicopters, the addition of Cavorite X7s to our fleet will be a critical advantage to help people in need when minutes matter. V-Star is committed to delivering leading powered-lift technologies across Australia to improve outcomes on critical missions, and this LOI with Horizon Aircraft brings us one step closer to a new standard for emergency services operations and cost-effective transport solutions in regional Australia."

Honeywell Aerospace and Shield AI collaborate to advance development of autonomous aircraft

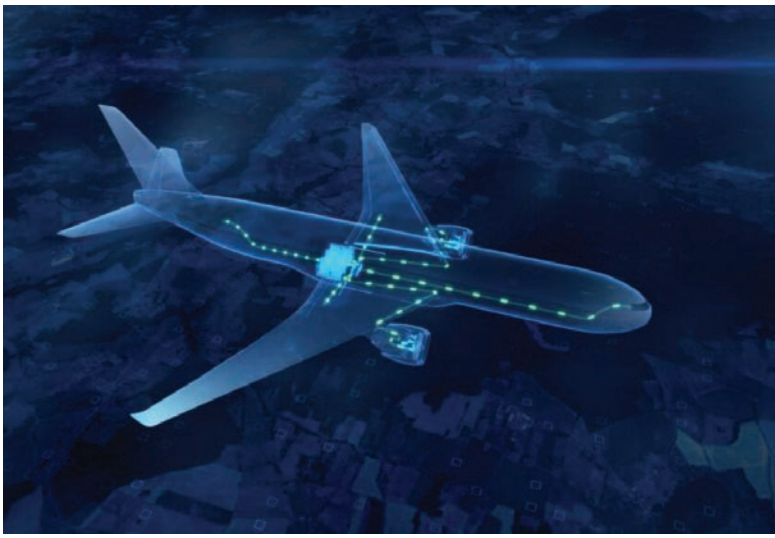
Honeywell Aerospace and Shield AI have announced a memorandum of understanding under which Honeywell Aerospace will develop a trusted autonomy software stack on Shield AI's Hivemind Software Development Kit, integrating Honeywell Aerospace's Anthem™ avionics, navigation, and sensing portfolio.

The collaboration aims to help defense operators move from demonstration to deployment faster across a wider range of operational environments, without having to rebuild confidence in each new system every time. In parallel, the companies will explore the architecture required to bring trusted, AI-piloted autonomy to commercial aviation and other transportation applications. Shield AI will also evaluate the use of Honeywell Aerospace's high-integrity, safety-critical products on its own uncrewed aircraft platforms.

The central challenge in mission autonomy is no longer whether software can fly an aircraft — it is whether that aircraft can be certified and trusted to fly without direct human control. Regulators, defense customers, and commercial operators each require confidence in the underlying system before it can be fielded. Closing that gap is the objective of this collaboration.



Airbus elevates hybrid-electric integration with LEIA Project



Airbus, with partners from across the European Union, the UK and the US, is pursuing its ambition to pioneer a hybrid-electric non-propulsive energy architecture for the next generation of commercial aircraft with LEIA – Large Scale Integration Demonstrator of Hybrid Electrical Architecture.

LEIA, a project supported by the European Union Clean Aviation Joint Undertaking, will be fundamental to advancing high-voltage generation and distribution for innovative electrical aircraft systems for short-to-medium range aircraft. By bridging the gap between component-level innovation and aircraft-level maturity, the project aims to prepare these technologies for future integration and certification.

LEIA builds on the successful completion of the SWITCH project, which focused on hybrid-electric powertrain subsystems and reached a key milestone in July when Collins Aerospace completed integrated laboratory testing. This achievement is a result of a strong collaborative effort by the project partners, including Pratt & Whitney, GKN Aerospace, and MTU Aero Engines.

These subsystems, which operate in tandem with simulated aircraft and engine systems, are now transitioning to the Airbus Sustainable Technology and Engineering Projects (STEP) laboratory in Ottobrun, Germany. There, Airbus teams will conduct critical aircraft-level integration testing, including design, battery interfacing and energy-management systems.

Curtiss-Wright Announces Plans For Advanced Surface Treatment Facility In Morocco To Meet Growing Aerospace Demand



Curtiss-Wright has announced a strategic expansion of its global footprint with plans for a new facility in Morocco.

The company is actively evaluating potential sites to support a new state-of-the-art surface treatment facility in this growing aerospace hub.

"Morocco has become a key growth location for premier aerospace manufacturers and their supply chain, and we are excited to provide critical surface treatment services to our valued customers", said Ray Lopuc, Senior Vice President and Division Lead, Curtiss-Wright Surface Technologies. "We expect the facility to be fully operational by mid-2027".

Connect your Operations with Onboard Intelligence

What if you could connect aircraft data and operational domains through a single platform, delivering actionable intelligence across your airline?

Teledyne GroundLink® Edge Computing Platform brings together aircraft data, applications, onboard processing, connectivity and cloud-based management, in one operator-controlled ecosystem, enabling better-informed decisions across the fleet.



GroundLink® ECP
Redefining the Aircraft Data Ecosystem.

Aerospace Electronics | Teledyne Controls
www.teledynecontrols.com/ecp

TELEDYNE



Air traffic control.
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How Air Traffic Modernization is Redefining Global Airspace

Modernization means more aircraft will fit into the same airspace safely.

Today's commercial aircraft are effectively flying supercomputers, thanks to their automated flight management systems, multi-constellation satellite receivers, and real-time diagnostic capabilities. Yet these advanced airframes are forced to fly within an antiquated air traffic management (ATM) system hobbled by voice-heavy radio procedures, overcrowded VHF frequencies, and rigid, legacy flight corridors.

This is why modernizing ATM has become a global priority, with digital technology driving much-needed change. "Digitisation means an aircraft is no longer flying in isolation; it can become an active, integrated participant in a broader, intelligent network," said Joel Klooster, Viasat's Senior Vice President of Aircraft Operations & Safety. "For a long time, satellite communications in aviation tended to focus on critical safety services, coverage maps, and bandwidth. Today, as ATM modernization gathers pace, the conversation is much more about operational value: how real-time data sharing can help pilots, airline operations centres, Air Navigation Service Providers, and engineering teams make better decisions together at scale, in real time."

A Fundamental Disconnect

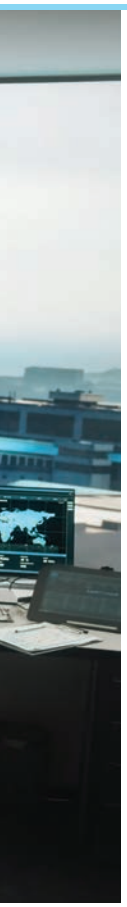
There is a fundamental disconnect in contemporary aviation between airborne capability and ground-based infrastructure. Modern flight systems continuously calculate hyper-efficient descent profiles and wind-optimized tracks, only to be ordered by ground controllers to expend fuel in holding patterns.

It doesn't help that the VHF radio channels being used for ATM are overcrowded and prone to interference and range limitations. "Terrestrial infrastructure is inadequate to handle the needs for reduced separation minimums and optimized flight levels," said John Peterson, Executive Director of Aviation Business Development at Iridium Communications. "Low-latency, high-availability L-band satellite communications with ADS [Automatic Dependent Surveillance] will be necessary to augment the limitations of ground infrastructure."

Then there's the operational bottleneck at the heart of ground-based air traffic management. Controllers working with legacy tools can only manage a finite volume of traffic before safety margins dictate holding patterns, vectoring delays, and inefficient cruising altitudes.

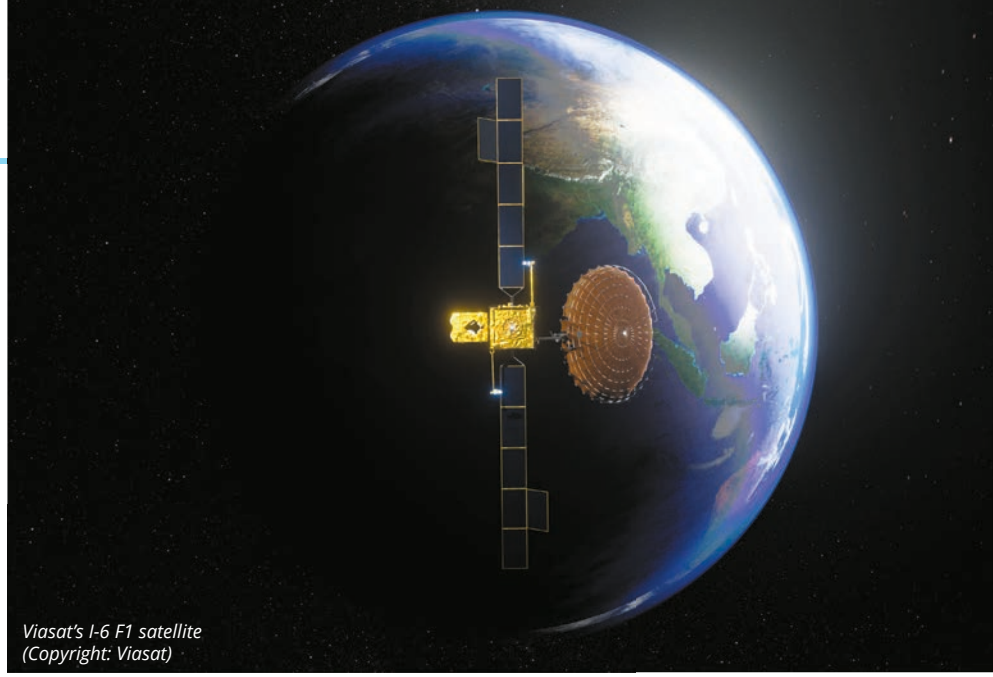
The solution to this problem is to expand effective airspace capacity without compromising strict safety margins associated with Communication, Navigation, and Surveillance (CNS) and Global Navigation Satellite System (GNSS) infrastructure. In a nutshell, ATM must be transformed from voice-based, reactive control towards automated, data-driven proactive trajectory management.

"Greater capacity does not come from simply reducing separation,"





Mark Watson (Copyright: EUROCAE)



Viasat's I-6 F1 satellite (Copyright: Viasat)

noted Brent Klavon, Chief Strategy Officer at ANRA Technologies. "It comes from increasing the precision, reliability, and predictability of the information on which separation decisions are based. Modern CNS combines highly accurate navigation, improved surveillance, digital communications, automation, and increasingly sophisticated trajectory prediction. That allows the system to use available airspace more efficiently while maintaining the required safety margins."

The SESAR 3 Catalyst

In Europe, the ATM transformation is being led by the Single European Sky ATM Research 3 initiative. Known as SESAR 3, this public-private partnership is working to replace fragmented legacy voice procedures with an automated, integrated digital ATM infrastructure across European airspace. To achieve this transition across airlines and Air Navigation Service Providers (ANSPs), the SESAR Deployment Manager is using regulatory frameworks such as Common Project One (CP1), while work advances toward a successor Common Project 2 (CP2), to coordinate and mandate specific modernization requirements.

"SESAR 3 is moving Europe from research toward increasingly operational digital ATM capabilities," said Klavon. "The important change is not one individual technology, but the transition toward a more connected, service-oriented, and trajectory-based airspace system."

This transformation is already delivering tangible results. For instance, SESAR 3's Iris program, which was developed with the European Space Agency, is using Viasat's enhanced SwiftBroadband Safety connectivity to create the digital systems needed for more accurate flight planning.

Of course, turning these research initiatives into certified operational tools requires input from industry groups, aviation regulators, and standards organizations such as EUROCAE (European Organisation for Civil Aviation Equipment), a non-profit organization that develops technical standards for civil aviation equipment, avionics, and ground systems.

"EUROCAE develops new standards or revises existing ones in support of the Single European Sky, with a view to accelerating the transition from development to deployment of SESAR solutions," said Mark Watson, EUROCAE's Technical Programme Manager. "As the research matures, it moves into the industrialisation phase, where EUROCAE and other standards bodies develop the industry standards, while EASA works on the corresponding regulations. From there, we enter the deployment phase."

A Hybrid Approach, For Safety's Sake

Using satellite communications for aviation is certainly addressing the coverage gaps associated with traditional ground-based VHF radio. Yet, despite the global reach of orbital satellite networks, some ANSPs are resisting a complete teardown of ground infrastructure. Their reluctance makes sense: the increased prevalence of electronic warfare—specifically GPS jamming and signal spoofing—has highlighted the danger of aviation relying exclusively on space-based navigation and communications. As a result, "the industry is placing greater emphasis on resilience and alternative sources of positioning and navigation because reliance on GNSS alone introduces vulnerabilities such as jamming and spoofing," said Klavon.

This is why advocates of ATM modernization are endorsing a hybrid approach to aviation communications. "Rather than satellite communications replacing terrestrial infrastructure, we see them coexisting as part of a multi-layered, resilient environment," Klooster told Aerospace Innovations.

The Living Flight Plan

Traditional flight planning is built around a filed route and a sequence of geographical waypoints. That route can certainly change in flight, but adjustments typically occur through a series of discrete clearances, tactical requests and controller interventions rather than through a continuously shared trajectory.

This limited flexibility is a primary driver of legacy air traffic management's overall inflexibility, which is why the industry is moving toward Trajectory-Based Operations (TBO).

TBO replaces connect-the-dots routing with a four-dimensional profile: latitude, longitude, altitude, and time. Using TBO, air traffic management can calculate where an aircraft will be at key points along its entire flight path. Systems leverage this data to predict and resolve traffic conflicts long before planes ever get near each other, utilizing airspace far



Advanced satcom solutions help airlines benefit from more efficient routing, improved situational awareness and enhanced safety services as air traffic management systems modernize.



A connected flight deck enhances situational awareness with real-time flight and weather information.

more efficiently and allowing more aircraft to fly safely at the same time.

Best of all, TBO flight plans adjust to reality rather than trying to force the reverse. In essence, TBO creates a living flight plan that allows pilots and air traffic controllers to respond to real-world conditions in real time.

"The primary hurdle with TBO is moving the industry towards a real-time, shared, and continuously updated 4D trajectory," said Klooster. "Rather than relying on a flight plan that is agreed before departure and then updated through a series of separate messages and interventions, TBO requires air-ground datalink capabilities and trajectory management tools. For TBO to work, everyone involved—pilots, controllers, dispatchers, and automated ground systems—needs to access the same trusted, up-to-date information."

Modern avionics leveraging advanced satellite networks support richer data communications and share real-time intent, fundamentally improving the predictability of aircraft performance. But TBO is not a single plug-and-play software update that can be purchased off the shelf.

"TBO is not one system, but a system of systems, and hence there is no single 'TBO standard,' but rather a stack of standards across CNS and ATM domains," Watson noted. He emphasized that TBO is enabled by four core capabilities working in tandem: trajectory sharing via standardized models like the Flight Information Exchange Model (FIXM), trajectory negotiation via data link, trajectory prediction accuracy via surveillance, and time-based execution through arrival management sequencing.

Furthermore, the technology's readiness is only half the battle. The actual deployment requires sweeping, synchronized, and highly expensive upgrades across an industry that is notoriously cautious regarding capital expenditure.

"TBO requires all stakeholders to implement new technology and transition together to a 4-dimensional flight trajectory," warned Eugène Tuinstra, Senior Aviation Consultant at To70 and co-chair of the CANSO ATFM/A-CDM working group. "In Europe, this transition has started. However, not all ANSPs and airlines are equipped. This transition requires time. Outside Europe, there are other factors that impact rollout and transition timelines."

Tearing Down Data Silos

Executing TBO trajectories on a global scale demands an architecture that can seamlessly share flight data across different airlines, airports, ground handlers, and national boundaries. Known as System Wide Information Management (SWIM), this architecture is becoming aviation's digital backbone, replacing legacy data silos with a common operating picture across the entire industry.

"SWIM is creating a digital information backbone for aviation," Klavon said. "Instead of operational data remaining within individual systems or organizations, authorized users can securely access standardized information such as flight plans, weather, aeronautical information, airspace constraints, and surveillance data. This common information environment improves situational awareness, supports more collaborative decision-making, and enables greater automation across the aviation ecosystem."

Beyond air traffic control, SWIM and continuous flight deck connectivity can deliver tangible benefits to airline operations centers. By streaming real-time diagnostic telemetry directly from aircraft engines and avionics to ground crews while airborne, engineering teams receive early warnings of technical issues long before touchdown. These alerts allow maintenance teams to stage replacement parts and technicians in advance, reducing costly Aircraft on Ground (AOG) delays and downrange disruptions.

The Federated Sky

As more and more aircraft operators enter the world's limited airspace, the need to establish standardized digital interfaces for air traffic management is literally an existential necessity. "When you look at industry forecasts from Valour Consultancy predicting over 5.6 million commercial drones and nearly 7,000 air taxis by 2050, it is clear our skies will become far more active," said Klooster.

To manage this massive influx of new airspace users, "the industry is

moving toward a federated model in which traditional ATM and highly automated digital traffic management services can interact rather than forcing every new aircraft into processes designed decades ago for conventional aviation," Klavon told Aerospace Innovations. "UTM [unmanned traffic management] and U-space services [the rules to run UTM in Europe] can manage functions such as flight intent, strategic conflict management, conformance monitoring, dynamic airspace information, and high-volume low-altitude operations, while exchanging relevant information with ATM."

Peterson stressed the need for autonomous platforms to be supported by satellite networks, so that they operate safely whenever ground infrastructure falls short. In response to this need, "ATM frameworks are evolving into more flexible, scalable architectures that accommodate new types of aircraft," he observed. "Dedicated UAS traffic management systems are being linked with traditional ATM, and clearer procedures are emerging for operations in controlled airspace."

AI and the Paradox of Trust

As data volumes from connected aircraft and drones keep increasing, artificial intelligence (AI) is stepping in to assist human controllers. However, the aviation industry is navigating a stark contradiction: it is building a digital sky increasingly dependent on automation while aviation regulators still demand extraordinarily high levels of human oversight, explainability, assurance and accountability.

This being the case, "AI will increasingly function as a decision-support capability before it becomes a decision-making authority," said Klavon. "Near-term applications include better trajectory prediction, demand and capacity forecasting, anomaly detection, weather-impact assessment, and identification of potential conflicts earlier in the planning process. However, aviation will require these systems to be explainable, validated, secure, and designed around appropriate human oversight. Trust and assurance will be just as important as algorithmic performance."

Klooster stressed that the ultimate accuracy of any AI decision-support tool is fundamentally linked to the data feeding it. In computer programming parlance, this is known as "garbage in, garbage out."

"A key requirement is data quality and reliability, as any AI tool depends entirely on the accuracy of the data feeding it," he said. "High-integrity, continuous flight deck connectivity from services like SB-S and the Iris programme supplies the live, trustworthy operational data feed that these predictive AI engines require."

This stringent requirement for data integrity is dictating the pace of international standardization. In Europe, "EUROCAE WG-114 is preparing technical standards, guides, and any other material required to support the development of systems and the certification of aeronautical systems implementing AI technologies," said Watson.

Sustainability and Cyber Risks

Besides using digital tools and predictive algorithms to optimize flight trajectories, "ATM modernization can produce significant environmental benefits without requiring changes to the aircraft itself," said Klavon. "More direct routing, improved trajectory planning, continuous climb and descent operations, and better demand and capacity management can reduce unnecessary track miles, holding, vectoring, and fuel burn for conventional aviation. The greatest opportunity comes from managing the complete trajectory rather than optimizing isolated portions of a flight."

"While the industry works on long-term developments like sustainable aviation fuel, making daily flight operations more efficient is the most practical way to reduce carbon emissions right now," Klooster agreed. "Connected flight decks unlock those savings by sharing real-time weather for better routing, enabling smoother climb and descent profiles, and keeping aircraft from burning fuel in unnecessary holding patterns. When multiplied across a large number of daily flights, those operational efficiency gains translate into meaningful environmental benefits."

At the same time, all this



connectivity will prove to be a tempting target for hackers. This is why a redundant, hybrid ground/orbital approach to communications would be wise, with redundancy and verification built in at multiple levels to reduce the odds of hacker success.

As well, cybersecurity in this new ATM environment must encompass all aspects of the aviation ecosystem, and do so in a deliberate and prioritized manner.

"Cybersecurity has to be built into ATM modernization from the outset through strong authentication, encryption, secure software development, continuous monitoring, and resilient system architectures," warned Klavon. "As ATM becomes more interoperable, every participant, not just air navigation service providers, must elevate its cybersecurity posture. Airlines, airports, UTM and U-space service providers, and technology providers all contribute to a shared digital ecosystem, making cyber resilience a collective responsibility."

A Change Will Come

Achieving a fully synchronized global airspace is a complex, multi-decade effort hampered by fragmented bureaucracies, differing political mandates, and legacy equipment footprints.

"The terminology, regulatory structures, deployment schedules, and evolving regulations differ, but Europe and North America are broadly moving toward the same operational principles," Klavon said. "ICAO and international standards organizations are critical because aircraft operate globally. A digitally connected aircraft should not require fundamentally different information exchange concepts every time it crosses an international boundary."

Providing a global solution to this ATM problem requires an unprecedented level of international cooperation, at a time when much of the world is not playing well with each other.

"When we talk about worldwide interoperability and global harmonisation, one thing becomes clear: we can't achieve it alone," said Watson. "EUROCAE works closely with RTCA, SAE, and many other standards organisations, and we coordinate closely with ICAO and the regulators."

The good news: Global aviation institutions are attempting to guide this transition through standardized roadmaps, such as the ICAO Global Air Navigation Plan (GANP) and the Complete Air Traffic System (CATS) Roadmap initiated by CANSO. And, for all the talk of rapid digitization, the actual timeline for a seamless global sky is painstakingly slow. For instance, ICAO's transition strategy envisages global cessation of the current ICAO 2012 flight-plan format in 2034, effectively making the transition to FF-ICE (Flight and Flow Information for a Collaborative Environment) a worldwide project.

Unfortunately, given the fragmented political and economic situation of nations on this planet, 2034 is probably a sensible goal—if not downright optimistic. "A realistic timeline for broader global implementation will extend through the next decade, and early progress depends heavily on communication systems that keep aircraft connected everywhere they fly," said Peterson. "The main challenges involve aligning different regional timelines, modernizing legacy systems, and ensuring operators can maintain uninterrupted access to the operational data these technologies require."

For all of these difficulties, the undeniable advantages of ATM modernization and the pressure being exerted by growing aviation traffic mean that this change will come, one way or another. Simply put, it has to.

"The digital transformation of ATM is no longer a future concept," Klooster concluded. "It is essential for the future growth, safety, and sustainability of global aviation."

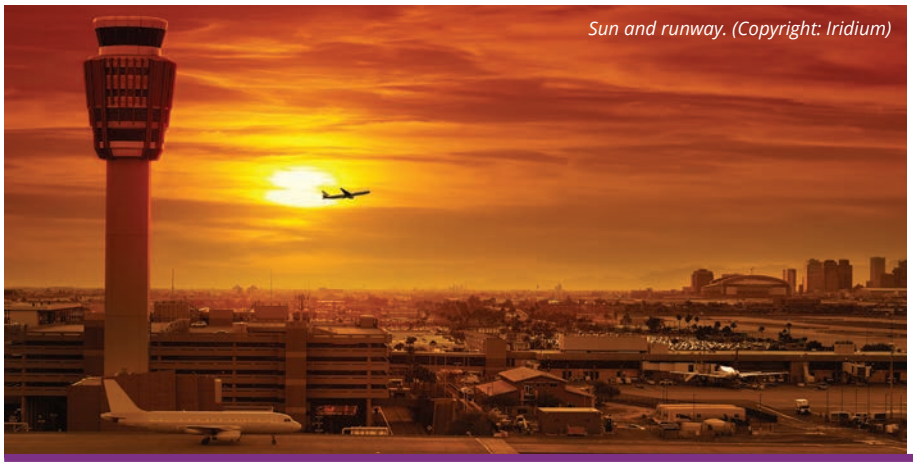
By James Careless



Joel Klooster, Viasat

"The digital transformation of ATM is no longer a future concept," Klooster concluded. "It is essential for the future growth, safety, and sustainability of global aviation."

Joel Klooster, Viasat



Sun and runway. (Copyright: Iridium)

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Before the Sky Becomes the Footpath: The Missing Civic Layer in Advanced Air Mobility

The Drone and Advanced Air Mobility Industry is rapidly solving certification, detect-and-avoid, digital traffic management and the interfaces with conventional ATM. But if the forecasts materialise, the harder question may be whether cities can live underneath it.

There is an interesting lesson for aviation currently lying on footpaths across London, Sydney, Melbourne, Adelaide, Brisbane and probably a city near you.

The 15-minute city, and its less ambitious 30-minute cousin, are built around an attractive idea: organise communities so everyday needs can be reached without dependence on a private car. Walking, cycling and micromobility fit naturally into that vision, and the electrically assisted bicycle ought to be almost the perfect technology for it.

Then reality intervened.

By late 2024, around 40,000 dockless e-bikes were operating across 22 London boroughs. Yet Transport for London and the boroughs lacked adequate powers to manage the schemes. Poorly parked bikes blocked footpaths and impaired accessibility, leaving government seeking stronger statutory powers after the operating model had already spread.

It's raised to a dangerous level in Australia with "ride-outs" by uncontrolled youth blocking major thoroughfares like the iconic Sydney Harbour Bridge. But the e-bike did not fail.

The governance model (or lack of one) arrived after the technology.

Aviation should pay attention, because drones and Advanced Air Mobility could repeat that sequence several hundred feet higher and at a scale that makes abandoned bicycles or disruptive ride-outs look quaint.

Scale changes everything

For much of the past decade, drones and AAM have inhabited the comfortable world of demonstrations, trials and individually approved operations. A handful of demonstration flights is manageable. A few hundred movements every day over the same neighbourhood are something else entirely.

Airservices Australia, Australia's ANSP, forecasts annual drone flights increasing from around 1.5 million in 2023 to 60.4 million by 2043. Britain's Civil Aviation Authority has cited a forecast of 321 eVTOLs operating 1.1 million UK flights annually by 2030, increasing to 6,500 aircraft and 58.8 million flights a year across the UK's 18 largest cities by 2050.

The studies use different assumptions, but the order of magnitude matters. The industry is discussing millions and tens of millions of movements.

For comparison, the six principal London-area airports recorded 1,154,473 aircraft movements in 2025. Sydney Kingsford Smith recorded 321,916 movements in the 2025 financial year and nearby Bankstown another 218,046. Even allowing for the differences between conventional aircraft movements and short-duration drone flights, the contrast is sobering. These numbers also exposes a weakness in one of the industry's favourite words: integration.

The dangerous comfort of "integration"

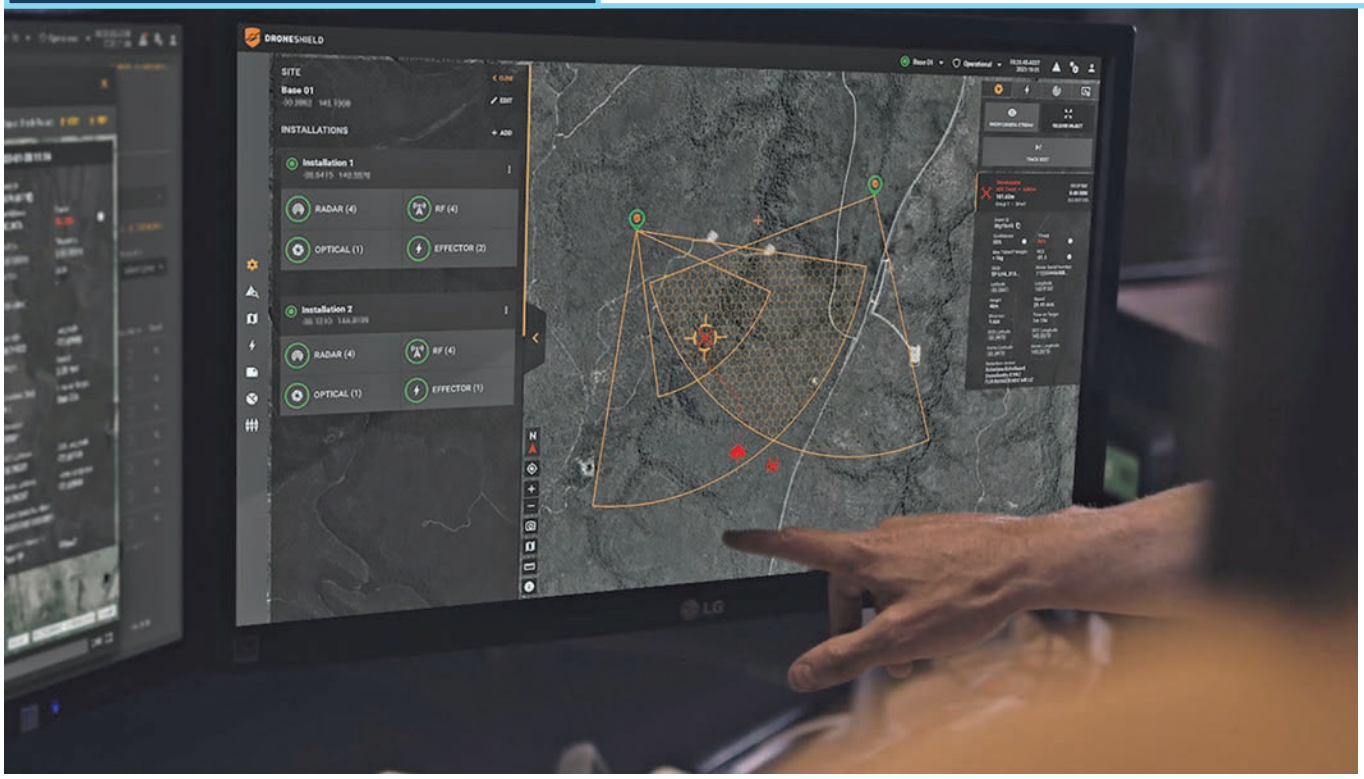
Almost every AAM strategy promises integration. Drones will be integrated into airspace. eVTOLs will be integrated with conventional traffic. UTM will integrate with ATM.

It sounds reassuring, but the word has become elastic enough to hide very different concepts.

In conventional terminology, integrated airspace concerns the ability of different users to coexist and interact safely within the wider aviation system. That remains essential. An AAM aircraft approaching a major airport, a drone crossing controlled airspace, or an emergency UAS operation may need interfaces with conventional ATS and crewed aviation.

That is not the same thing as trying to absorb millions of routine low-level drone and AAM movements into conventional ATM.

Here, fully managed sky means something different: the drone/AAM operating environment itself a digitally managed ecosystem in which legitimate operations are known,

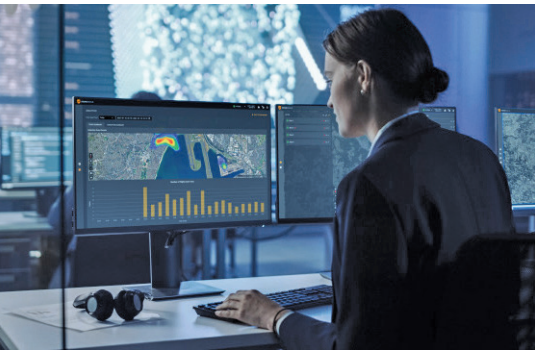


authorised, strategically deconflicted and monitored against declared intent.

A fully managed sky should not be confused with integrated airspace. They touch one another, but they are not synonyms.

The points where the two environments meet may be comparatively few: an AAM aircraft transitioning into terminal airspace, a UAS corridor intersecting a conventional route, an emergency operation receiving priority, or a conventional aircraft entering the low-altitude environment unexpectedly. Those interfaces need rigorous standards and information exchange. They do not require every suburban delivery flight to become another movement for ATC to tactically separate.

The challenge is managed interoperability, not universal tactical mixing.



The distinction leads to what may be the most important architectural proposition in the whole debate:

We do not need to integrate millions of drone and AAM movements into conventional ATM. We need to manage them within their own scalable operating architecture, and integrate that architecture with conventional ATM wherever the two need to interact.

Manage intent, not encounters

Conventional aviation has already spent years developing the intellectual logic required.

Trajectory Based Operations moves ATM away from an overwhelmingly tactical model towards one in which the intended four-dimensional trajectory — latitude, longitude, altitude and time — becomes a common organising object.

Know the intent. Share the intent. Identify conflicts early. Resolve as much as possible strategically. Intervene tactically when reality departs from the plan.

If two drone trajectories occupy the same volume at the same time and that conflict is visible twenty minutes beforehand, perhaps one departure moves by thirty seconds. If both aircraft are allowed to continue until their onboard systems must evade, the network has consumed far more safety margin, energy, airspace and uncertainty to solve a problem already visible in the data.

DAA cannot become air traffic control by another name

Detect-and-Avoid is indispensable, but it needs to occupy the correct place in the architecture.

DAA enables an aircraft, or supporting system, to detect traffic or hazards and take action to remain clear or avoid collision. It is critical to BVLOS operations and particularly valuable where unexpected traffic enters the operating environment.

But tactical DAA cannot become the normal mechanism by which a mature high-density network organises itself.

Strategic deconfliction exists to arrange operational intent — trajectories, volumes, routes or time assignments — so conflicts are unlikely to arise. Tactical deconfliction is what is required when the strategic layer fails, degrades or is overtaken by events.

Every tactical manoeuvre also creates a new trajectory, potentially creating another conflict. At high density, a network depending principally on reactive avoidance risks becoming less like a transport system and more like an exceptionally sophisticated flock of startled birds.



DAA is the safety net for uncertainty, non-conformance and the unforeseen.

If routine DAA manoeuvring is what keeps a high-density urban network apart, the traffic-management system has failed.

A different CNS/ATM architecture

This is why UAS Traffic Management should not simply be described as "ATC for drones".

The emerging model is more digital, distributed and automated. Europe's U-space already requires services including flight authorisation, geo-awareness, network identification and traffic information. Australia's Airservices is developing its Flight Information Management System, or FIMS, through approved UAS Service Suppliers.

Communications will be predominantly machine-to-machine. Navigation will depend heavily on assured positioning and trajectory conformance. Surveillance will combine cooperative and non-cooperative sources. Traffic management will have to be highly automated because humans cannot tactically control millions of movements.

ADS-B illustrates the problem of simply extending conventional technologies. It transformed cooperative surveillance, but that does not mean every small drone can simply be added to the same architecture. Remote ID reflects the need for identification mechanisms designed for far denser populations.

Knowing an aircraft exists is surveillance.

Knowing who it is, is identification.

Knowing where it intends to be is trajectory information.

Ensuring another aircraft has not been planned through the same place at the same time is traffic management.

Avoiding it at close range when something has gone wrong is DAA.

The security dividend of a fully managed sky

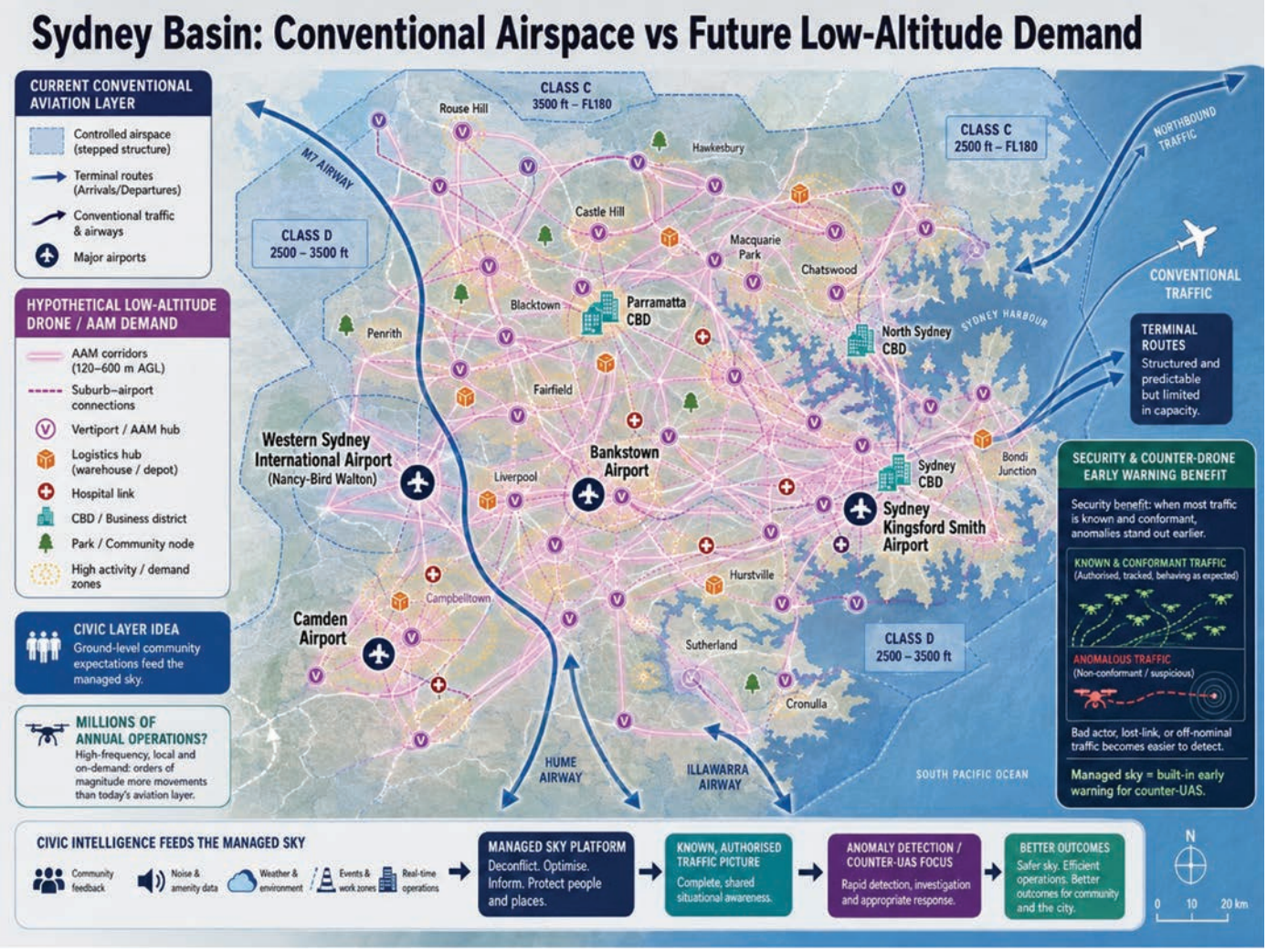
A fully managed drone/AAM sky can also reduce security risk, not because it eliminates bad actors, but because it shrinks the unknown.

A mature low-altitude environment will contain navigation errors, lost links, technical failures, unauthorised operations and, inevitably, aircraft used for nefarious purposes. Counter-UAS therefore has to determine what an observed aircraft is, whether it should be there and whether intervention is justified.

This is where the managed-sky concept overlaps with the counter-drone layer.

Andrew Kell, Product Manager at DroneShield, sees value in the additional context a managed sky could provide. As drone and AAM activity increases, he says, "having greater situational awareness across the air domain will be increasingly important". A managed-sky environment in which legitimate aircraft are known, authorised and operating as expected can provide context around what should be in the air and where.

If the great bulk of legitimate traffic is already known, authorised and knowingly conformant to declared intent, the unusual aircraft becomes more conspicuous. An aircraft



appearing where no operation is expected matters. So does an authorised aircraft materially departing from its trajectory.

The managed sky has not proved malicious intent, and it does not replace radar, RF detection, electro-optical sensing or specialist counter-UAS systems. But nor should non-conformance automatically be treated as hostile.

DroneShield is clear on that point. Kell notes that "malicious, unauthorised or otherwise nefarious drones are unlikely to rely on cooperative identification systems." In high-risk environments, operators cannot assume every aircraft will identify itself or comply with established rules. Independent detection and tracking therefore remain essential.

That qualification strengthens the managed-sky argument.

The value lies in combining a trusted picture of cooperative, authorised activity with independent detection of everything else. Kell describes the likely future as a layered approach covering cooperative and non-cooperative detections to provide a "unified and holistic airspace overview".

In effect, the counter-drone layer gains a built-in early-warning advantage. Instead of beginning with a sky full of unexplained objects, security systems can correlate detections against a picture of what should be there and how authorised traffic should behave.

Kell puts the objective neatly: counter-UAS operators need to understand "what is normal, expected and authorised within a particular environment." Information from managed-sky platforms can contribute to that understanding, while counter-UAS provides an independent layer of detection and assessment.

The key enabler is interoperability. Where systems can securely share accurate and timely information, Kell argues, security personnel can focus more effectively on genuinely anomalous or unauthorised activity.

So the relationship is not substitution. Done properly, the two systems are complementary. At sufficient maturity, the fully managed sky becomes part of the security architecture itself.

But even that leaves one crucial question unanswered.

Safe is not the same as acceptable

Suppose all of this works.

We know what the aircraft is, where it is going, that it has been strategically deconflicted, that it is conforming, and perhaps that it is legitimate and benign.

There remains another question:

Should that trajectory be there in the first place?

Not from an airworthiness, collision-risk or security perspective but from the perspective of the people underneath it.

Governments and industry have been talking about social licence for years. The Metrops white paper, Cities as the Missing Layer, identifies the structural problem: aviation safety and airspace are regulated nationally, while the impacts people experience; noise, privacy, visual amenity, time of day and compatibility with local land use, occur on the ground and are inherently local.

Recognition has been abundant.

Operational machinery has not.

Texas is beginning to demonstrate the consequence. Amazon Prime Air commenced drone delivery operations from Richardson in the Dallas metropolitan area in December 2025. Residents from Richardson, Garland and Plano have since organised through Quiet Skies TX to protest and agitate against repeated noise, privacy and neighbourhood overflight.

The aviation authority regulates the aircraft and airspace. The operator flies the mission. But Local government is left to deal with land use and the consequences of unhappy and annoyed residents.

Noise does not respect municipal boundaries. Nor does privacy, or visual amenity. Or public tolerance.

The aircraft may be safe, secure, authorised and conformant — and still be profoundly unwelcome.

The missing civic layer

This is the gap Metrops' Argon was created to address.

Its proposition is not that councils should manage airspace. They should not. National regulators, ANSPs, UTM providers and operators should continue performing aviation functions.

Local government has a different role.

Metrops describes Argon as a civic layer through which councils define two-dimensional ground-level expectation zones: what people in a residential precinct, industrial area, school zone, hospital district, park or other place can reasonably expect in relation to noise, privacy, amenity and time of day. Those expectations can then become machine-readable rules for the traffic-management layer.

Argon does not plan trajectories or separate aircraft. It supplies local rules to the systems that do those jobs and provides a mechanism for monitoring whether what communities were told to expect is what they actually experienced.

The conceptual key is that impact is judged where it is felt, not merely where the aircraft flew.

A drone may remain over industrial land while its acoustic footprint reaches nearby homes. From an airspace perspective it may have complied perfectly. From a civic perspective a residential expectation may nevertheless have been breached.

That suggests another extension of trajectory management.

The future trajectory must not be assessed only against weather, capacity, airspace and other trajectories. It must also be assessed against structured information describing the reasonable expectations of communities beneath it.

The loop becomes:

community expectation **>** machine-readable constraint **>** trajectory planning **>** strategic deconfliction **>** operation **>** conformance monitoring **>** experienced impact **>** evidence **>** refined expectation.

Design the system while the map is still blank

There is a tendency in emerging aviation to postpone these questions until certification, regulation and economics are settled.

But that may be precisely backwards.

Once distribution centres are built, vertiports established, routes optimised and customers accustomed to a service, changing the pattern becomes expensive. Operators have capital invested. Residents have grievances. Governments have political ownership of decisions already made.

Setting expectations beforehand is cheaper. The Metrops white paper makes the same point: expectation-setting while operating patterns are still soft is easier than attempting to unwind them after they become established.

That's the lesson from micromobility. E-bikes were not the mistake. Allowing the operating model to mature faster than the governance around it was.

AAM is still early enough to avoid repeating that error.

TBO teaches us to manage intent rather than wait for conflict. UTM and U-space provide the basis for scalable digital management. DAA protects against the tactical and unforeseen. Remote ID, ADS-B and other surveillance technologies contribute identification and situational awareness. Counter-UAS focuses on the aircraft that does not fit the expected picture.

The fully managed drone/AAM sky connects those layers.

Conventional ATM remains alongside it, with deliberate interfaces wherever the two operating environments need to interact.

And Metrops adds the information none of those aviation systems inherently possesses: what the people underneath consider reasonable.

Safe is not the same as secure.

Secure is not the same as acceptable.

A mature AAM ecosystem has to manage all three.

Metrops reduces the civic part of that argument to six words:

Airspace is federal. The noise isn't.

The industry still has time to design that principle into the system rather than discover it through public backlash later.

Because the hardest constraint on mass low-altitude aviation may not be whether millions of aircraft can fly safely.

It may be whether millions of people still want them there.

By Michael Bryan

Guarding the Digital Gateway:

How Aircraft Interface Devices are Reshaping EFB Data Governance

As aviation has increasingly embraced digital technology, Aircraft Interface Devices (AIDs) have evolved from simple hardware adapters into central avionics hubs. Today, AIDs are serving as the digital bridge between certified aircraft systems—such as Flight Management Systems (FMS) and ARINC data buses—and commercial-off-the-shelf Electronic Flight Bags (EFBs) or personal devices (bring your own devices, aka BYOD). In this role, AIDs feed real-time positional, atmospheric, and operational data directly to flight crews. They also provide moving-map displays, automated flight logging, and dynamic performance calculators, with their future capabilities pointing toward onboard edge computing (processing data locally on the aircraft) and real-time air-to-ground synchronization.

The growing capabilities of AIDs come with significant engineering and operational challenges. Connecting commercial mobile hardware to safety-critical avionics can lead to complex cybersecurity issues, requiring strict domain isolation and defense-in-depth protocols. Operators also face steep integration challenges when retrofitting legacy fleets that were never designed for IP-based networks, as well as compatibility issues caused by proprietary software interfaces and vendor lock-in. Additionally, as data volumes explode, the aviation industry's primary concern has shifted from physical connectivity to data governance—ensuring that every bit of data interacting with the cockpit is secure, authorized, and operationally sound.

To explore how aircraft operators can navigate these complex technical, regulatory, and security challenges, Aerospace Innovation spoke with Klaus Olsen, CEO and EFB Administrator at EFB Admin Services Int. AS. With more than two decades of operational experience in aviation technology, Olsen provides independent assistance to ensure that airline programs remain audit-ready, and supports operators across major global frameworks including EASA and the FAA.



Klaus Olsen, CEO and EFB Administrator, EFB Admin Services Int. AS

Aerospace Innovations: Please begin by telling us about your company's work on interfacing EFBs and other BYODs with aircraft interface devices (AIDs).

Klaus Olsen: EFB Admin Services supports airlines with the implementation, regulatory approval and continuing operation of Electronic Flight Bag programs. Our work includes portable and installed EFB solutions, operational evaluations, safety risk assessments, EFB policies and procedures, application governance, mobile device management, cybersecurity, training and coordination between operators, avionics suppliers, software vendors and aviation authorities.





Illustration: EFB Admin Services Int. AS

Aircraft data securely delivered through an Aircraft Interface Device (AID) to the Electronic Flight Bag (EFB), providing authorised applications with trusted real-time information.

We do not manufacture Aircraft Interface Devices. Our role is to help operators ensure that the complete end-to-end interface between the aircraft, the AID, the EFB hardware and the EFB applications is operationally suitable, secure, supportable and correctly documented.

This distinction is important. An AID may be technically capable of delivering aircraft data to an EFB, but the operator must still determine which applications are authorized to receive that data, how it may be used, what happens when it is unavailable or incorrect, and how configuration changes are controlled throughout the operational lifecycle.

The industry has largely solved the problem of connecting systems. The next challenge is governing the information that flows between them.

Aerospace Innovations: What is the current state-of-the-art in AIDs these days, in terms of the devices they can connect to aircraft systems and the degree of information swapping they can support?

Klaus Olsen: The state-of-the-art has moved well beyond the AID being a simple one-way data converter.

Modern AIDs can interface with multiple aircraft data sources, including ARINC 429, ARINC 717, discrete signals, serial data, avionics Ethernet and, depending on the aircraft architecture, higher bandwidth IP based networks. They can then securely distribute selected data to installed systems, airline controlled tablets, portable EFBs, maintenance devices and, in some cases, ground systems through cellular or satellite connectivity.

Typical data delivered to EFB applications include aircraft position, altitude, heading, groundspeed, airspeed, wind, outside-air temperature, fuel information, weight and balance data, flight phase, engine parameters and selected FMS information.

The most important development, however, is not simply the amount of available data. It is the ability to manage data according to its source, integrity, latency, authorized destination and intended operational use.

Aerospace Innovations: Are these data exchanges fully bidirectional, or are they restricted for safety reasons?

Klaus Olsen: Most portable EFB integrations remain predominantly aircraft-to-EFB rather than genuinely bidirectional. That is deliberate. Sending information from a portable or commercially developed device back into safety-critical aircraft systems creates a very different certification and cybersecurity exposure. Bidirectional exchange is possible in controlled architectures, but it requires strong separation, validation and explicit system authority.

FAA guidance distinguishes between operational EFB applications and aircraft-installed equipment and directs installation-related connectivity considerations to the applicable airworthiness approval process.

Aerospace Innovations: As AIDs become the central hub connecting core aircraft systems to Electronic Flight Bags (EFBs), how are you ensuring these data transfers remain entirely secure from external cyber threats?

Klaus Olsen: I would be cautious about describing any connected system as “entirely secure.” The appropriate objective is to reduce risk to an acceptable level, maintain

defense in depth and ensure that a compromise of an external device cannot propagate into safety-critical aircraft domains.

The fundamental controls should include strict segregation between aircraft control domains, airline information systems, and passenger or public networks; controlled and preferably one-way data flows where bidirectional communication is not operationally necessary; and the allow-listing of permitted data, applications, devices, and services.

Operators must also ensure authenticated and encrypted communications, implement certificate and cryptographic-key lifecycle management, and utilize secure boot alongside signed software and controlled firmware updates. Further measures require restricted physical and maintenance access, active network monitoring with event logging and anomaly detection, and comprehensive vulnerability management and continuing-airworthiness processes. Finally, these controls must include tightly managed EFB devices using mobile device management and application controls.

Aerospace Innovations: So once the AID has been certified and the AID has been installed, the operator is off the hook?

Klaus Olsen: No. The operator's responsibility does not end when the AID is certified and installed. Security assumptions made during aircraft certification must remain valid in service. That means controlling the EFB operating-system version, application versions, device enrollment, certificates, connectivity profiles and supplier changes.

It also requires cooperation between the aircraft design approval holder, AID manufacturer, application provider, EFB Administrator, IT security function, maintenance organization and flight operations department. Cybersecurity is a shared lifecycle responsibility, not a feature that can be assigned to one piece of equipment.

Current airworthiness-security practice is structured around standards including RTCA DO-326/ED-202, DO-356/ED-203 and DO-355/ED-204. EASA AMC 20-42 specifically addresses the identification of assets, attack paths, safety consequences, mitigations, residual risk and continued protection after entry into service.

Aerospace Innovations: What specific data points from the Flight Management System (FMS) are pilots demanding most on their EFBs today, and how do AIDs facilitate that real-time translation?

Klaus Olsen: The greatest demand is for data that removes repetitive manual entry and improves



Illustration: EFB Admin Services Int. AS

The emerging connected EFB ecosystem. Aircraft Interface Devices provide a secure bridge between aircraft systems and the EFB environment, while interoperability standards such as ARINC 840A have the potential to enable more efficient data exchange between authorised EFB applications.

As aircraft systems, AIDs and EFB applications become increasingly interconnected, the EFB Administrator's role is evolving towards that of a "Guardian of Trust", ensuring that information remains accurate, secure, authorised and operationally appropriate throughout its lifecycle.



Illustration: EFB Admin Services Int. AS

situational awareness without introducing ambiguity.

Depending on the aircraft type, application, and approved interface, the most commonly requested data from the FMS and associated aircraft systems include present position, track, heading, altitude, and groundspeed; active flight-plan information and route progression; as well as origin, destination, and alternate information. Pilots also frequently require estimated times, distance-to-go, and fuel predictions; aircraft gross weight and fuel-on-board information; alongside wind and temperature data. Lastly, demand is high for departure and arrival runway information, and aircraft state or flight-phase information.

These data can support moving-map applications, airport situational awareness, chart positioning, weather applications, turbulence reporting, flight-log automation, electronic operational flight plans and performance-related workflows.

Aerospace Innovations: Beyond simply converting the physical protocols, what role does the AID play in managing this data?

Klaus Olsen: The AID performs more than physical protocol conversion. It may need to acquire data from different avionics buses, identify and validate the relevant parameters, apply scaling and engineering-unit conversion, timestamp the information, filter it according to the approved data set and make it available through a controlled interface that the EFB application can understand.

Pilots naturally want increasing levels of automation, but the operational question must always be: What is the source and integrity of the data, how current is it, and what may the pilot safely use it for? Automatically populating an advisory application is very different from permitting that application to influence a certified aircraft function.

Aerospace Innovations: What are the primary installation and integration challenges when retrofitting older fleets with modern Aircraft Interface Devices compared to forward-fitting them on next-generation aircraft?

Klaus Olsen: Retrofitting is significantly more complex because the aircraft was not originally designed around a connected digital ecosystem.

Common challenges include limited access to suitable avionics data sources, older ARINC 429 or analog architectures with limited bandwidth, and incomplete or aircraft-specific interface documentation. Integrators also face differences between individual aircraft within the same fleet, restricted space, cooling capacity, electrical power, and wiring routes, alongside electromagnetic compatibility and environmental qualification requirements.

Additional hurdles involve antenna placement and wireless-coverage limitations, certification through an STC or approved design change, and the creation of maintenance access and continuing-airworthiness documentation. Finally, there is a critical need to avoid unintended effects on existing certified systems.

Mixed fleets are particularly demanding. An airline may operate several variants of the same aircraft type with different avionics standards, software loads and modification statuses. A solution that appears common at application level may therefore require different installation designs and data mappings on each subfleet.

Forward-fit installations allow segregation, processing capacity, connectivity, power, cooling and future growth to be incorporated into the aircraft architecture from the



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beginning. Retrofit programs must find safe ways to introduce those capabilities into an established design, usually with tighter physical, technical and commercial constraints.

FAA AC 20-173 addresses certification considerations for installing EFB components and aircraft-connectivity provisions, while EASA's security guidance also applies to supplemental type certificates and changes to existing products.

Aerospace Innovations: With the sheer volume of data generated by modern aircraft increasing exponentially, how is the architecture of Aircraft Interface Devices evolving to handle future bandwidth and processing requirements?

Klaus Olsen: The architecture is evolving from dedicated interface boxes towards secure edge-computing platforms.

Rather than simply forwarding every available parameter, future AIDs will increasingly need to aggregate, normalize, filter and prioritize data onboard. They may perform local processing, event detection, compression and secure buffering before delivering selected information to the EFB or transmitting it to the ground.

We are also seeing a gradual transition from point-to-point interfaces towards IP-based architectures, modular software services and publish-and-subscribe data distribution. This allows multiple authorized applications to consume standardized information without each application requiring a separate physical aircraft interface.

Aerospace Innovations: As AIDs take on more processing power, how do you prevent them from becoming a vulnerable bottleneck?

Klaus Olsen: Increased processing capability must not result in an uncontrolled concentration of functions. The AID's role, software configuration, data rights and security boundaries must remain clearly defined. Otherwise, the central hub can become both a performance bottleneck and a high-value cyber target.

Future architectures will therefore need scalability together with partitioning, data governance, deterministic behavior where required, remote health monitoring and an effective mechanism for maintaining security throughout a much longer aircraft lifecycle than that of the connected consumer devices.

Another important trend is that connectivity no longer ends at the AID. Once aircraft data reaches the EFB environment, airlines increasingly expect multiple authorized applications to consume the same trusted data without requiring separate proprietary integration for every combination of applications and software vendors. This is where emerging interoperability standards such as ARINC 840A have the potential to play an important role. By providing a common framework for application-to-application data exchange within the EFB environment, they can reduce integration complexity while



supporting appropriate governance and security controls.

Aerospace Innovations: What pain points remain between external devices, AIDs, and aircraft systems?

Klaus Olsen: One of the largest remaining pain points is fragmentation.

Aircraft manufacturers, AID suppliers and EFB application vendors may use different interfaces, data definitions and proprietary software development kits. The same parameter may be represented differently across aircraft types or may not be available with the same integrity, update rate or metadata.

Other recurring issues include limited transparency concerning which aircraft parameters are genuinely available, inconsistent documentation and data dictionaries, and proprietary interfaces leading to supplier lock-in. Operators also struggle with application updates that unintentionally affect compatibility, unclear responsibility when several suppliers are involved, and complex certificate, key, and software-lifecycle management. Lastly, the industry faces long aircraft certification cycles compared with rapid mobile-device development, difficulty reproducing aircraft data environments during testing, and insufficient end-to-end monitoring of the complete data chain.

Aerospace Innovations: What can be done to relieve these pain points?

Klaus Olsen: The solution is greater interoperability, but interoperability

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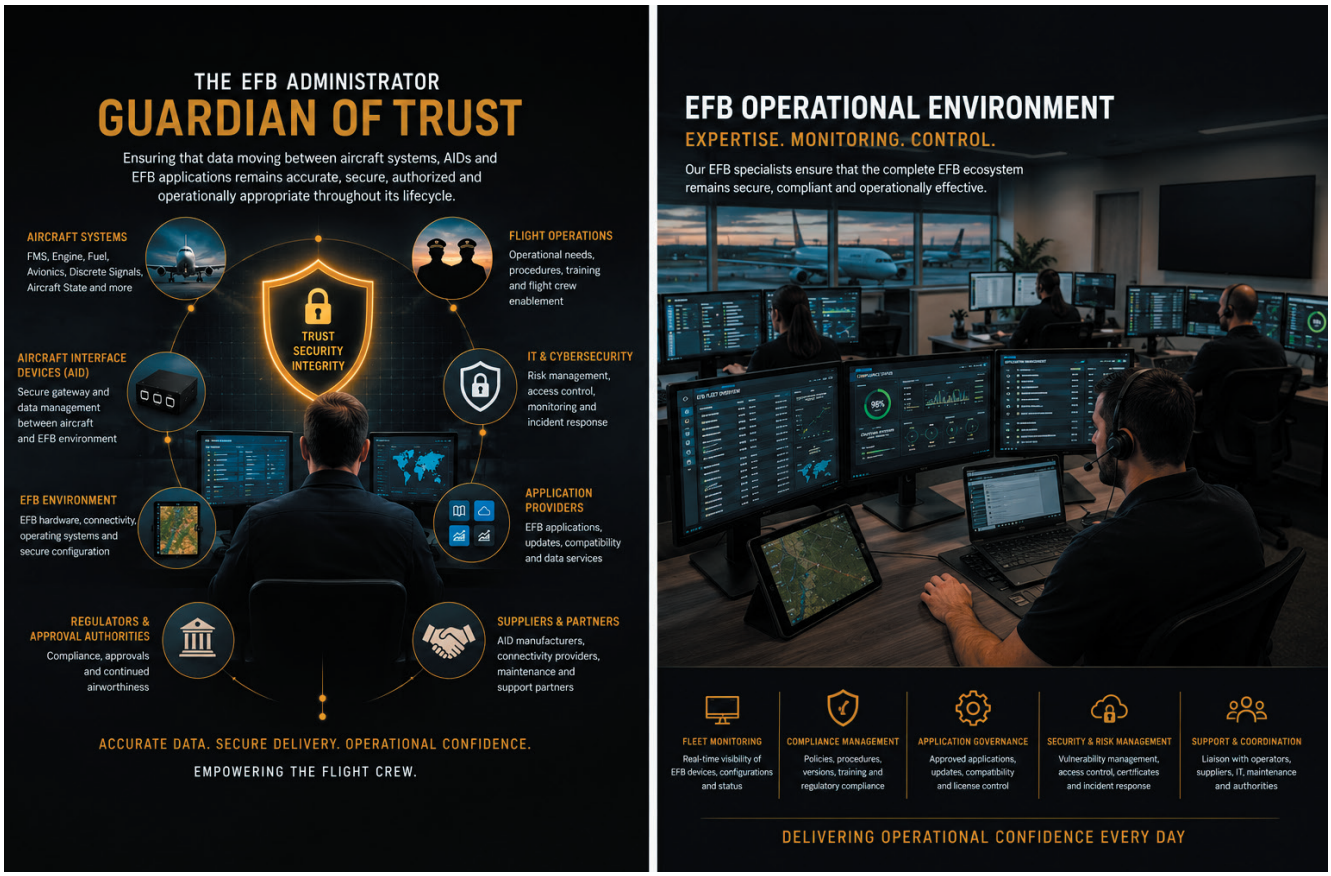


Illustration: EFB Admin Services Int. AS

Modern EFB administration extends beyond device and application management, bringing together flight operations, avionics, IT, cybersecurity, compliance, suppliers and continuing operational oversight.

must not mean unrestricted access.

The industry needs standardized and semantically consistent data interfaces, clearly defined data-quality attributes, stable APIs, representative integration test environments and contractual clarity concerning configuration control and continued support.

Operators must also treat the EFB, AID and connected applications as one operational ecosystem. Every change to an operating system, application, AID software load, aircraft configuration or security certificate should be assessed for its effect on that ecosystem.

I believe the future EFB Administrator will increasingly become the Guardian of Trust, ensuring that data moving between aircraft systems, Aircraft Interface Devices and EFB applications remains accurate, secure, authorized and operationally appropriate throughout its lifecycle.

The aim should not be to connect everything simply because it is technically possible. The aim should be to provide the right information to the right authorized application, at the right time and with a clearly understood level of integrity.

Aerospace Innovations: Overall, how well has the aviation industry dealt with the challenge of connecting EFBs to aircraft, and what do you foresee happening next?

Klaus Olsen: The industry has made significant progress in connecting aircraft to EFBs, but the next challenge is connecting the EFB ecosystem itself. Airlines should not be forced into proprietary application silos simply because each vendor uses different interfaces. Open, well-governed interoperability standards, combined with robust cybersecurity and clear operational ownership, will allow operators to choose the applications that best support their operation while maintaining the integrity of trusted aircraft data. I believe this will be one of the defining developments in EFB architecture over the next decade.

Aircraft Interface Devices are rapidly becoming the digital gateway between certified aircraft systems and the airline's operational ecosystem. Their success will ultimately be measured not by how much data they can transfer, but by how securely, reliably and intelligently that data can be governed throughout its operational lifecycle.

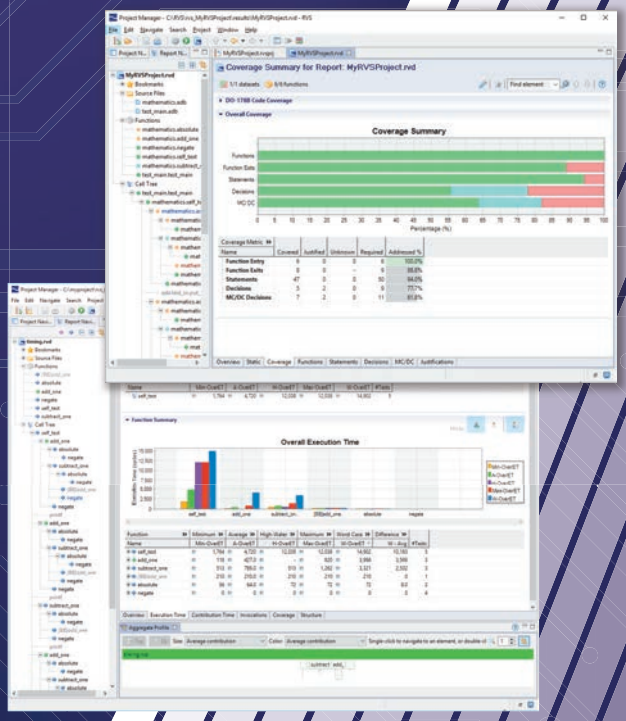
Within the next decade, I believe the industry will move away from isolated EFB applications towards integrated digital ecosystems where trusted aircraft data can be securely shared between multiple authorized applications through standardized interfaces.

By James Careless

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The connected cabin uses connectivity to move the data, then turns that data into information pilots and operators can act on. (Credit: Thales)

The Connected Cockpit

Cockpit Connectivity is moving information more efficiently between aircraft, pilots and airline operations so, transforming into insights that support better decisions in the air and more efficient operations on the ground.

"Airlines are of course always determined to improve passenger experience," remarks Viasat's Sean Reilly, Senior Director, Business Development, Aircraft Operations & Safety.

The recent news that Gulf Air has equipped 75% of its A320neo fleet and SAS its entire A320neo fleet with high-speed Wi-Fi from Starlink aptly demonstrate this commitment.

"At the same time, however," says Reilly, "they [airlines] are also looking beyond the cabin and increasingly seeing the flight deck (or the 'cockpit') as a major focus for digital transformation."

As Reilly observes, many airlines still use a technology called VHF ACARS to move simple data to and from the aircraft. Advanced flight deck connectivity, however, opens up a separate operational layer for secure data exchange between flight crews, airline operations centres, maintenance teams and Air Navigation Service Providers (ANSPs).

"For airlines, that changes what connectivity can contribute to the airlines operations," he opines.

Unlocking opportunities

Philippe Lievien, Marketing Manager, Aerospace Communications at Thales agrees that airlines are increasingly looking beyond the cabin and recognising the value of connectivity in the cockpit. He says the two domains follow different economic paradigms: cabin connectivity primarily supports passenger satisfaction and ancillary revenue, while cockpit connectivity directly contributes to the airline's operational performance and ultimately its profit and loss. "The key point is that the same connectivity infrastructure can serve both purposes, allowing airlines to generate value from a single asset across the cabin and operational domains."

With an IP satellite-based solution, says Reilly, moving larger amounts of enhanced data can bring operational efficiencies to the airline. It can help turn aircraft issues into earlier warnings, better in-flight decisions

and closer coordination with the ground, supporting safety, punctuality and efficiency improvements.

Adam Evanschwartz, VP of Strategy & Business Development at Collins Aerospace also believes that as newer-generation aircraft make significantly more operational data available, airlines are increasingly looking at inflight connectivity solutions that can improve situational awareness, operational efficiency and aircraft performance.

"That capability is becoming increasingly important as global airspace grows more crowded, complex and less predictable," he notes. "Modernising aviation will require not only better connectivity, but the ability to turn growing volumes of aircraft and operational data into timely insights that pilots and operators can act on."

"With geopolitical tensions resulting in longer flight routes and increased operational costs, airlines are placing greater emphasis on technologies that can improve operational efficiency and resilience," adds Lievien.

Lievien asserts that the connected aircraft is becoming a mobile node within the airline's broader network. This is enabling new operational models, from 5G cellular gate connectivity and SATCOM links dedicated to airline operations, to remote software and database distribution. Instead of requiring an engineer to physically access an aircraft, software and operational data can increasingly be distributed remotely. Likewise, recorded aircraft data can be transferred automatically to the ground rather than waiting for a dedicated download during a maintenance or ground visit.

As Evanschwartz observes, "Airlines not only want access to more data; they need it presented quickly, efficiently and in a way that allows crews to assess and act on the information without increasing workloads. Providing pilots with real-time weather, flight condition and aircraft performance insights can improve situational awareness and enable more efficient operations. Ground teams also benefit by using data coming off the aircraft to inform maintenance planning, fleet operations and aircraft turnarounds."

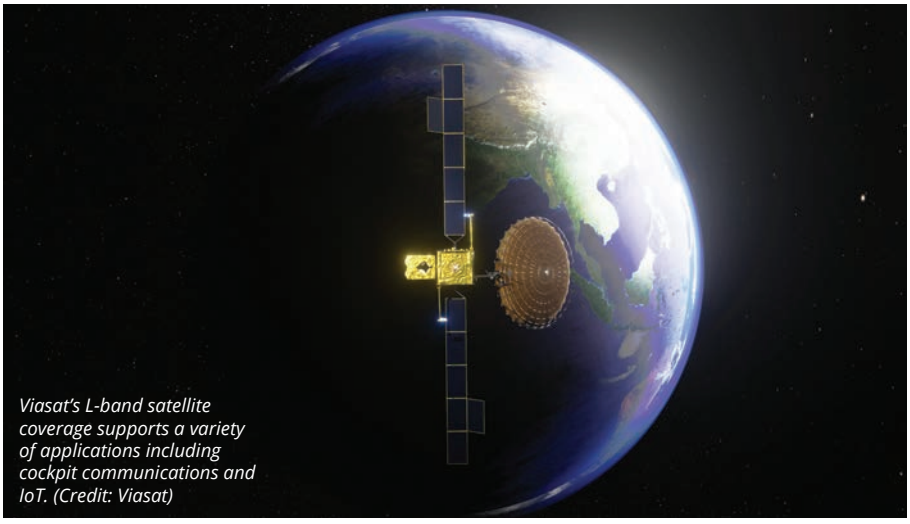
A goodbye to legacy?

Connectivity is creating opportunities to move away from legacy communication models, which have historically relied on VHF, HF and narrowband SATCOM. Advances in secure broadband, satellite and IP connectivity for the cockpit are creating additional capacity to move larger volumes of operational data while preserving traditional networks for the safety-critical and operational communications they were designed to support.

Shifting operational messaging from traditional character-based links towards IP-based communications can fundamentally change both the economics of data transmission and the way pilots interact with operational information. Technologies such as ACARS over IP, as well as emerging hybrid communication networks that combine public 5G and satellite broadband with legacy aviation safety links, will therefore be important enablers of this transition, believes Lievien.

It's a viewpoint shared by Evanschwartz. He says that advances in secure broadband, satellite and IP connectivity for the cockpit are creating additional capacity to move larger volumes of operational data while preserving traditional networks for the safety-critical and operational communications they were designed to support.

As an example, Collins' ACARS over IP (AoIP) solution allows airlines to move appropriate aircraft and engine data to broadband channels, preserving traditional VHF, HF and SATCOM channels for safety and operationally critical communications. On the ground, Collins' OpsCore flight tracking solution brings together flight information, predictive capabilities and alerts to give airline operations teams greater situational awareness and help them anticipate events that could affect a flight.



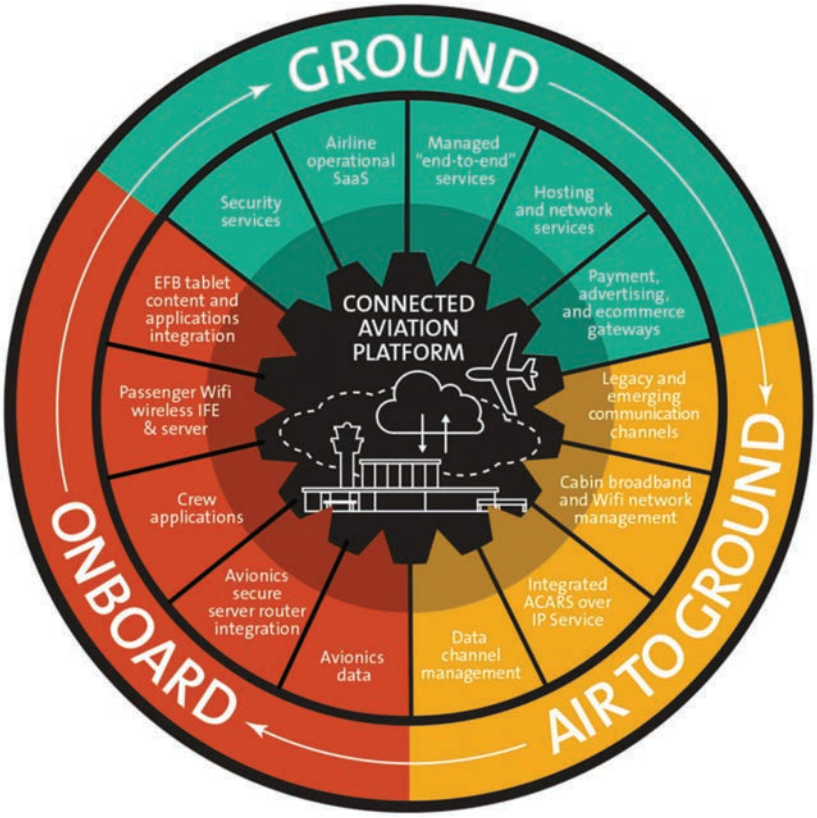
Viasat's L-band satellite coverage supports a variety of applications including cockpit communications and IoT. (Credit: Viasat)

Enriching the workload

Excitement around connectivity isn't new. The cabin has been "connected" for the past two decades as Lievien points out. However, the cockpit and flight operations, by contract, have remained largely disconnected he believes. "Cockpit connectivity is now closing that gap, transforming the aircraft from an asset that the airline primarily interacts with at the gate only into a connected system that can operate as part of the airline's network continuously, from gate to gate."

This shift towards an increasingly connected and digitally enabled aircraft brings two major families of benefits, as Lievien identifies.

"First, decisions can move from AFTER the flight to DURING the flight. Airlines can now run trajectory and fuel optimisation against live weather



Collins' GlobalConnect provides secure access between EFB applications in the flight deck and aircraft data in the avionics bay, and to all available air-to-ground media. (Credit: Collins Aerospace)

information and real-time air traffic control (ATC) constraints, re-planning en-route while airborne, transmitting updated load sheets or performance data during the flight. Each individual intervention may appear relatively small, but when applied consistently across a fleet and over a full year of operations, the cumulative impact on fuel consumption, delays and operational efficiency can be significant.

"Second, ground processes no longer need to be physically tied to the aircraft. Software and database updates, configuration management, log retrieval and health monitoring can increasingly be performed remotely rather than from the flight deck itself. This has the potential to fundamentally change how airlines organise and manage aircraft operations and maintenance however it is also where regulatory work is still in progress."

Cockpit connectivity differs greatly from cabin connectivity. While cabin connectivity is primarily designed around the passenger experience, cockpit connectivity supports operational and, in some cases, safety-related functions. It therefore places a particularly high priority on security, availability and reliability, ensuring that the most important operational information is transmitted appropriately.

Aircraft architectures are designed to segregate and protect those different domains based on the function and criticality of the information being carried.

As an example, Viasat's advanced SwiftBroadband-Safety (SB-S) service uses the company's highly reliable L-band satellite communications network. It's installed on more than 1,000 aircraft, and Viasat's wider safety portfolio supports more than 12,000 aircraft equipped with certified safety terminals worldwide.

"That gives us scale, experience and a strong platform to help airlines adopt richer, IP-enabled operational services," says Reilly.

"Building on this foundation, initiatives like the Iris programme, developed alongside the European Space Agency (ESA) and European Satellite Services Provider (ESSP), use this SB-S connectivity to help create the digital systems needed for more accurate flight planning, better data sharing and more connected air traffic management," he says.

Reilly says that in Europe, Iris is enabling the industry progress towards Trajectory Based Operations (TBO), which allows air traffic control to see where an aircraft is heading and plan 120+ waypoints further ahead rather than reacting to events as they appear. "The focus now is on turning proven connectivity into a broader operating model that supports TBO and gives airlines, controllers and air navigation partners a clearer pathway to adoption," he remarks.

A strong case

Considering what is happening in the skies, the need for cockpit connectivity is clear. Lievien contends there are four main pillars behind this motivation, but the two fundamental drivers are economic and regulatory.

At an economic level, fuel is the largest controllable operating cost. Live trajectory and fuel optimisation based on real-time weather and operational constraints are only possible if the relevant data reaches the aircraft during flight, he says.

He identifies aircraft availability as critical. "Faster and automated access to and management of aircraft data, such as QAR/DAR flight data, and automated data loading process including navigation databases can reduce ground time and engineering workload," he says.

Recognising that legacy operational messaging can be costly, Lievien says that moving traditional messaging onto IP-based connectivity can significantly reduce the cost per message.

As for regulatory and environmental drivers, emissions reporting and fuel-efficiency schemes require reliable evidence. Regulations and programmes such as ETS and CORSIA depend on collecting accurate data at scale, whilst flight data monitoring and safety



By 2028, Iris will be well placed to enable flight optimisation across the globe and the datalink will become the primary means of communications between pilots and air traffic controllers. (Credit: ESA)

programmes benefit from faster, more complete and more frequent access to aircraft data.

As Lievien observes, air traffic management (ATM) modernisation programmes (e.g., SESAR, NEXTGEN) increasingly assume digitally connected aircraft as the foundation for future ATM concepts such as TBO.

On an operational level, the connected Electronic Flight Bag (EFB) have rapidly become operationally critical, supporting a growing range of use cases, including real-time weather updates, updated aircraft performance data, live load sheets and two-way operational messaging. "Connectivity means that these capabilities are no longer limited to the aircraft on the ground at the gate but can increasingly be used in flight. A recent example is EASA Safety Information Bulletin 2022-02R4, "GNSS Outage and Alterations leading to CNS Degradation," which recommends the integration of EFB technology capable of displaying areas affected by GNSS radio-frequency interference," he says.

Structurally, the volume of data generated on board has increased dramatically, far beyond what traditional manual retrieval process can efficiently handle. As Lievien remarks, analytics and AI (Artificial Intelligence) are only valuable when the data is available in time to support decisions. "Connectivity enables aircraft data to be transferred while it can still be acted upon, rather than after the aircraft has returned to the ground.

To address these requirements, Thales AEC has developed SATCOM Systems such as Thales Aviator S, providing reliable and secure connectivity for cockpit operations and enabling the continuous flow of operational data between the aircraft and the ground.

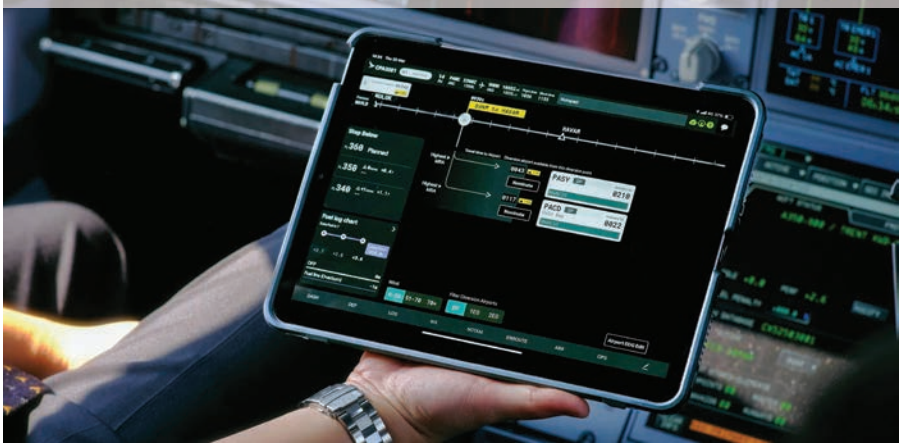
The industry is currently working on certified onboard platforms that connect the aircraft to the airline's network, give the airline access to its own aircraft data, and enables airlines to run their own applications on board, without interfering with the systems that actually fly the aircraft.

For its part, Collins approaches cockpit connectivity as an end-to-end ecosystem rather than as a single communications product.

Its portfolio spans onboard avionics and connectivity hardware, air-to-ground communications networks, ground infrastructure and applications that help airlines turn aircraft and flight data into useful operational information.

GlobalConnect services provide a platform for bringing multiple communications links together, while AoIP gives airlines another path for transmitting appropriate aircraft and engine data over broadband connectivity. Solutions such as OpsCore flight tracking then help operators use flight and operational data on the ground to improve situational awareness and decision-making.

"The direction of travel is toward greater interoperability between those pieces," says Evanschwartz. "The value isn't simply in generating or transmitting more data. It is in helping customers access that data, move it



First developed in 2019, Cathay Technologies' Electronic Flight Folder has revolutionised how pilots access and manage flight information. (Credit: Cathay Group)

securely and reliably, and ultimately transform it into actionable insights for pilots and operators.

"That is an important part of aviation modernisation. As the airspace becomes more complex, the industry will increasingly need systems that connect information across the aviation ecosystem and make that information useful to the people making decisions."

Built on confidence

Ultimately, greater connectivity only delivers value if pilots, airlines and regulators can trust the information moving through the system.

Connectivity and cybersecurity have to advance together stresses Evanschwartz. "As aircraft become more connected, the architecture has to protect the separation between systems and information with different levels of criticality while still enabling the data flows that create operational value.

"That means security has to be considered throughout the architecture rather than added after the fact. Depending on the application, that can include network segmentation, controlled interfaces, secure communications and multiple layers of protection between aircraft and ground systems."

Reilly is in agreement that cybersecurity cannot be treated as an add-on once an aircraft is connected. "It should be designed into the architecture from the beginning, especially when the data being carried supports flight operations and safety-critical decision-making," he states. "That is why Viasat has always built protected connectivity around separation, prioritisation and assurance, so operational traffic is kept distinct from passenger networks and supported by the safeguards required for regulated aviation environments. This distinct difference sets our services apart from traditional passenger networks that are 'open' to the internet. Security is not just a VPN anymore and the network must be protected."

"A useful way to think about it is the onion-ring principle," says Lievien. We do not rely on a single security mechanism or a single line of defence. Instead, multiple complementary mechanisms are implemented at the hardware, software, system and process levels. The objective is that if one layer is compromised or fails, the other layers continue to provide protection."

The time is now

Looking ahead, there is broad agreement that the future of cockpit connectivity is already here and taking shape.

"Airlines increasingly have access to broadband satellite and IP-based communications alongside traditional aviation datalinks, creating the foundation for a more connected cockpit," Evanschwartz says. "The next step is making those connections work together more intelligently."

Reilly sees aviation currently moving through a significant digital shift, and flight deck connectivity sits right at the center of that change. "Airlines must maintain the highest safety standards while improving efficiency and sustainability. The future of flight deck connectivity is therefore the future of a more connected, integrated aviation system, where aircraft are no longer treated as isolated assets once they leave the gate.

"Data is already essential to safe and efficient operations, and as aircraft generate and exchange more information across every phase of flight, complementary communications technologies are playing an increasingly important role. Resilient communications powered by IP-based connectivity can support the exchange of larger volumes of data, enabling shared flight plans, weather-aware routing, digital air traffic tools and better coordination between aircraft and the ground. Connectivity will help the industry move from fragmented information to a more predictable, collaborative and sustainable way of operating, while safely integrating aircraft like air taxis and delivery drones.

"Many of these capabilities can be enabled using equipment aircraft have today allowing operators to start benefiting from richer data exchange while regulatory frameworks continue to evolve and adoption expands across the industry," he remarks.

For Lievien, the aircraft is progressively becoming a permanent, secure node on the airline's network, exchanging data continuously with operations, maintenance and air traffic management.

"We are not waiting for that future, it is already arriving in stages, and the pace of adoption, however, will be determined by certification and regulation rather than by technology. If we look at the evolution ahead, I would distinguish between the medium and long term.

In the medium term, he sees an increase in the number of ground-managed aircraft, with software and data distribution, configuration and health management performed remotely, with the aircraft treated

as a managed asset by the airline's IT organisation.

Predictive maintenance will be based on near-continuous data rather than occasional or sampled downloads, and airlines and their chosen partners developing directly against their own aircraft data through open interfaces, "which could shift the pace of innovation from traditional supplier release cycles to airline-driven development cycles."

"And importantly, regulatory maturation will be a key gate. The technical capability is progressing rapidly; certification and regulatory acceptance will determine how quickly these capabilities can be deployed at scale," he says.

Turing to the long term, Lievien envisages full digital continuity between the aircraft, the operator and ATM, and Trajectory-Based Operations —where the aircraft can negotiate or continuously optimise its trajectory against live operational constraints, supported by the flight information exchange standards the industry is developing today such as FF-ICE Release 2 -Flight and Flow Information for a Collaborative Environment.

Finally, he foresees greater onboard processing and pre-processing including AI, with the aircraft processing data locally and transmitting recommendations, insights or decisions rather than simply sending large volumes of raw data.

A flow not a deluge

As Evanschwartz is at pains to point out, the future isn't a cockpit flooded with more data. "It's a cockpit where connectivity, data and increasingly intelligent applications work together behind the scenes to surface the right information at the right time.

"That is an important part of modernising aviation: using technology to simplify complexity, reduce pilot workload and enable better-informed decisions across the aviation ecosystem.

"For Collins, the goal is ultimately to empower pilots and operators with better insights while allowing the technology and connectivity behind those insights to become increasingly seamless."

"So, the future is not simply about having more bandwidth in the cockpit," highlights Lievien. "It is about creating a secure, certified digital architecture in which the aircraft can continuously exchange information with the airline and the wider aviation ecosystem - while maintaining the safety principles that govern aviation today."

By Alex Preston



Aviation is moving through a significant digital shift, and flight deck connectivity sits right at the center of that change. (Credit: Collins Aerospace)



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How Aerospace and Defense Can Overcome the Big Challenges of Vertical Supply Chain Integration

The Aerospace and Defense Industry is facing a reality it can no longer ignore: the most advanced aircraft, missiles, satellites, drones, and defense systems in the world are only as strong as the supply chains behind them.

For decades, aerospace and defense companies built global supplier networks designed for efficiency, specialization, and cost control. OEMs and prime contractors focused on design, integration, program management, and final assembly, while thousands of suppliers handled everything from forgings and castings to electronics, propulsion components, software, sensors, fasteners, and specialty materials.

That model worked when the world was more stable.

Today, it is under stress.

Defense demand is rising. Commercial aerospace production is trying to ramp up. Missile inventories need replenishment. Space systems are becoming more strategically important. At the same time, suppliers are facing labor shortages, inflation, raw material constraints,





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cyber risk, geopolitical instability, and limited production capacity.

The result is a new strategic question: should aerospace and defense companies vertically integrate more of their supply chains?

The answer is yes—but carefully.

Vertical integration does not mean owning everything. It means gaining control over the parts of the supply chain that are too critical to fail.

The New Reality: A Single Weak Link Can Stop the Mission

Aerospace and defense products are among the most complex systems ever built. A modern aircraft, missile system, or satellite may depend on thousands of parts from hundreds or even thousands of suppliers. One missing casting, one delayed chip, one unavailable forging, one failed supplier, or one unqualified special process can delay an entire program.

That is the danger of today's supply chain: the weakest link is often hidden.

Many OEMs have good visibility into their Tier 1 suppliers. But the real bottleneck may be deeper—in Tier 2, Tier 3, or Tier 4. It may be a small machining company, a specialty heat-treat provider, a rare material supplier, a foundry, or a producer of electronic components that few executives have ever visited.

When that supplier fails, the impact moves upward fast.

This is why vertical integration is becoming attractive again. Companies want more control, more visibility, more resilience, and more certainty. But vertical integration is not a magic solution. Bringing work in-house can reduce some risks while creating others: higher capital cost, workforce pressure, operational complexity, supplier tension, and reduced flexibility.

The industry must therefore move from a simple outsourcing mindset to a strategic control mindset.

The question should not be, "Should we make or buy?"

The better question is, "What must we control to protect the mission?"

Real Example: Safran and the Power of Controlling Critical Processes

Safran offers a strong example of strategic vertical integration in action.

In 2026, Safran announced a major investment in its Gennevilliers site near Paris, including a 30,000-ton hydraulic press to strengthen its forging capability. The company said the investment would support strategic parts for commercial and military aircraft engines and help increase output by 2029.

This is not just a factory upgrade. It is a strategic supply chain move.

Forgings are not ordinary parts. In aircraft engines, they are often mission-critical components exposed to extreme stress, heat, and performance requirements. If forging capacity becomes constrained, engine production slows. If engine production slows, aircraft deliveries suffer.

Safran's investment shows a key principle: vertical integration makes the most sense when the capability is technically difficult, strategically

THE BIGGEST CHALLENGES OF VERTICAL INTEGRATION



1. Companies Must Decide What Truly Matters

The first challenge is knowing what to integrate.

Some companies make the mistake of reacting emotionally to supply chain pain. A supplier misses deliveries, so leadership says, "Let's bring it in-house." But that approach can lead to expensive and unnecessary integration.

Not every problem requires ownership.

Aerospace and defense companies should classify supply chain capabilities into four categories:

Own: Capabilities that are mission-critical, scarce, sensitive, or too risky to leave fully outside the company.

Partner: Capabilities where suppliers have strong expertise but need deeper collaboration, investment, or long-term agreements.

Dual-source: Components where redundancy is needed to reduce risk.

Monitor: Lower-risk parts that can remain outsourced but require better visibility.

This prevents companies from trying to vertically integrate everything. The goal is not maximum ownership. The goal is intelligent control.

2. Vertical Integration Requires Serious Capital

Vertical integration is expensive. Facilities, equipment, tooling, automation, inspection systems, cybersecurity, certifications, and workforce development all require major investment.

In aerospace and defense, the payback period can be long because processes must be qualified, audited, certified, and stabilized. A new internal production line is not valuable simply because it exists. It must meet strict quality, safety, regulatory, and customer requirements.

That means the business case must include more than unit cost.

Leaders must calculate the cost of disruption: missed deliveries, production delays, expedite fees, quality escapes, customer penalties, lost market share, and weakened national readiness.

A low-cost supplier that cannot deliver is not truly low cost. It is a hidden liability.

3. The Workforce Gap Can Break the Strategy

Vertical integration does not work without people.

A company can buy a machine. It cannot instantly create experienced machinists, welders, inspectors, manufacturing engineers, quality engineers, software specialists, supply chain analysts, and production supervisors.

This is one of the most serious constraints facing the industry.

If aerospace and defense companies want to bring more critical work in-house, they must also rebuild the industrial workforce. That means apprenticeships, technical schools, university partnerships, veteran hiring programs, supplier talent pipelines, internal academies, and stronger retention strategies.

Vertical integration is not only a supply chain strategy. It is a workforce strategy.

4. Supplier Relationships Can Become Complicated

When an OEM or prime contractor starts bringing work in-house, suppliers may feel threatened. They may worry that today's support will become tomorrow's competition.

This can damage trust.

The solution is transparency. Companies should communicate clearly with suppliers about which capabilities are strategic control points and which areas remain partnership opportunities.

In many cases, supplier development is better than supplier replacement. A struggling supplier may need help with quality systems, capacity planning, lean manufacturing, automation, digital tools, or financing. Helping that supplier improve may be faster and less costly than acquiring or duplicating its capability.

The strongest companies will not destroy their supplier ecosystems. They will strengthen them.

5. Digital Visibility Is Still Too Weak

One of the biggest weaknesses in aerospace and defense is limited visibility beyond Tier 1 suppliers.

Many companies still do not have a clear picture of where critical materials originate, which lower-tier suppliers are overloaded, which parts depend on single sources, or which suppliers are exposed to cyber, financial, or geopolitical risk.

This is dangerous.

The industry needs supply chain illumination: the ability to see deep into the supplier network and identify risk before it becomes a production crisis.

That requires part-level traceability, supplier mapping, digital thread systems, capacity dashboards, predictive analytics, cybersecurity monitoring, financial risk indicators, and early-warning systems.

Vertical integration without visibility is incomplete. You cannot control what you cannot see.

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important, capacity-constrained, and essential to long-term competitiveness.

Safran is not trying to own every part of the supply chain. It is strengthening control over a bottleneck capability that directly affects engine production, resilience, and national industrial capacity.

That is smart vertical integration.

Real Example: Lockheed Martin and Missile Production Capacity

Lockheed Martin provides another example from the defense side.

In 2026, the company began construction of a new munitions production facility in Troy, Alabama, to support systems such as THAAD interceptors and Next Generation Interceptor production. The move is part of a broader effort to expand missile production capacity at a time when U.S. and allied defense demand is increasing.

This example highlights another reason vertical integration matters: surge capacity.

Defense supply chains cannot be designed only for peacetime efficiency. They must also support crisis response, replenishment, and deterrence. If demand suddenly increases, the supply chain must be able to respond.

Missile production depends on complex networks of propulsion suppliers, electronics providers, energetics manufacturers, precision machining companies, test systems, guidance components, and specialized materials. If any of these areas lacks capacity, production cannot scale.

Lockheed Martin's expansion shows that vertical integration is not always about acquiring suppliers. Sometimes it is about building internal capacity, modernizing facilities, securing production lines, and aligning investment with long-term government demand.

In defense, capacity is not just a business issue. It is a national security issue.

How the Industry Can Overcome These Challenges

The aerospace and defense industry needs a practical playbook.

First, companies should map their real supply chains. Not just Tier 1 suppliers. Not just contracted suppliers. They need visibility into lower-tier suppliers, critical materials, special processes, and capacity constraints.

Second, they should identify strategic bottlenecks. These are the components, processes, technologies, and materials that can stop a program if they fail.

Third, they should choose the right control model. Some capabilities should be owned. Some should be supported through long-term partnerships. Some should be dual-sourced. Some should be protected through inventory, capacity reservations, or government-backed investment.

Fourth, they should invest in supplier development. Many



suppliers do not need to be replaced; they need help becoming stronger.

Fifth, companies should align engineering and supply chain decisions earlier. A design that depends on one rare material, one fragile supplier, or one unproven process creates risk before production even begins.

Sixth, government and industry must work together. Defense suppliers need stable demand signals, multiyear procurement, faster contracting, and targeted investment in critical industrial base capabilities. Suppliers cannot justify major capital investment if future demand is uncertain.

Finally, vertical integration must become a board-level issue. It affects strategy, production, finance, quality, cybersecurity, national security, and customer trust. It is too important to be treated as a purchasing project.

The Leadership Shift: From Cost Control to Mission Control

For years, supply chain was often viewed as a cost center. That mindset is outdated.

In aerospace and defense, supply chain capability is now a strategic advantage. The companies that can secure capacity, protect critical materials, develop suppliers, and scale production faster will outperform those that only chase lowest price.

The industry must stop asking only, "Who can make this cheaper?"

It must also ask, "Who can help us deliver reliably, securely, and at scale?"

That shift changes everything.

Safran's investment in forging capacity shows how controlling a critical process can strengthen resilience. Lockheed Martin's missile production expansion shows how capacity investment can support national defense needs. These examples point to the future: the winners will be the companies that understand where control matters most and act before the bottleneck becomes a crisis.

Conclusion: Control the Chain Before the Chain Controls You

Vertical supply chain integration is not about owning everything. It is about protecting what matters most.

The aerospace and defense industry should integrate selectively, invest strategically, and partner intelligently. It should own the capabilities that are too critical to fail, develop suppliers that are too important to lose, and digitally monitor the deeper tiers that are too risky to ignore.

The next generation of aerospace and defense competition will not be won only by the best designs. It will be won by the companies that can actually deliver those designs—on time, at scale, and with confidence.

In this industry, supply chain resilience is no longer a back-office function.

It is mission readiness.

It is competitive advantage.

And in many cases, it is national security.

By Azita Hajihassani, Ph.D., MBA
www.LeadingDisruption.net

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Engineering Confidence:

How Digital Twins Transform Simulation and Validation in Aerospace

Aerospace Innovation Needs a New Validation Paradigm

Aerospace engineering has always been defined by complexity. However, the challenges facing today's aircraft, unmanned or manned, and space systems differ in both scale and character. Modern aerospace systems are increasingly software-defined, highly interconnected, and expected to perform advanced functions reliably. Flight controls, avionics, propulsion, and autonomy functions are no longer developed as isolated domains. They interact continuously. A change in one subsystem can affect the behavior of the integrated system and even the overall aerial vehicle. Therefore, aerospace platforms must satisfy an ever-growing list of requirements: functional safety, reliability, cybersecurity, operational efficiency, and autonomy.

Unmanned aerial vehicles (UAV) include autonomous mission systems with AI-supported decision-making functions or are optionally remotely piloted. Therefore, they must be developed for and validated across a vast number of operating scenarios. These include nominal flight conditions, rare edge cases, degraded sensor states, communication losses, environmental disturbances, and combinations of faults that can be too risky, too expensive, or sometimes almost impossible to reproduce in physical testing.

Traditional development, verification, and validation methods are reaching their limits. Physical prototypes and flight tests remain indispensable, but they are costly, capacity-constrained, and typically available only late in the development cycle. By the time all system components are integrated into a physical test bench or an aircraft for flight-testing, design changes can be expensive and time-consuming. For AI-based systems in particular, the challenge is even greater. Before engineers can be confident in the behavior of perception algorithms, decision-

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making logic, and control functions, the algorithms must be trained with an enormous variety of scenarios and data, which can be provided realistically only by synthetic data generation and virtual flight testing.

This is where digital twins become a key enabler, bridging the gap between simulation of a single system and real-world behavior of the entire aerial vehicle. By combining high-fidelity models, real-time simulation, validated system behavior, and data from development and operations, digital twins allow aerospace engineers to shift validation activities into earlier phases, scale scenario-based testing, and enter real-world testing with more mature systems. The result is not the replacement of physical testing, but a smarter balance between virtual and physical validation to reduce time and cost.

Digital Twins in Aerospace

A digital twin is more than a simulation model. It is a dynamic replica of a physical object or system, including a simulation of the physical environment. A digital twin can represent a single component, such as an actuator or engine subsystem, a complete aircraft system, such as flight control or propulsion, or even an integrated aircraft, UAV, or mission environment. It can include validated simulation of physics-based models, software models, control algorithms, communication networks, sensor models, and environmental models. With these high-fidelity models, a representation of the real-world counterpart is accomplished that is sufficiently realistic for the intended engineering decision, with assumptions, deviations, and validity boundaries made explicit.

The required level of fidelity of a digital twin depends on its purpose. For early concept evaluation, a simplified model can be sufficient to compare architectures. For later stages of controller development, engineers need real-time-capable plant models that capture relevant dynamic behavior. For safety-critical validation, models must be validated against measurements and used within clearly defined limits. This makes digital twins highly practical engineering assets. They create a digital thread between requirements, models, software, hardware, test cases, test results, test automation, and operational data. When connected to simulation platforms, software-in-the-loop (SIL) environments, or real-time hardware-in-the-loop (HIL) systems, they become the backbone of a simulation-driven validation strategy.

Shifting Left: Virtual Development and Early Testing

Digital twins introduce a disruptive change in the development process, because they allow engineers to move a substantial part of testing activities to earlier development phases. Aircraft behavior can be simulated under many different near-real-world scenarios using models of systems, controllers, and the environment, long before a complete physical prototype is available.

This shift-left approach moves testing activities from late-stage integration to earlier phases of the development process. Instead of waiting until hardware, embedded software, and system components are physically available, teams can already begin validating assumptions, interfaces, and control strategies virtually.

The benefits are substantial. Integration issues can be detected earlier. Design alternatives can be iterated on and compared faster, leading to enhanced design accuracy and performance validation. Test benches can be designed and prepared based on digital twins and their interfaces before all components are available. This accelerates the setup of physical test benches once real components are available. Ultimately, the number of design iterations and required physical prototypes can eventually be reduced, improving risk management and accelerating time to market.

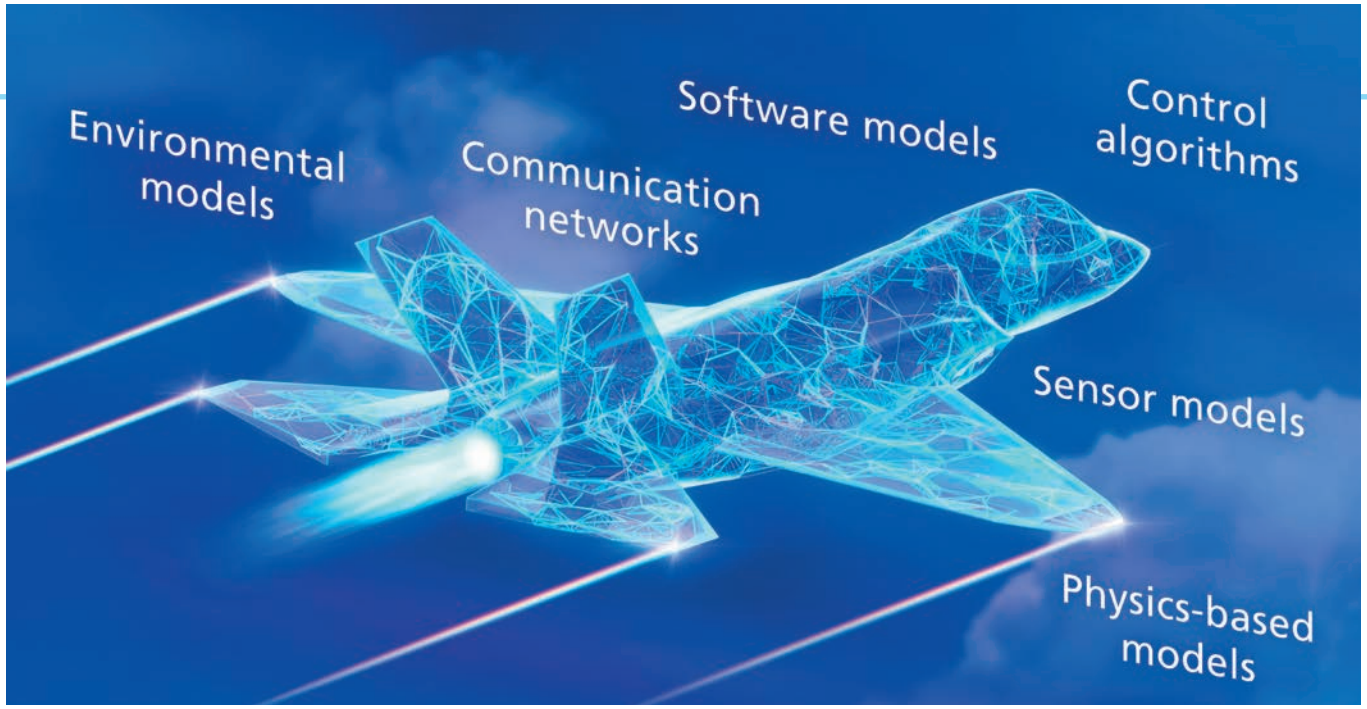
In addition, digital twins strongly support continuous integration (CI) and continuous testing (CT). In an agile software development approach, e.g., in software-defined autonomous systems, an automated simulation-based test environment is essential to enable fast software updates between iteration cycles. Every software build can be executed against a defined set of regression tests, continuously and as part of automated workflows. Test results can be traced back to requirements and failures can be reproduced exactly. This creates a more controlled, data-driven development process.

Digital Twins for Safety-Critical Validation

For AI-based systems, digital twins are even more important. Perception and decision-making algorithms require extensive exposure to diverse operational scenarios. Synthetic data generation and virtual flight testing allow teams to create controlled, repeatable datasets for training, testing, and validation. Weather conditions, lighting, sensor noise, air traffic density, terrain, mission profiles, and fault cases can be varied systematically, which is essential for reproducibility and traceability of test results.

This is a clear advantage compared to physical tests, where environmental conditions, hardware states, timing, and operator inputs can vary. In a digital twin environment, the same scenario can be executed repeatedly with precisely controlled parameters. This allows engineers to isolate root causes of failures, compare software versions, and verify whether a design change has resolved an issue.

Moreover, when failures occur, teams need to know which scenario was executed, which model version was used, which software build was tested, and which requirement was affected. A validation environment based on digital twins enables the linking of test cases, requirements, model versions, software versions, configuration data, and results to provide this traceable chain of evidence.



Scenario-based testing is another major advantage. Aerospace systems must be validated across enormous operational envelopes. For autonomous or AI-supported systems, the number of relevant scenarios can grow exponentially. Digital twins make it possible to define, execute, and manage large scenario catalogs, including rare edge cases and even catastrophic scenarios. These may include sensor dropouts, actuator faults, GPS degradation, unexpected obstacles, severe weather conditions, communication latency, or simultaneous subsystem failures. This virtual fault injection is particularly valuable, since faults that would be dangerous, expensive, or impractical to create in physical testing can be introduced safely in simulation. In aerospace, testing is not just about proving that a system works under ideal conditions. It is about building confidence that the system behaves safely and predictably under expected, unexpected, and degraded conditions. This makes virtual validation with digital twins a critical and powerful complement to real-world data collection and testing, because it enables engineers to deepen their understanding before entering costly physical test campaigns.

Simulation-Based Integration of Complex Systems

To realize the potential of digital twins, aerospace organizations need the appropriate simulation and test architecture. Two key approaches are software-in-the-loop (SIL) and hardware-in-the-loop (HIL) testing which can also be combined in a hybrid setup.

In SIL testing, embedded software or application code, referred to as the system under test (SUT), is tested in a fully virtual environment without requiring the final target hardware (see figure 1). Because the test setup is independent of dedicated simulation hardware, test cases can be executed as fast as possible and scaled efficiently using standard computing infrastructure. VEOS, a PC-based platform for SIL simulation from dSPACE, integrates a wide range of simulation models, including functional algorithms, bus systems, virtual electronic control units, and vehicle models. To accelerate project setup, developers can incorporate highly accurate and realistic models from the dSPACE ASM suite. The ASM suite contains open models that are implemented in MATLAB/Simulink® and can easily be extended by developers, for example, with aircraft-specific dynamics models. As a result, SIL testing is especially well-suited for early software verification, regression testing, virtual electronic control unit validation, controller validation, and large-scale scenario execution.

HIL testing puts physical devices into a closed-loop simulation (see figure 2) by stimulating electrical I/O, network and bus interfaces in real time. Actual Line-Replaceable Units (LRU), electronic control units, avionics computers, sensors, actuators, or network components are connected to real-time HIL simulators, such as SCALEXIO from dSPACE, to simulate the environment. The hardware interacts with simulated aircraft dynamics, loads, signals, buses, and environmental conditions as if it were operating in the real system. As with SIL testing, high-fidelity virtual worlds with realistic environmental modeling, including weather dynamics and terrain, can be provided by dSPACE AURELION. It delivers pixel-accurate ground-truth data for all sensor types and supports AI use cases with synthetic data generation. Furthermore, easy parameterization and positioning of camera, radar, and lidar sensors, combined with real-time simulation, enable cost-effective generation of realistic sensor data. HIL testing is essential when timing behavior, electrical interfaces, communication protocols, and embedded hardware constraints must be validated.

For aerospace systems, distributed and networked testing is increasingly important. Modern aircraft architecture includes multiple interconnected systems communicating over avionics buses, including Ethernet-based networks such as AFDX® / ARINC 664. Test environments must therefore simulate not only individual components, but also communication

behavior, timing, latency, bus loads, and fault conditions. With digital twins, a flight control computer can be connected to a simulated aircraft and environment model. Avionics software can interact with virtual sensors and communication buses. A propulsion controller can be validated against a real-time engine model. Autonomy software can process synthetic sensor inputs from a simulated environment. Different test stages - from desktop simulation to SIL, HIL, and hybrid benches - can reuse models and test scenarios where appropriate.

This reuse is one of the most important practical benefits. Organizations can avoid rebuilding models and tests for every phase. Instead, models can mature over time, becoming increasingly validated and connected to real system behavior.

Maximize Use of Digital Twins

Digital twins do not deliver much value in isolation. They require an infrastructure that supports performance, scalability, automation, interoperability, and collaboration.

First, high-performance simulation environments are essential. Some use cases benefit from faster-than-real-time execution, for example, when running thousands of virtual test scenarios in parallel in a SIL environment. Others require deterministic real-time simulation, particularly for HIL testing, where real hardware expects accurate timing. The infrastructure must therefore support both scalable cloud or server-based simulation and real-time test systems.

Second, automation of test workflows, test system orchestration, and data management matters. Digital twin environments can generate large amounts of data: model parameters, simulation outputs, test results, scenario definitions, software versions, signal traces, sensor data, and operational feedback. Without automation and structured data management, the value of virtual validation is quickly lost. Teams need clear versioning, metadata, result comparison, and traceability.

Third, interoperability is critical. Aerospace programs involve OEMs, system suppliers, software suppliers, tool providers, and certification stakeholders. No single tool environment covers every discipline. Standards are therefore essential for exchanging models, connecting simulation components, and protecting intellectual property.

Collaborative Ecosystems and Standardization

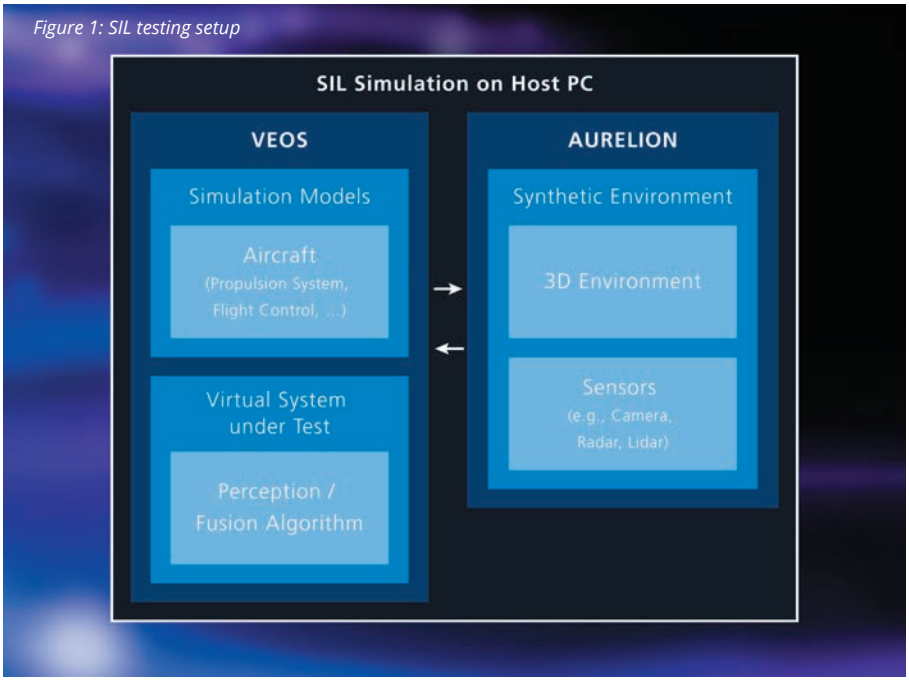
The full value of digital twins emerges when they become part of collaborative engineering ecosystems. Aerospace platforms are rarely developed by a single organization. Alongside OEMs and Tier-1 suppliers, specialists contribute to the final system. Therefore, models must be exchanged, interfaces must be agreed upon, and test scenarios must be reused, so that results become usable across organizational boundaries. However, suppliers cannot simply hand over detailed internal models or proprietary know-how. Standardized interfaces and packaged "black-box" simulation components make it possible to share behavior while protecting implementation details. This is crucial for building integrated digital twins across OEM and supplier boundaries.

The Functional Mock-up Interface (FMI) is a prominent example of how cross-organizational work can succeed. FMI is a free, tool-independent standard for exchanging dynamic simulation models, distributed as Functional Mock-up Units (FMU), and is supported by more than 280 tools. FMI is maintained as a Modelica Association Project. It supports model exchange and co-simulation, enabling models from different tools and suppliers to be integrated more easily, either as open or as black-box containers.

Additionally, in virtual and hybrid testing, EUROCAE standard ED-247 is highly relevant. It envisions new possibilities for designing future test benches architectures and advances test strategies. ED-247 aims to standardize virtual and hybrid testing by defining virtual component integration and interface rules for aircraft signals and buses. It further addresses interoperability between virtual and real avionics components, hybridization, command, and notification methods, and exchange processes between component providers and integrators, thereby also enabling distributed testing.

Standards reduce friction and make simulation assets reusable across projects, platforms, and lifecycle phases. Open and industry-accepted standards play a central

Figure 1: SIL testing setup



role. FMI supports model exchange and co-simulation across tools. ED-247 supports virtual and hybrid avionics testing. Other aerospace and systems engineering standards can contribute to requirements traceability, data exchange, communication simulation, and model-based systems engineering. Standardization is a central element of scalability, because it unlocks the full potential of digital twins. If every supplier delivers models in a clearly defined and easily usable format, integration becomes fast and affordable. If every test bench uses agreed interfaces, test reuse becomes virtually unlimited. Continuous validation becomes realistic if every simulation component is ready to use without manual adaptation. This ultimately leads to a collaborative digital twin ecosystem, which helps improve quality. When models from different domains are integrated earlier, interface issues become visible earlier. When suppliers can test against OEM-provided virtual components, integration risk decreases. When OEMs can validate supplier components in system context, confidence increases. The result is a more mature system entering physical testing.

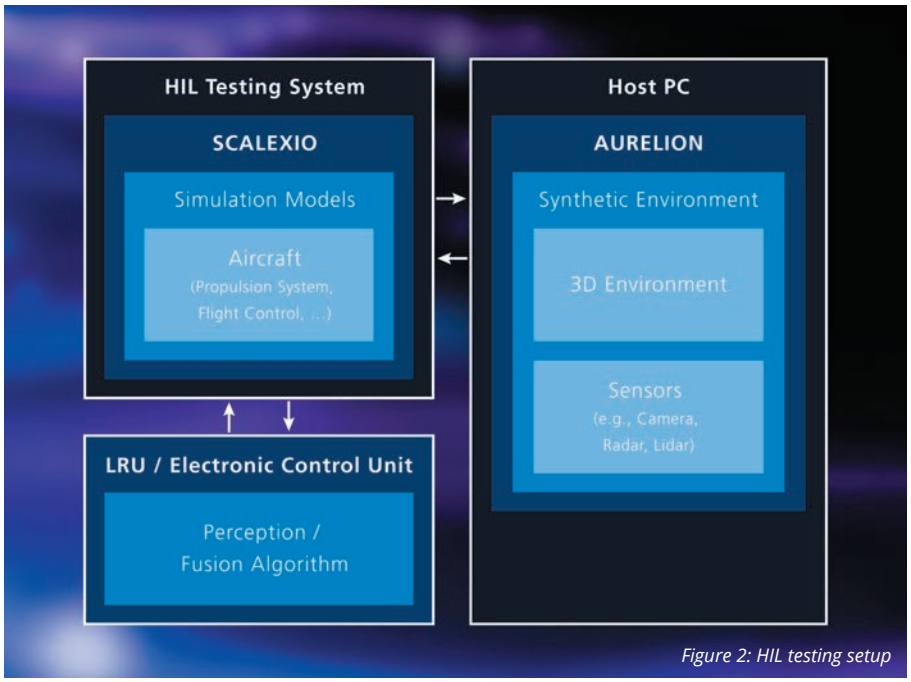


Figure 2: HIL testing setup

Beyond Testing: Digital Twins Across the Lifecycle

While simulation and validation are among the most compelling use cases, the application of digital twins does not stop at testing. Their long-term potential lies in connecting development, production, operation, and maintenance, while serving as the central pillar of an end-to-end digitalization strategy. This lifecycle perspective is important because every stage generates data that can improve the next and provides information in digital form.

This feedback loop is strategically important. Operational data can be used to refine models. Refined models can improve future validation. Future validation can improve the next aircraft generation. In this way, digital twins become not only a development tool, but an engine of continuous learning.

For AI-based aerospace systems, this lifecycle feedback is particularly relevant. Operational data and edge cases observed in the field can be fed back into simulation environments. New scenarios can be generated. Updated algorithms can be tested virtually before deployment. This creates a closed-loop validation process that supports continuous improvement while maintaining control over safety-critical behavior.

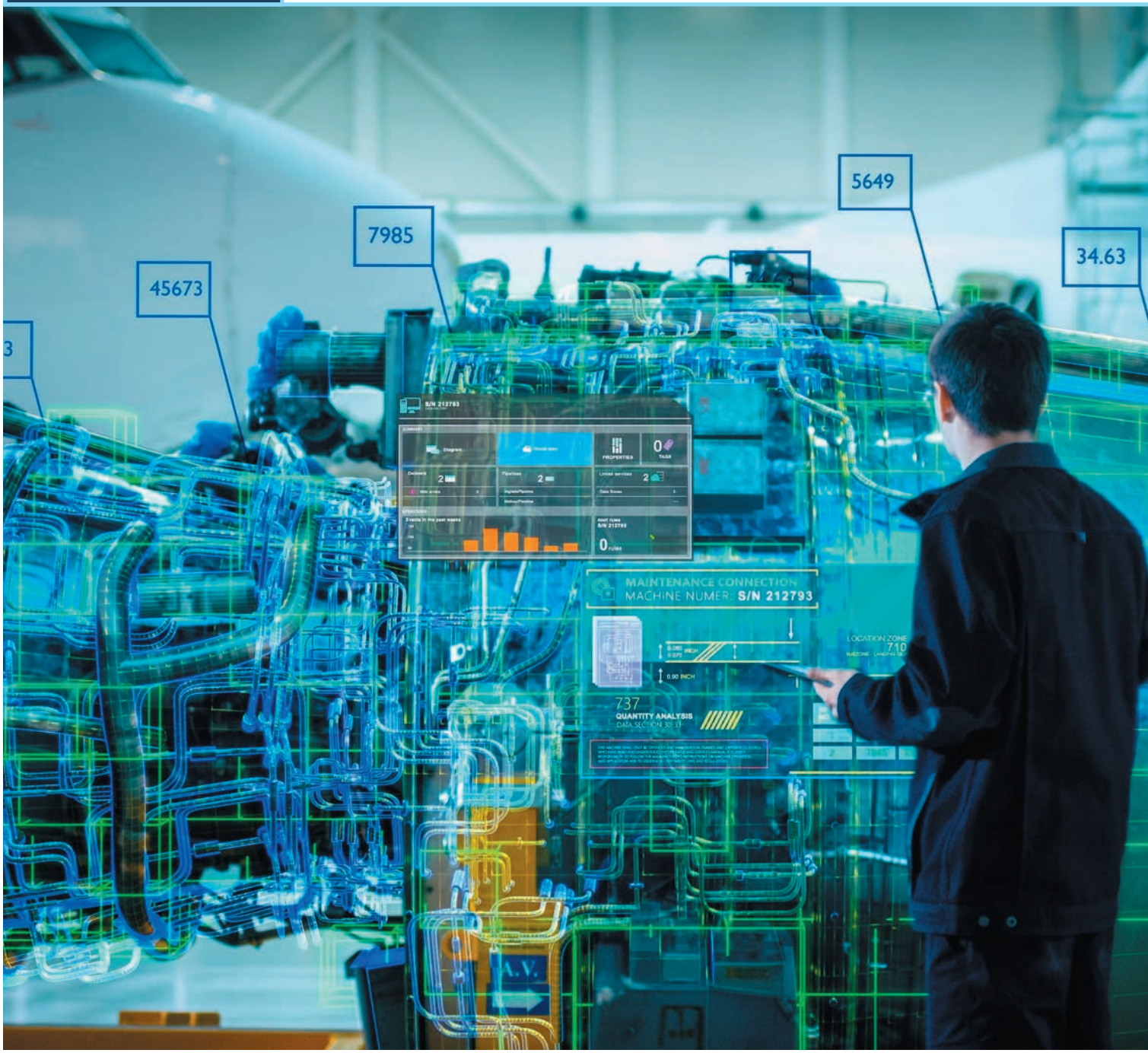
Towards Simulation-Driven Aerospace Validation

Digital twins are transforming aerospace development and testing because they address one of the industry's central challenges: How to build confidence in systems that are becoming too complex, too software-defined, and too scenario-dependent for traditional methods alone. The enablement of earlier testing, faster design iterations, automated workflows, scalable scenario execution, reproducible validation, virtual fault injection, and better integration across domains helps teams bridge the gap between simulation and real-world behavior by allowing systems to enter physical testing at a higher level of maturity.

In a simulation-driven era, digital twins will become increasingly strategic for next-generation aircraft, UAVs, autonomous platforms, and space systems. Aerospace organizations need high-performance simulation environments, including SIL and HIL, automated test workflows, robust data management, and open standards for model and system integration. This is where an end-to-end SIL/HIL tool chain becomes essential, supporting both classical control systems and AI-based functions - from early virtual development to system-level validation. By combining validated models, real-time simulation, automated testing, scenario management, and hardware integration, companies such as dSPACE can support aerospace organizations in setting up digital twins for the development and validation of both classical and AI-based systems.

As aerospace enters a new era of autonomy, connectivity, and software-defined functionality, validation strategies must evolve. Digital twins provide the foundation for that evolution - helping engineers manage complexity, reduce risk, and accelerate innovation with confidence.

By dSPACE



The Virtual Flight Test:

How Digital Twins are Reshaping Aircraft Certification

Today's supercomputers can model hypersonic airflow across a complex airframe in a fraction of a second. Unfortunately, getting human review committees to update, reconcile, and sign off on the corresponding PDF hazard analysis binders can take a fiscal quarter or more. This operational lag—which could be described as "extreme human runtime latency"—is often the silent killer of aerospace innovation.

Today, the aerospace industry is overcoming these administrative delays through "digital twins." These are virtual models of physical systems that act as a bridge between the physical and digital worlds throughout an aircraft's entire lifecycle. During the design phase, digital twins allow engineers to simulate and validate systems virtually. Once the aircraft is built, the twins are continuously updated using real-world data generated by the physical equipment in service.

The payoff: By using digital twins, aerospace companies are able to compile accurate performance



profiles and identify potential issues quickly. The result is a much faster and more accurate path to type certification, backed by solid, documented research, as well as highly optimized fleet maintenance once the aircraft takes to the skies.

Speeding Up Certification via Digital Twins

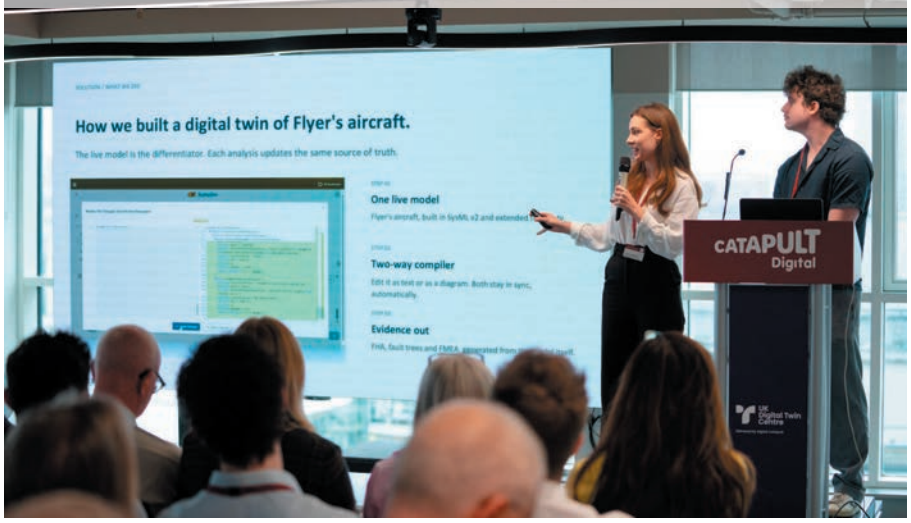
The reason that digital twins are so useful for speeding up aircraft certification is due to the rigorous standards and structured engineering frameworks that govern them.

A case in point: "The Boeing Company adheres to and supports the DOD (U.S. Department of Defense) Instruction 5000.97 definition of digital twin," said Boeing in answers provided to Aerospace Innovations. "A more concise definition that is supportive of DOD 5000.97 definition is often utilized by Boeing: 'A digital twin in aerospace is a replica of a physical aircraft, system, or component that is continuously updated with real-world data throughout its lifecycle. Digital twins maintain a persistent, bidirectional link between the physical asset and its virtual counterpart.'"

The Boeing spokesperson explained that Boeing organizes this capability based on its Model-Based Engineering (MBE) Diamond, pairing the systems engineering design phases directly with synchronized virtual models. "Digital twins are assembled based on use cases representing the product and consist of one or more models that are maintained in synchronization with the current state of the corresponding system," he told Aerospace Innovations magazine. "The composition of the digital twin and integration with the physical product is realized through the digital thread by enabling the data required for virtualization and simulation."

This being said, "it is important to look beyond design and certification alone," noted Rob Mather, IFS' Vice President of Aerospace & Defense. "In

Caroline Welsh from BusbySim showcasing the project together with Reuben Carter from Flyer AI at the UK Digital Twin Centre in Belfast (Copyright: BusbySim)



The Digital Twin cohort 2026, taken at the UK Digital Twin Centre in Belfast (Copyright: BusbySim)




Rob Mather (Copyright: IFS)

that context, the digital twin becomes a living representation of the asset as it operates in the field, not just a model of how it was expected to perform when it left the factory."

For Leonardo Helicopters, digital twins support the entire rotorcraft lifecycle, from development and certification to training and mission preparation. "Over the years, we have developed a robust flight-modeling framework and a range of applications that leverage different components of the helicopter digital twin," said Dario Iannucci, the company's Head of Digital Transformation & Sustainability. "Our models are continuously enhanced using data collected from millions of flight hours across the global fleet. To support this ecosystem, we have also implemented a dedicated Rotorcraft Digital Twin framework that ensures traceability, configuration control, and continuous improvement through structured change and problem-report management."

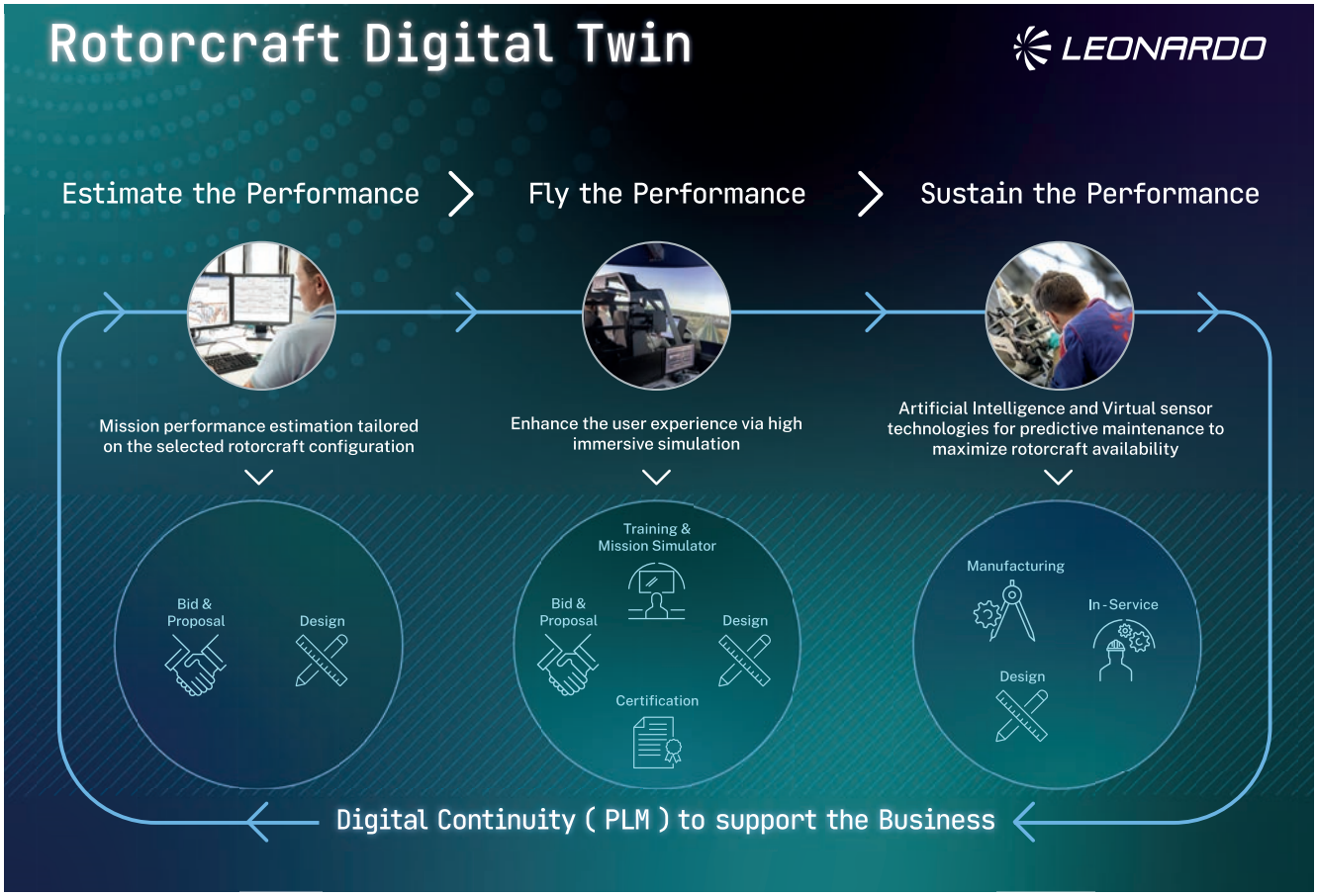
Meanwhile, emerging IT platforms are reimagining the digital twin by integrating design geometry and safety compliance into a single executable model.

For instance, "BusbySim is a new platform that builds a digital twin of an aircraft and puts it to work completing real safety engineering workflows," said Caroline Welsh, founder of BusbySim. "The problem we're solving is that every aircraft that flies has to prove it is safe, and today that proof is built by hand by engineers, often working in silos across different tools, docs, sheets, you name it. Every time the design changes, the analysis has to be changed, and this process is often slow, painful, and it's extremely easy to miss things. As a result, errors are rife, and the safety case is always at least one step behind the design."

Welsh said BusbySim's approach to digital twins eliminates this division. "In BusbySim, the design and the safety analysis aren't separate documents, they're one live model," she explained. "The aircraft's functions, architecture and requirements all live in one place, and so does the safety evidence: the FHAs, the fault trees, the FMEAs. Change the design and the safety case moves with it, and an engineer reviews and approves every step along the way."

The practical impact of BusbySim's integrated approach was recently validated during an active flight program. "BusbyFlyer showed what's possible when the digital twin extends into assurance and certification,

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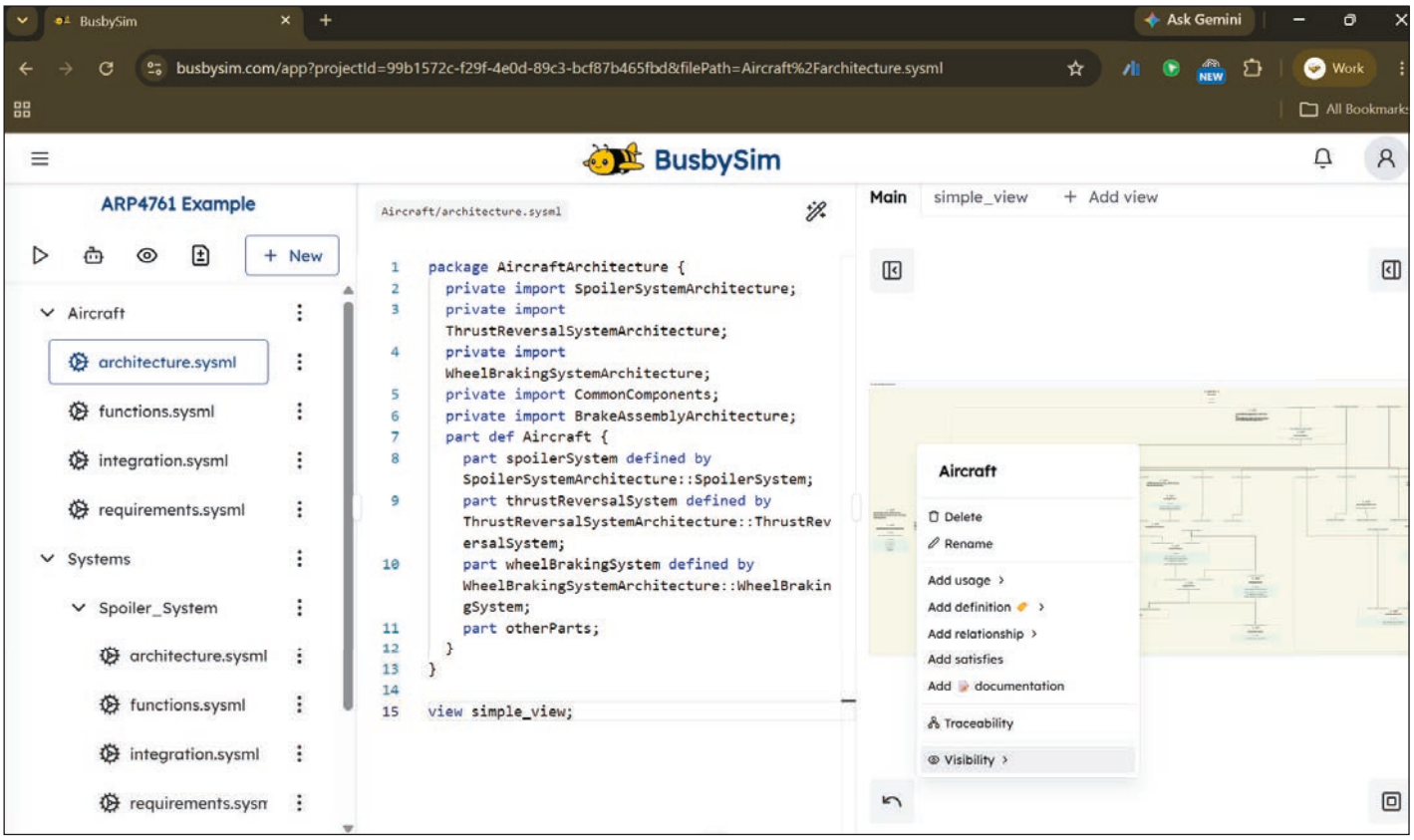
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A product shot of the BusbySim tool in action (Copyright: BusbySim)

linking the live design model directly to the evidence needed for regulatory approval," said Dr. Katrina Thompson, Director at the UK Digital Twin Centre. "Having that evidence accepted by the regulator on a flying aircraft is practical evidence that digital twins can transform how complex systems are designed, assured and certified. That's exactly the kind of demonstrable impact the UK Digital Twin Centre and the Adoption Accelerator programme is here to deliver."

Winning "Credit for Simulation" from Regulators

Reducing required physical flight test hours by using virtual simulations is not something that EASA and the FAA do casually. This is because regulators do not grant certification credit based on theoretical models alone. They demand documented proof that the digital twins' conclusions are accurate and replicable in the physical world.

"At Boeing, our model-based engineering data architecture is built around three core principles that directly address regulatory expectations for simulation credit: traceability, quantified uncertainty, and configuration control," the Boeing spokesperson said. "Traceability means that every model's output can be traced back through its input parameters, boundary conditions, material properties, and underlying assumptions to validated test data that anchors it. Uncertainty quantification refers to our framework propagating uncertainties from material variabilities, manufacturing tolerances, and operational loading spectra through our models, producing statistical distributions of outcomes rather than deterministic predictions. And under configuration management, our digital system model enforces strict version control of the digital twin at every level—model geometry, mesh parameters, solver settings, material databases, and load definitions. When we present simulation evidence to regulatory bodies, we can reproduce any result exactly and demonstrate that the model configuration matches the type design configuration being certified."

But do digital twins actually speed up certification in the real world? Leonardo Helicopters says yes. "One tangible example is the AW169 automatic landing capability, where a significant portion of the design, testing, and tuning activities was carried out within the Rotorcraft Digital Twin environment," said Iannucci. "This approach enabled a substantial reduction in development time while also minimizing the flight-testing effort required on the prototype, accelerating the path from concept to certification."

Overcoming Validation Hurdles and Supply Chain Friction

Of course, validating high-fidelity computer models against actual physical flight test data presents complex technical and organizational hurdles.

"The fundamental challenge is the continuous calibration of model simulations to the physical product," the Boeing spokesperson said. "This necessitates a control loop to evaluate the validity of the

digital twin effectivity." He cited four primary obstacles:

- Data complexity and volume: Aligning variables across millions of individual parts and configurations per aircraft.
- Data provenance and governance: Ensuring consistent naming, source validation, and lineage tracking.
- Integrating lifecycle data: Reconciling real-time operational sensor feeds with baseline physical flight tests.
- Security and IP protection: Balancing regulatory data transparency with commercial trade secret protections.

Meanwhile, making digital twins work reliably and accurately across global aerospace supply chains remains an industry-wide challenge.

"One of the key challenges in advancing the Rotorcraft Digital Twin is integrating data from vendors and partners," said Iannucci. "While digital engineering capabilities are rapidly evolving, industry-wide standards for data exchange and interoperability are still maturing. This makes the seamless integration of component-level digital twins into the overall helicopter model more complex. To address this challenge, Leonardo Helicopters has developed a dedicated Rotorcraft Digital Twin framework that includes standardized interfaces and data dictionaries, enabling controlled, consistent, and traceable data exchange across different systems and models."

Iannucci also highlighted the ongoing problem of creating digital twins for legacy aircraft fleets.

"Newly designed helicopters are born digital, so maintaining their datasets over time is now as standard a process as maintaining paper-based datasets was 20 years ago," he said. "The greater challenge is maintaining the digital configuration of aircraft that were not originally designed in a fully digital environment and still rely on a combination of digital and traditional data. This also requires support personnel to develop a hybrid document-management mindset that can effectively manage both types of information throughout the aircraft lifecycle."

Proving ROI in Dollars, Hours, and Availability

When applied correctly, digital twins deliver dramatic reductions in program schedules, labor hours, and operational expenditures.

A standout proof of this point is the U.S. Air Force's T-7A Red Hawk trainer jet.

"The T-7A Red Hawk is an all-new advanced pilot training system for the U.S. Air Force, widely considered the first digital pathfinder jet," said the Boeing spokesperson. "Using model-based engineering and 3D design tools, the T-7A represents an aircraft with a 75% increase in first-time quality, an 80% reduction in assembly hours and a process that cut software development time in half. In just 36 months, the production-representative jet, called T-X, aircraft moved from firm concept design to first flight, which occurred in 2023."

In field maintenance, using digital twins boosts aircraft availability and fleet revenue. Mather cited one situation where "An IFS customer identified a component issue that, if left unaddressed, could affect other systems, increase maintenance costs, and drive unplanned removals in locations where removing the engine would be highly disruptive," he said. "Using the digital twin, the team modelled different incorporation rates and maintenance approaches for the fix. The analysis showed that a task normally performed off-wing could be done safely on-wing with the right controls in place. That reduced disruption for the operator, helped avoid downrange removals, protected availability, and reduced maintenance risk."

In commercial drone development, BusbySim has demonstrated order-of-magnitude time savings during live safety certification—and created a viral real-world sensation.

"We've been working with Flyer AI, founded by former RAF test pilot Justin Paines. Flyer build autonomous aircraft for last-mile package delivery," explained Welsh. "In April 2026, they delivered the world's first drone fish and chip delivery to none other than James May, complete with a gin and tonic. To get there that fast, we built Flyer's aircraft as a live model in BusbySim and generated the safety analysis from it in the required format. The systems-level functional hazard assessment went from blank sheet to draft in one working day. Flyer's own engineers had budgeted two months for it. In the same way, the Preliminary System Safety Assessment took two days with BusbySim drafting, against an expected three months."

Paines offered an emphatic endorsement: "BusbySim's tooling makes one of the hardest tasks in design and development—systems engineering and systems safety management—an order of magnitude quicker and simpler," he said. "I would have given my right arm for this tool in some of my previous work, with Joby and Vertical particularly."

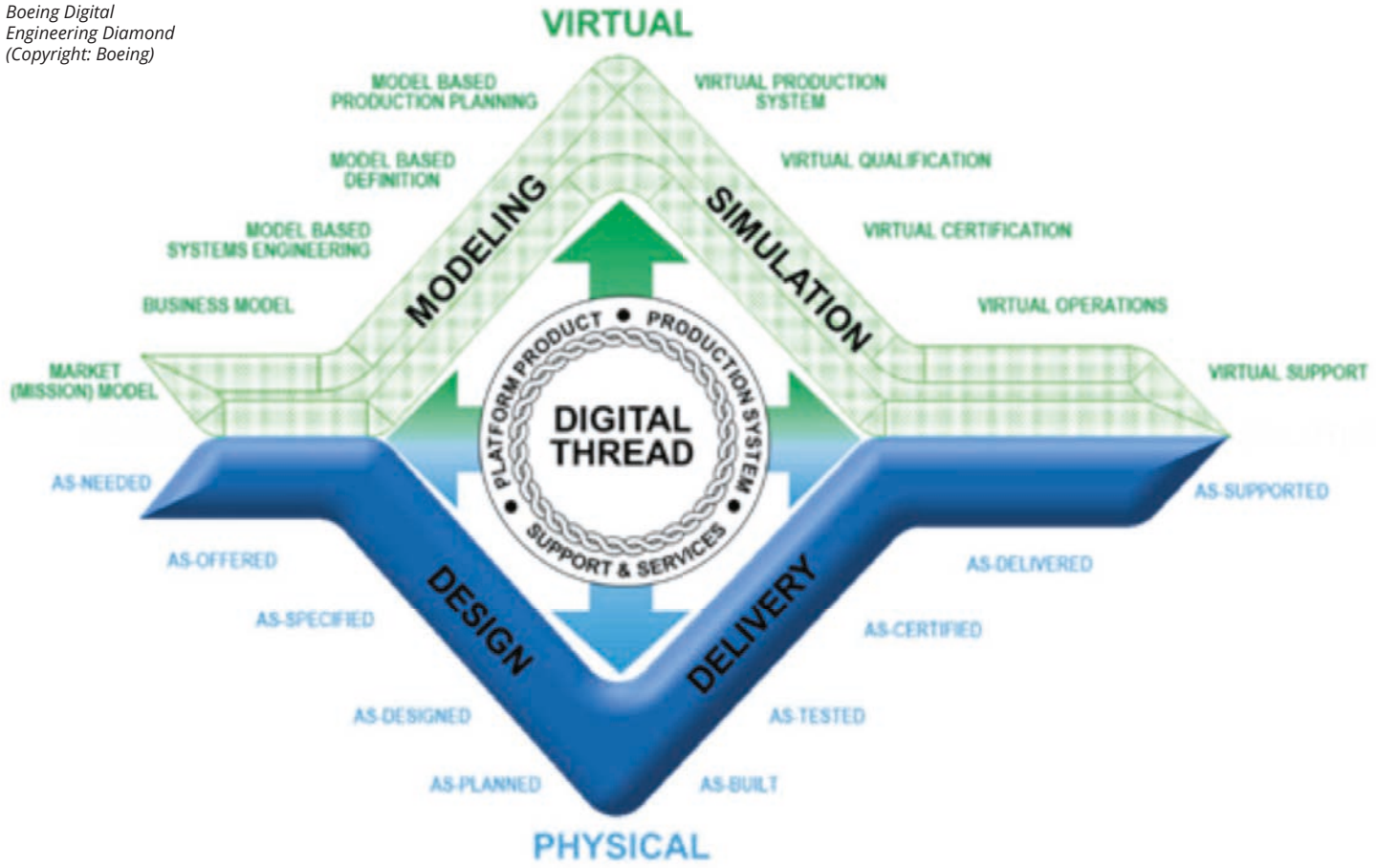
AI as an Active Safety Partner

Artificial intelligence (AI) is rapidly shifting digital twins from static analytical models into active engineering advisors. This shift saves money and time for aircraft operators and maintainers alike.

"In BusbySim, an integrated AI advisor reviews the model continuously against the standard you're working to," said Welsh. "It looks for single points of failure, probability budget violations, and architectural weaknesses. Rather than just flagging an issue, it proposes the specific change, which the engineer sees in full before deciding whether to accept or edit it. This also means junior engineers using BusbySim get a senior-level review every time they save, rather than waiting weeks for a senior colleague to have capacity."

AI also makes sense of data that is too unstructured and vast for humans to understand.

"AI can help refresh models faster, work across larger and less



Boeing Digital Engineering Diamond (Copyright: Boeing)

structured datasets, identify trends earlier, and support faster, more confident decisions," Mather noted. "The opportunity is not prediction for its own sake. It is helping organizations turn complex fleet data into timely, actionable insight with much greater speed and fidelity."

At Leonardo Helicopters, AI's predictive capabilities are being aligned directly with emerging regulatory frameworks to deliver better results.

"Our objective is to leverage the Rotorcraft Digital Twin and advanced analytics to anticipate potential issues before they occur, ranging from technical failures to material and spare-part shortages," said Iannucci. "At the same time, we are preparing for the future adoption of AI in certified aviation environments. To facilitate this process, Leonardo Helicopters is already aligning its development approach with the guidelines and principles outlined by Certification Authorities, helping to establish a robust foundation for the certification and regulatory framework of future AI-enabled solutions."

Navigating IP and Cybersecurity Risks

Sharing high-fidelity digital twin data across international supply chains and regulatory agencies introduces significant intellectual property and cybersecurity risks.

Boeing safeguards proprietary engineering data using strict zero-trust security protocols, a cybersecurity model that assumes no user or device is safe by default and requires constant verification.

"Boeing addresses these risks through strict governance frameworks implemented in its zero-trust security strategy," the Boeing spokesperson told Aerospace Innovations. "Role-based and attribute-based access controls regulate who can view or modify sensitive data. Consolidating data into a centralized, secured platform avoids dispersing sensitive data across insecure mediums like emails or spreadsheets. Detailed audit trails and provenance tracking ensure all access and modifications are monitored."

IFS recommends managing cybersecurity risks by exchanging specific operational data outputs rather than transferring raw digital twin models.

"A practical way to address that is not to share the full digital twin, but to agree on the inputs and outputs that create value for both sides," said Mather. "Operators provide enough fleet information to make the model more accurate, and in return they get forward-looking insight that helps with readiness, budget planning, capacity planning, parts availability, and maintenance execution." He cited major sustainment initiatives—such as the Rolls-Royce TotalCare program and Arcfield's CF-18 avionics support—as prime examples where aligning operational value eliminated data-sharing hesitation across supply chains.

For its part, BusbySim manages supply chain risk through granular, role-based visibility.

"Where a digital twin needs to expose something to a partner across a supply chain, the answer is controlled visibility," Welsh explained. "Partners see the interfaces and the evidence they need, and nothing else. The idea is that you don't have to hand over the whole model." She added that BusbySim is currently working on expanding its models to cover cybersecurity airworthiness standards ED-202A and ED-203A, ensuring cyber threats are tracked in lockstep with physical failure modes.

The Next Frontier: AAM and Beyond

As the aerospace industry advances into Advanced Air Mobility (AAM), eVTOL architectures, and novel hydrogen propulsion, digital twins offer an efficient development path for agile startups.

"For new entrants, the opportunity is to build the digital thread from the start. That is much better than trying to retrofit it later," said Mather. "Digital twins can support design analysis and reduce the need for the traditional 'fly, break, fix, fly again' cycle by giving teams a clearer picture of how an aircraft or system is expected to perform before it is fully fielded."

Welsh pointed out that single-source digital models fundamentally democratize who gets to certify aircraft.

"Plenty of good aircraft die at the business case rather than in the wind tunnel, because the compliance bill grows bigger than the development bill," Welsh added. "Certification has always been for the big players. But now, a cash-strapped team building a new airframe doesn't have to build a safety case from a blank page and then rebuild it every time the design shifts, because the architecture and the safety case are the same model. That single source of truth is what lets a handful of engineers carry a certification workload that used to need a department. Our bet is that the proof can move at the speed of the design, and when it does, it changes how quickly new innovations can take to the sky."

As for the future of digital twins? "The next wave of progress will come from better automated data capture, stronger digital thread continuity, richer IoT sensor integration, improved data cleansing and validation, and the use of AI to refresh and analyze complex models faster," said Mather. "The value is moving beyond a system of record and toward a system of execution: capturing the operational reality of the asset, applying intelligence to that data, and helping organizations make better decisions across maintenance, logistics, capacity, supply chain, readiness, and lifecycle planning."

"Boeing is moving aggressively to leverage the value of the digital twin and the associated capabilities it will enable," the Boeing spokesperson concluded. "This includes enhanced individualization, increased lifecycle support, and a collaborative industry ecosystem."

Ultimately, digital twins are much more than a revolutionary solution for certification challenges. They are becoming the connective tissue for the entire aircraft lifecycle, ensuring that the rotorcraft and drones of tomorrow are not just designed faster, but are safer, smarter, and more cost-effective to operate than ever before.

By James Careless





An AI-based material assistant can help forecast shop-visit workscopes months in advance. (Credit: Lufthansa Technik)

Agents of Change

Agentic AI Offers a Remedy to the Inherently Reactive Architecture of Traditional MRO Practices

Administrative burden in aircraft maintenance remains stubbornly manual. As such traditional MRO is not held back by one single bottleneck, but by the fragmentation of the entire technical operations value chain.

Saravanan Rajarajan, AVP and Head of Aviation Consulting at Ramco Systems paints a picture of a data silo trap.

"Service Bulletins and Airworthiness Directives arrive as unstructured PDFs that compliance engineers must manually extract, cross-reference against fleet data, and convert into Engineering Orders. Technical logbooks and defect data are scattered across manual records or managed in different systems; when an AME encounters a recurring defect, historical record searches are manual and time-consuming. Workscoping for heavy checks requires iterative coordination across engineering, supply-chain, and planning teams. Parts kitting involves multi-factor sourcing decisions (Effectivity, Interchangeability, Certifications, TAT) made under time pressure, often leading to increased exposure to both TAT extensions and cost overruns. Compliance audit trails are fragmented, especially due to hybrid manual and system processing, making regulatory traceability weak," he explains.

Commenting upon this administrative bloat and lack of prediction, Abraham Saada, Founder and Technical Lead at ADO Aerospace says that the industry is fragmented across legacy ERPs (like SAP and Oracle) and static listing sites. "These systems rely on disconnected communication modules and point-to-point emails, meaning getting from a raw document to an actionable maintenance plan is heavily delayed.

Rajarajan adds that these hurdles cluster around a core constraint: every hour of administrative work performed by a licensed AME is an hour not spent on hands-on maintenance. Indeed, as Craig Gottlieb, Managing Director of Aerospace and Defence at Accenture notes, across the industry, planners and engineers spend 40-60% of their time coordinating resources rather than optimising outcomes and making decisions.

Asset lock-up

Another challenge is manual procurement. According to Saada, the entire supply chain relies on

manual RFQs and phone calls. "Furthermore, multiple contracting documents are generated manually on each step, like purchase orders, invoices, and air waybills; which drastically bottlenecks speed and limits the ability to rapidly resolve constraints," he says.

This trickles down into supply chain visibility. Anupam Singhal, President – Manufacturing at TCS says that an aerospace manufacturer may have strong visibility of Tier-1 and Tier-2 suppliers, while dependencies further down the chain can remain less clear. A Tier-4 or Tier-5 supplier producing a small component can still affect the availability of an engine or aircraft, particularly where parts availability is affected by logistics, labour, financial or geopolitical disruption.

"Aviation is also rightly rigorous in its compliance requirements. Every inspection, repair and replacement must be documented and traceable. Maintaining complete and accurate records across multiple systems and stakeholders creates a significant administrative burden, but it remains essential for airworthiness, auditability, regulatory compliance, and passenger trust."

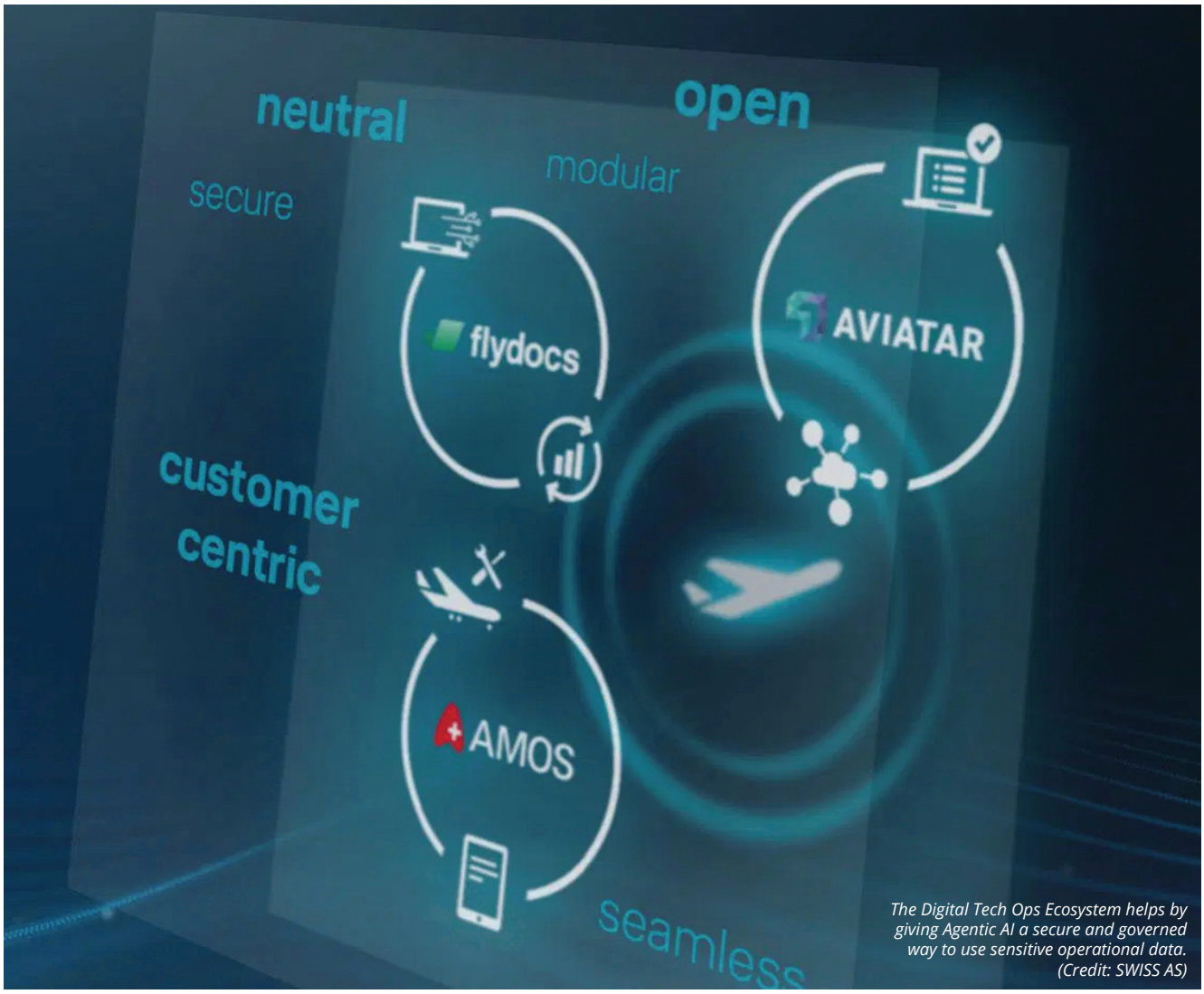
Traditional MRO processes are generally better equipped for maintenance events that are known and planned, but as Saada states, conventional MRO software is strictly reactive —designed for scheduled maintenance. "It operates like a static data storage repository rather than an interactive digital twin, he says.

"When a non-routine event occurs, the ERP system stops, and the manual scramble begins. Traditional platforms lack the dynamic capability to be context-aware; the ERP cannot dynamically reason across global supply chains, it forces humans into a manual fire-fighting exercise across emails and phone calls," he asserts.

According to Gottlieb, unplanned maintenance can cost 30–50% more because of emergency logistics and equipment sourcing. The financial impact becomes even more important within fixed-fee and outcome-based agreements, where providers carry greater responsibility for cost and performance.

Frank Martens, CCO of the Lufthansa Technik Digital Tech Ops Ecosystem remarks that unplanned and non-routine events show why isolated systems are no longer sufficient.

"A defect is rarely just a defect entry," he says. "It can trigger troubleshooting, engineering assessment, material checks, operational decisions, work-order



The Digital Tech Ops Ecosystem helps by giving Agentic AI a secure and governed way to use sensitive operational data. (Credit: SWISS AS)



Agentic AI is not designed to replace sales and procurement managers but is built to replace the admin fraction that keeps them bogged down in manual tasks. (Credit: ADO Aerospace)

creation, execution, sign-off, records updates and follow-up analysis. If those steps are handled in disconnected environments, response time suffers and the organisation loses transparency. The Ecosystem view is different: aircraft health signals, historical maintenance information, operational constraints and documentation are connected so that teams can move more quickly from detection to decision and from decision to compliant execution. This is especially important when the objective is not only to fix one event, but also to learn from it and reduce recurrence."

The common thread is that none of these problems is insurmountable individually, but together they create a context of manual, error-prone, labour-intensive workflows that scale poorly. This is precisely where Agentic AI begins to address the constraint.

Interactive digital twins

Gottlieb claims Agentic AI is particularly well-suited to MRO because it's built to gather and connect dispersed data quickly and at scale. "Individual AI agents perform specific roles—such as monitoring parts availability, workforce readiness or maintenance requirements—while sharing a common view of aircraft condition, documentation, decisions and deadlines. An orchestrator agent can coordinate those agents and bring the right information together as conditions change. In the near term, the biggest value is faster, better insight," he says. "For example, an AI-based material assistant can help forecast shop-visit work scopes months in advance, helping reduce turnaround times and improve material flow. Agentic AI can build on this by continuously connecting operational signals and helping planners respond faster, while humans remain in the lead."

Dr. Yasar Goedecke, Head of Analytics & AI at Lufthansa Technik agrees that Agentic AI goes beyond generative AI, acting as an intelligent assistant that not only retrieves information but also coordinates tasks across systems and workflows.

He provides the example of an engineer reporting corrosion during a C-check.

"An AI agent could automatically identify the affected aircraft configuration, search historical maintenance records, review relevant repair procedures, check parts availability and assess the potential impact on the maintenance schedule. It could then present engineers with recommendations and prepare supporting documentation for



review. The agent acts as a digital coordinator, helping engineers navigate complex maintenance scenarios while ensuring the human experts remain in control of decisions and approvals.

"By reducing the effort required to gather and process information, Agentic AI can accelerate decision-making, improve productivity, increase consistency and ultimately help reduce aircraft downtime. At Lufthansa Technik, we have already explored and developed AI-driven solutions in collaboration with partners including Microsoft, giving us valuable insights into how these technologies can support maintenance operations."

A further illustration is given by Rajarajan, who describes how Agentic AI synthesises information from fragmented data sources and surfaces actionable recommendations within defined guardrails and human approval gates.

"At the document layer, an SB/AD agent extracts structured compliance requirements from PDFs using large-language models trained on aviation technical language, evaluates fleet applicability by cross-referencing against aircraft master data, and generates Engineering Order drafts with task sequencing and resource requirements." He claims processing time drops from 8–12 hours to 30–60 minutes. "At the decision-support layer, a discrepancy-resolution agent performs semantic search over historical maintenance records, surfaces top-ranked resolutions with success-rate scoring, and enables mechanics to resolve faults in minutes rather than hours. At the supply-chain layer, a kitting agent evaluates all feasible sourcing options against a multi-gate framework (EIPC certification, SB/AD compliance, TAT vs. need date, contract rules), autonomously recommends or executes sourcing within pre-approved parameters, and reduces material costs by 8–20%."

However, the proviso here is that these are outcomes from controlled deployments; results vary based on data quality, integration depth, and organisational adoption. "The throughput gains are real, but they depend on foundational data governance and change management," states Rajarajan S.

TCS has applied this approach with an aerospace engine manufacturer. As Singhal recounts, rather than requiring an engineer to work through multiple manuals and large volumes of repair data, the AI-enabled system uses in-service engine data and technical knowledge to present two or three possible repair options, including the advantages and considerations associated with each. "We refer to this as 'Intelligence Choice Architecture'. Here, the engineer remains responsible for the final decision, supported by more relevant information delivered more quickly.

"In one such use case, this approach has the potential to reduce repair turnaround time by around 50%—for example, bringing a six-month process closer to three months. The same approach can also support supply chain resilience. An Agentic AI knowledge graph can map relationships across Tier-1 to Tier-5 suppliers, components, locations and risk signals, helping an aerospace manufacturer identify potential component risks and evaluate alternative options before they become an aircraft-on-ground event," he imparts.

It's about execution, not just answers for Saada. "Agentic AI moves beyond chatbots; it acts as execution software that plans and carries out multi-step work across various systems. Combining these workflows in the various systems is actually something like creating a smart contract or a digital twin of the procurement and supply chain process of the company."

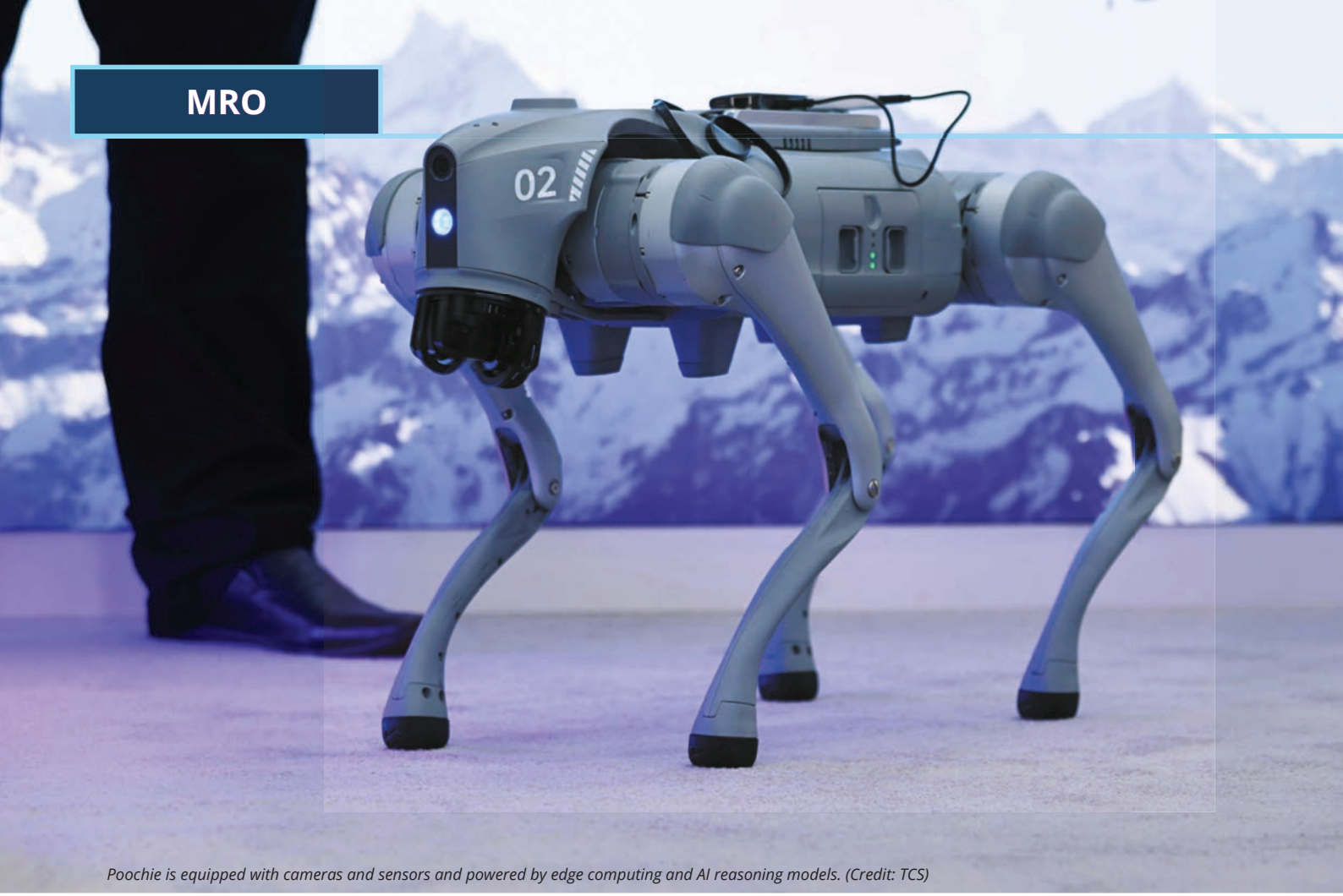
Under the ADO approach, the company deploys context-aware agents that act as an interactive layer. "If a part is needed, the agent instantly queries our "Network of Partners," communicates directly with OEMs or suppliers' inventory gateways, and negotiates the transaction," he says.

The improvement is that a procurement cycle that normally takes days is compressed into hours, drastically reducing AOG time, recovering lost wrench time, and streamlining the aftermarket supply contracts.

Despite these advantages, Agentic AI is cloaked in misconceptions.

Humans in the loop

The most pervasive misconception, says Rajarajan, is that Agentic AI operates autonomously without human oversight. In reality, aviation is a regulated environment where airworthiness decisions cannot be delegated to autonomous systems. No current regulatory framework permits an AI system to make or certify airworthiness decisions without human validation. Every credible deployment preserves human sign-off at the safety-critical decision point:



Poochie is equipped with cameras and sensors and powered by edge computing and AI reasoning models. (Credit: TCS)

an agent recommends, a licensed engineer approves."

Singhal agrees – "We see it as a human-plus-AI operating model. AI can process large volumes of information and identify patterns more quickly, while engineers continue to provide the operational understanding and experience required in a safety-critical environment."

Martens stresses that autonomous aircraft maintenance in aviation is neither realistic nor desirable. "AI should support highly skilled and certified professionals, not replace accountability," he remarks.

For Saada, humans stay in command, and every step runs under human direction or approval. "At ADO Aerospace, we are building sales and procurement agents that learn from the user's behaviour and experience over time, utilising human-centric design to safely provide higher autonomy in the future. The agent will work from the best procurement managers and even elevate their capabilities at the same time.

"Agents carry the heavy administrative lifting of checking global parts availability in multiple data lakes, negotiating with suppliers, and issuing purchase orders. However, the final sign-off, especially for safety, compliance, and airworthiness, always remains with a certified human expert. The agent simply provides the proofs and does the heavy lifting for the human to approve faster," Saada states.

Another misconception is that hallucination (confident but false outputs) makes aviation deployment impossible. Mitigation exists through retrieval-augmented generation (RAG), which grounds outputs in approved source material and requires page-level citations, reducing hallucination substantially.

Agentic AI is not simply a more advanced chatbot. As Saada upholds, the biggest misconception is that Agentic AI is just a generative text wrapper for reading technical manuals. "It isn't just about answering questions and telling you what to do next; it's about securely carrying out the work for you and acting as the execution muscle for the manual tasks."

Dr. Goedecke adds that while conversational capabilities are part of the technology, Agentic AI can also coordinate processes, retrieve information from multiple systems and support complex workflows.

However, Agentic AI cannot simply be layered onto existing MRO processes and technology for maximum benefit. As Gottlieb points out, its value depends on the quality and accessibility of underlying data and, importantly, on rethinking how work gets done. "MROs need to connect data across planning, engineering, workforce and supply chain—and redesign workflows so that AI-generated insights can translate into operational decisions. Agentic AI should therefore be treated as an operational and data transformation, not simply a technology deployment," he says.

An important misconception is that Agentic AI is solved, mature technology ready for enterprise deployment at scale. The reality is still nascent. "Regulatory frameworks are being written, standards are evolving, and integration challenges persist. Organisations deploying Agentic systems today should expect iteration and continuous learning," says Rajarajan.



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Frank Martens, CCO of the Lufthansa Technik Digital Tech Ops Ecosystem


Craig Gottlieb, Managing Director, Aerospace and Defence at Accenture


Anupam Singhal, President - Manufacturing, TCS

Then there is also the misconception that AI can compensate for fragmented processes. If systems remain disconnected, AI will only accelerate isolated recommendations. AI-generated outputs are not always correct, as Dr Goedecke observes. "Like any technology, AI systems can make mistakes and therefore require governance, validation and human oversight," he says.

So, where are we with the adoption of Agentic AI in the MRO environment?

An adoption gap?

Agentic AI in MRO is still emerging, but adoption is accelerating. According to research from Accenture, 61% of aerospace companies are already deploying digital tools across supplier tiers, and 42% identify AI and automation on operational data as their top lever for increasing output without adding capacity. "These are important foundations, but Agentic AI requires another step: connecting data, workflows and decision-making around specific operational outcomes. The MROs getting this right are treating it as a cross-enterprise operational transformation," remarks Gottlieb.

There is a consensus around best practice beginning with targeted use cases where the business value and governance model are clear, such as troubleshooting support, repetitive defect analysis, work package readiness checks, material decision support, audit preparation or lease-transition readiness, before expanding to more advanced Agentic workflows.

To achieve that, the industry must avoid 'rip and replace', advises Saaba. "The best practice is deploying context-aware agents that sit as a layer on top of legacy systems. Instead of forcing OEMs to dump their proprietary data into a shared lake, companies should use strict data sharing protocols where agents securely query local servers without exposing the underlying backend data. We are currently conducting R&D workshops with OEM partners using this exact interactive layer to modernise their ERPs," he says.

If this is the now, then what of the future?

TCS sees Agentic AI working alongside Physical AI. "For example, at Farnborough Airshow, we demonstrated AI-enabled quadruped systems that combine cameras, sensors, edge intelligence, and reasoning models to perform inspection tasks," Singhal says. "These systems can capture images from the required angles, analyse the findings, and provide maintenance teams with a summary of detected anomalies and possible corrective actions. These kinds of systems are valuable for repetitive, difficult-to-access or hazardous inspections, with any certified aviation application progressing through operational validation and regulatory acceptance."

Over the next five years, Ramco expects wider adoption of specialised Agentic agents, regulatory validation of Agentic workflows, and the emergence of multi-agent orchestration as the dominant architecture.

As Rajarajan explains multi-agent orchestration will become standard architecture: multiple agents (SB/AD, discrepancy, kitting, compliance, predictive, scheduling) communicating and coordinating, activating in parallel for complex scenarios. Robotics and Agentic AI will integrate; Agentic inspection robots will identify defects and feed findings into maintenance agents that recommend repairs. "The result is Agentic systems delivering step-change in efficiency and labour productivity—exactly what the industry needs to serve growing fleet demand with shrinking technician availability."

"Over the next 5-10 years, we are likely to see AI become a digital operations layer across the entire MRO ecosystem," believes Dr. Goedecke.

He says the future of Agentic AI in MRO lies in increasingly connected maintenance ecosystems where specialised AI agents support planning, engineering, logistics and


Dr. Yasar Goedecke, Head of Analytics & AI at Lufthansa Technik


Saravanan Rajarajan, AVP and Head of Aviation Consulting, Ramco Systems


Abraham Saada, Founder and CEO, ADO Aerospace

compliance activities in real time. Combined with technologies such as predictive maintenance and digital twins, these capabilities could help move the industry from reactive maintenance towards more proactive and efficient operations

However, the goal is not autonomous maintenance. "Instead, Agentic AI will serve as a powerful digital assistant that enables human experts to make faster, better-informed decisions and keep aircraft available for service more efficiently.

Martens agrees, adding that these agents will help teams detect issues earlier, assess operational impact, check readiness, coordinate follow-up actions, document outcomes and learn from the result. "The strongest value will come from closed-loop processes where prediction, planning, execution, records and asset insight are no longer separate steps, but part of one connected operating model," he asserts. "In practice, this could involve AVIATAR watching the condition of your entire multi-fleet and detecting and interpreting an issue, AMOS and AMOSmobile supporting planning and execution and supporting parts decisions, and flydocs preserving the long-term asset view. For airlines, lessors and MROs, this means fewer disruptions, faster decisions, better compliance readiness, stronger asset value protection and more effective use of scarce technical expertise."

Saada contends we are moving towards the 'Autonomous Supply Mesh': a decentralised "network of networks," where the data lakes from listing websites, OEMs, and supplier inventories can communicate securely with each other through AI agents which intelligently regulate data sharing.

Predictive Liquidation is also on the horizon, whereby agents will continuously audit global inventory, autonomously identifying aging stock and negotiating its sale to active operators before it loses market value.

Saada also sees B2B procurement evolving into high-speed machine transactions within a multi-agent ecosystem. "In this environment, a buyer's agent and a supplier's agent securely negotiate and execute workflows instantly. The true breakthrough, however, is how this architecture seamlessly incorporates and compensates third-party data lakes or networks. If an external data owner—whether an OEM, a supplier, or an existing listing site—provides the critical inventory context that allows a smart supply contract to successfully reach the Purchase Order (PO) stage, the protocol instantly rewards them with a fractional micro-transaction fee. Similar to the instant micro-settlements seen in decentralised finance (DeFi) and cryptocurrency networks, this ensures immediate compensation for contributing to the fulfilment of the contract. We are not aiming to replace existing platforms; we are turning them into monetised nodes within a dynamic mesh."

He reveals that the company is soon to launch its 'most advanced' model, the MRO Edge agent, in Q4. Designed to independently authenticate part availability, initiate multi-party negotiations, and present finalised freight forwarding options, MRO Edge "completes half the procurement workload before a human ever needs to step in."

Encouragingly, according to Accenture 42% of aerospace executives identify AI and automation on operational data as their top action for increasing output without adding capacity.

"Agentic AI can take this further," says Gottlieb, "by continuously connecting signals across demand, supply, workforce, maintenance and customer commitments, giving planners faster and better insight as conditions change. The business outcome is greater responsiveness, more productive use of existing capacity and more consistent delivery against customer commitments."

By Alex Preston



Remote Visual Inspection in MRO

Deeper Insights on Multiple Levels

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In aviation remote visual inspection (RVI) is a non-destructive inspection method in aircraft maintenance that uses camera-based tools to examine engines and various aircraft parts and structures. It enables maintenance personnel to assess internal or inaccessible areas and components quickly and safely. With recent improvements it also enables a higher quality of documentation.

Over the last decade RVI has evolved in a variety of ways. Firstly, it is moving on from the mere approach of looking and documenting findings towards enabling a more measuring-based, analytic and predictive approach to maintenance. In parallel, AI is becoming an essential element in RVI.

Over the last years there were also significant changes to the human element in the MRO process, increasing the need for better RVI technologies. The loss of the experience and tribal knowledge of the boomer generation will need to be replaced and/or bettered. At the same time an increased focus on the consequences of human errors in MRO requires a different approach to documentation discipline, evidence collection, and comparability.

Market developments

For engine maintenance in particular, the growth in demand is driven by the increase in the global aircraft fleet and related engine shop visits. Furthermore, the pressure on aircraft MRO turnaround times, general MRO capacity constraints, as well as increasing requirements from regulatory authorities for safety, traceability, and the better quantifiability of aircraft and engine inspections increases the demands on the industry.

In response to pressures from severe shop capacity constraints and material shortages there is also a trend towards the wider use of an MRE (Maintenance, Repair & Exchange) model. MRE is an evolution of the classic MRO model, but working on the module level, i.e. targeted module swaps and exchange pools, rather than traditional full engine overhauls. It offers a faster and modular alternative and enables the operator to keep engines longer on wings. By also using more Used Serviceable Materials (USM) in the process and offering more Mobile Engine Services (MES) to perform on-wing or near-wing inspections -obviously the natural habitat for more sophisticated RVI technologies- the industry tries to mitigate the above-mentioned risks.

The Evolution of Aircraft Engine Maintenance

Engine maintenance was the first area of the MRO world in which RVI was applied consistently. Engines are the most expensive subsystems of the aircraft and most important for the operation.

Driven by fleet growth and capacity constraints from various factors, RVI technology applied to engines is also the fastest moving segment. This includes the integration of digital workflows that use cloud computing and enable records to be linked to serial numbers.

RVI is literally and metaphorically at the core of aircraft engine

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maintenance because it enables the inspection of internal components such as compressors, turbines or bearings without disassembling the engine. That results in faster turnarounds for each engine, thus lower costs, higher engine availability and less risk of damage induced during teardown. Overall, RVI is shifting from a diagnostic tool that offers a snapshot of the engine status to becoming a source of data for predictive maintenance. In addition, the emergence of digital twins does not only help to avoid the disassembly of engines, but the creation of a complete digital replica of the engine enables much improved analysis and context information.

At the same time the trend towards MRE (Maintenance, Repair, exchange) for engines is becoming more mainstream.

Aircraft Engine Evolution as the Baseline for the RVI Development

The evolution of jet engines from their beginnings is well known to us all. The developments towards the latest generation of commercial turbofan engines (LEAP, GTF, Trent XWB, GE9X..) affected in particular three areas.

Engine Architecture and Geometry

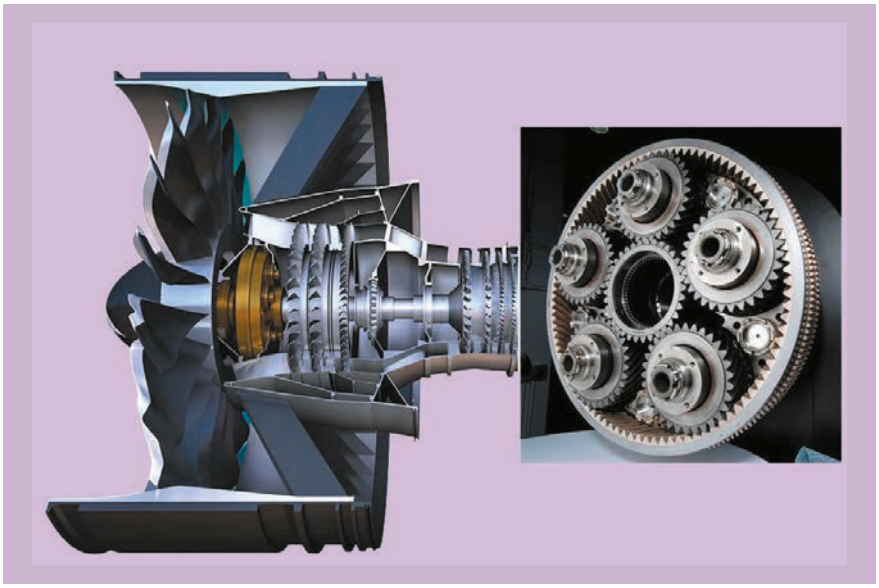
The emergence of the geared turbo fan as an evolution of the direct-drive engine is the most significant development. It changed the engine architecture substantially by introducing a highly complex planetary gearbox which contains a multitude of gears operating at very high speeds and therefore naturally susceptible to damage and wear and tear. In this engine architecture RVI is applied to the various engine modules that range from compressors and combustors via turbines to the mentioned gearbox to detect cracks, burn, FOD (Foreign Object Damage), loss of coating, and erosion.

Engine Materials

The materials used to build and coat components and subassemblies of engines have also evolved. From the increased use of composites to new coatings, the change in materials has an impact on its maintainability and the diagnostic processes or tools required to detect defects. A classic example are highly reflective materials that, with older camera and lighting technology, might prevent the borescope operator to see issues clearly.

Digitalisation of engine related data

The latest-generation engines generate far more data than previous generations. Due to expanded sensor suites and integrated health-monitoring architectures typically more than 5,000 parameters are recorded and streamed per flight, thus enabling predictive maintenance and real-time health monitoring.



Also, the digitisation of maintenance on engines has changed in terms of the types, amounts, and structure of data that are now available. Furthermore, the increased ability to access and validate older data has a major impact on the overall engine maintenance knowledge pool, provided these data are integrated into the bigger MRO data landscape.

The Evolution of Core Techniques in Engine Maintenance

Parallel to the evolution of the engines themselves, the technologies used in the maintenance of engines are evolving.

The main technologies in use today are:

- **Borescopes and videoscopes:** There are a few different types in operation:
- **Rigid borescopes:** These are the first-generation borescopes and are used where there is a straight-line access to parts of the engine like e.g. some combustor elements. Their lack of flexibility limited their applicability.
- **Flexible fibre borescopes:** These second-generation devices offered more flexibility and enabled entering other parts of the engines via various curved paths. Whilst offering better manoeuvrability, the image quality still could be improved.
- **Video borescopes / videoscopes:** These last-generation tools are standard in modern advanced engine MRO. They typically feature high-resolution sensors, high degrees of articulation, and come with interchangeable tips with integrated lighting and inbuilt measuring (2D/3D) capabilities generating 3-dimensional measurements with the help of photogrammetry. That way the maintainer can establish immediately and more accurately the length of cracks, depth of pits, or any foreign object damage (FOD). The introduction of these devices resulted in a step change for quantitative defect sizing as well as the automatic recording of data and images.



Digital Transition driving further developments

Some of the most impactful and efficiency generating developments in MRO RVI technology can be found in the digital world.

- **AI-powered visual inspections**

With its capacity to handle vast amounts of data and the ability to recognise correlations and patterns far beyond what humans are able to see, AI can identify potential defects in real time. Its learning capability helps to quantify and classify defects (Assisted Defect Recognition - ADR). Things like burn marks, cracks, erosions, or loss of coating can be conclusively identified with far higher consistency than a human-only inspection could ever do. They immediately support the inspector in the decision on next steps or even give recommendations. As a result, there will be fewer missed defects as well as fewer unnecessary removals.

The AI-supported defect identification will also bring more decision consistency by eliminating operator variability between inspections by the same inspector, between different inspectors, and across several MRO entities. It will help inspectors to focus on the most relevant data a/o images. Some sources state that AI is cutting inspection time by 50–75%, thus resulting in much faster inspections, shorter ground times and improved fleet availability. Naturally these data feed also perfectly into the overall predictive maintenance landscape.

Overall, AI is not just analysing images, it is changing how images are captured and interpreted, resulting in substantially richer data, much more automated measurements, and less subjective judgements.

- **Cloud platforms as data backbone**

The cloud-enabled centralized storage of reports, images, measurements, and their remote accessibility by different people enables fleet-level predictive maintenance that results in insights which in turn will optimise shop visits and thus supports better long-term fleet planning. This shift from managing individual inspection events to building a structured lifecycle record for each asset by serial number is the capability that will enable fleet-level predictive maintenance.

- **Digital workflows**

Another important aspect of the evolution of RVI tools is how they address and guide inspection workflows. Traditional workflows typically have interruptions between steps. Digitisation, and a more standardised approach supports more consistency and continuity. It reduces the variability between inspections and inspectors whilst speeding up the overall process for repetitive engine inspections. Furthermore, the digitisation-driven much easier integration with maintenance management systems and digital twins enables the deeper and more immediate embedding of the RVI process into the wider MRO landscape. This is particularly relevant for the latest generation engines. They tend to be too complex for legacy RVI workflows, which is why new advanced RVI tools offer a range of features that optimise and integrate workflows (viewing, measuring, recording, changing probes etc.) and with that provide repeatable and quantifiable data for MRO decisions.

Naturally the benefits of the improved digital workflows are applicable to all parts of the aircraft where RVI is used, not just for engines.



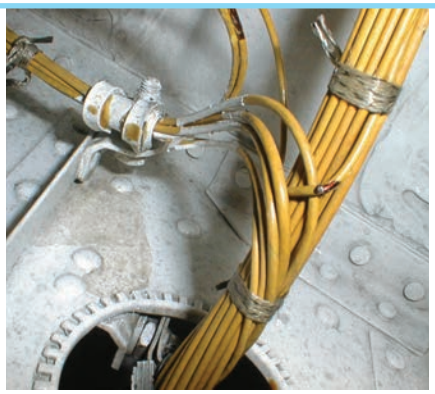
Aircraft Maintenance Beyond Engines

As newer aircraft are becoming increasingly complex and most fleets are currently aging more than originally planned, RVI is becoming a universally applicable inspection method across the entire aircraft. As more aircraft are now flying beyond the 20 to 25-year horizon, the need for corrosion and structural inspections is inevitably growing. Also, regulatory pressures e.g. regarding EWIS requirements (Electrical Wiring Interconnection System) or the need for more focused corrosion prevention programs require more frequent visual checks.

The RVI technologies used outside engine maintenance are largely similar. Naturally videoscopes or borescopes are being used for any confined spaces. Similarly, articulating snake cameras are very useful in the inspection of wiring and ducts. In large structures like cargo bays or wings robotic crawlers -not yet used a lot in engines- can be used as well.

The aircraft sections where RVI is increasingly used are:

- **APU (Auxiliary Power Unit):** The use here is naturally similar to engines.
- **Airframe structures:** Particularly the inspection of fuselage cavities, wing boxes, cargo bays, spars, ribs, and stringers benefits from the use of RVI technology to detect corrosion, moisture ingress, cracking, or delamination.
- **Aircraft fluid systems (fuel, hydraulics, pneumatic):** Similar to the airframe structures, tanks and fuel lines need inspections by RVI. It enables the inspection of internal tubes and reservoirs and is able to detect contamination, wear, foreign objects and microbial growths.
- **Landing gear:** Considering the stresses the landing gear takes; the frequent inspection of the whole assembly is central in MRO. Internal bores of shock struts, actuators, or linkages need to be checked for corrosion, contamination or seal damage.
- **Environmental control systems:** These systems are complex,



large and, whilst not critical to the immediate operability of the aircraft, do have a big impact on the passenger experience. For example, ducts and heat exchangers need to be checked for blockages or contamination.

- **Wiring and avionics:** Especially the detailed inspection of wiring bundles in tight spaces to identify chafing, insulation damage, or loose connectors benefit from RVI technology.

Key Industry Contributors

The market for high-end RVI solutions -whether for engines or other aircraft parts - is dominated by two companies. These are Evident (formerly Olympus Scientific Solutions), and Waygate Technologies (now part of Hexagon). There is also Karl Storz, a company that focusses on RVI endoscopy in a wide range of industries, as well as some regional specialists and several NDT and MRO integrators that bundle RVI hardware with inspection services and data.

EVIDENT

Evident is a major supplier of industrial borescopes and videoscopes that are widely used in aircraft MRO, esp. engines. Evident offers hardware, software, and services in a portfolio that includes guided inspection workflows to enable repeatable borescope paths, on-device annotation and reporting, cloud connectivity for storing images and videos, measurement validation tools for regulatory compliance, and the integration with wider MRO record systems.

In the market Evident is particularly recognised for their family of IPLEX videoscopes which feature highly articulated probes with interchangeable diameters to be able to negotiate the tighter geometries of modern engines. They feature high-resolution optics (Swoptix) for sharper imaging supported by bright, uniform LED illumination. Swoptix works in conjunction with MultiView, an application that lets the inspector switch between views (different sides, near/far) and enables 3D measurement for crack and corrosion sizing. In addition, an app named ViSOL helps to connect the inspection data into cloud storage, various analytics dashboards and ultimately into the bigger asset management workflow. ViSOL's latest release introduces the Blueprint/ Asset model that supports the overall shift from only managing individual inspection events to building a structured lifecycle record for each asset by serial number. This capability makes fleet-level predictive maintenance possible. Evident has clearly taken on the challenges of the next generation engines and used them as a catalyst to refocus their





solution development efforts, having realised that a very big value lies in how these technologically optimised and much more capable tools on the frontline are embedded into the wider MRO landscape. To that effect they are focussing beyond the immediate inspection technology (smaller hardware, maximised optics and lighting (Swoptix)) on optimising in-engine workflows and on integrating documentation and AI-supported analytics processes.

Often Evident is perceived as the default choice for line maintenance teams because of their portability and reliability. However, their move from hardware-centric to software-platform thinking shows a strategic repositioning in the above-mentioned direction. This additional focus on post-inspection workflows will also reduce the need for further inspections in the future.

In an interview Evident addressed the opportunities more digitalised RVI processes offer also for training and skill development. Inasmuch as the digitally enhanced and optimised data from inspections enable more efficient workflows for the inspector on the engine, they can also create much more effective training material which should help to overcome the skill gap that boomers will be leaving behind.

Asked about future developments, Evident sees that even smaller, higher-resolution probes that enable more advanced 3D measurements and AI-assisted defect recognition will create even better RVI findings that will feed into a growing cloud-native inspection ecosystem.

WAYGATE

Waygate Technologies (now Hexagon) is particularly strong in aerospace, power generation, and the oil & gas industry. Like Evident, Waygate is one of the two global leaders in industrial RVI and NDT in aviation MRO. Their key products are the Mentor Visual iQ videoscopes, the InspectionWorks suite of software for workflow management, as well as automated defect recognition, AI analytics, 3D measurements and the resulting data for MRO intelligence.

Through their focus on AI and cloud connectivity Waygate has also realised that the integration of guided workflows and process support functions like e.g. automated labeling to ensure consistent global MRO processes result in better data which in turn leads to fewer repeat inspections and more reliable maintenance decisions. By partnering with engine OEMs such as Rolls-Royce, Waygate is making sure to maximise the value from engine borescope inspections for the MRO.

Future Developments & Conclusions

The market for latest generation RVI solutions will be growing steadily. Within that engine MRO is the fastest moving segment, driven by fleet expansions, MRO capacity constraints, the need to reduce asset downtime and human risk, as well as the increasing demands from the regulatory side.

The following trends are likely to continue or emerge:

- The high-value segments of the market are clearly shifting towards a more integrated hardware-plus-software ecosystems.
- RVI continues to move from a sporadic reactive diagnostic tool to become a more integrated element in the proactive predictive maintenance world.
- The availability of ultra-high-resolution sensors and routine 3D measurement on most mid- to high-end scopes will result in higher resolution imagery. Smaller and more manoeuvrable probes will cope with tighter, more complex engine architectures.
- AI's impact on the industry will grow exponentially by enabling much more robust automated defect classification (ADR) processes as well as more accurate severity scoring.
- AI will help to develop pre-programmed borescope paths and will be able to learn optimal routes through specific new engine models, resulting in improved repeatability and speed.
- AI will result in on-device inference for real-time guidance and defect flagging during the inspection process.
- There will be a much deeper digital integration into cloud-native inspection ecosystems that host standardized templates and processes for automated report generation and supports multiple processes, incl. e.g. the remote sign-off by OEMs or lessors.
- The use of digital twins to assess situations and for training purposes will expand drastically, enabled by the links to RVI imagery and measurements.
- UAV / drone-based inspections are maturing rapidly, especially for external surfaces. Similarly, robotics will become more relevant with e.g. robotic crawlers becoming more prevalent.

These technological trends and capabilities will result in better defect detection, more consistent inspections, much richer data for fleet-level analytics, faster turnaround times, as well as more effective training for new technicians, thus mitigating the risks from labour shortages. All of this will ultimately result in lower lifecycle maintenance costs and higher aviation safety.

By Markus Gilges



Engine Prophets

Predictive Engine Maintenance is Turning Data Into Better Maintenance Decisions

Global GDP growth, rising urban populations and increasing middle classes are driving the upwards trajectory of demand for air travel. Over the next two decades passenger numbers are predicted to grow by up to 4% annually resulting in a doubling of global air traffic, ultimately reaching about 10 billion passengers per year.

Satisfying this appetite for wanderlust will require the global aircraft fleet to grow by around 42,000 new deliveries, with approximately 81% being new-generation single aisle aircraft.

But there's chokepoints in the supply chain that are affecting airline operations. At the time of writing, the aircraft order backlog currently stands at over 18,000 and the average fleet age has reached a record 15.2 years, as airlines retain aging aircraft as a hedge against delivery uncertainty. The result is a shortage of 5,000 more fuel efficient replacement aircraft that the industry had counted on.

Willie Walsh, the then outgoing Director General of IATA told attendees to its 82nd AGM in Brazil in June this year, that this 'ghost fleet' means missed efficiency gains, higher lease rates and increased maintenance costs.

"Why? Because the aerospace supply chain continues its failure to deliver aircraft and engines as promised," Walsh pointedly remarked.

Single-aisle hold up

IATA's June 2026 study, Single Aisle Aircraft Engines MRO: Strategic Levers to Address Supply Chain Challenges, conducted with Emerton, found that the bottleneck is particularly acute for the latest engine models equipping the new generation of single aisle aircraft: A320neo (powered by CFM's LEAP-1A or Pratt & Whitney's Geared Turbo Fan GTF engines), 737 MAX (LEAP-1B), and A220 (GTF engines).

The study further highlights that the single aisle aircraft market is in



Fleet-level predictive models that aggregate data across operators to train better predictions is growing, enabled by OEM data-sharing frameworks and third-party analytics providers (Credit: MTU Maintenance)

a transition phase between legacy aircraft (A320 powered by CFM56-5 or Pratt & Whitney's V2500 engines and 737 NGs powered by CFM56-7 engines) and new-generation aircraft (A320neo powered by LEAP-1A or GTF, 737 MAX powered by LEAP-1B and Comac C919 powered by LEAP-1C).

At the end of 2024 over 23,000 CFM56 (introduced in the early 1980s) and 5,000 V2500 (introduced in the late 80s) were still in service, while around 7,000 LEAP1A (EIS of 2016) EIS) and 5,000 GTF engines (EIS early 2016) had already been delivered by this date.

However, a ramp-up in new aircraft delivery targets, combined with a series of engines design maturity and production quality issues have significantly reduced the engines Time On Wing (TOW). Indeed, the annual number of shop visits required through 2040 will increase further, reaching a peak of over 5,000 shop visits for the LEAP and 2,000 for the GTF respectively, according to the IATA/Emerton study.

While engine OEMs are expanding their overall shop-visit capacity, another lever to enhance engine service is the progress being made in maintenance strategies.

The promise of predictive

As Vikram Gupta, Founder and CEO of India-based Awiros explains, preventive maintenance follows predefined schedules, while condition-based maintenance relies on operational parameters and sensor readings to determine when maintenance is required. For him, predictive maintenance represents the next evolution.



Vikram Gupta, Founder and CEO, Awiros

"It combines historical inspection data, engineering knowledge, operational context and artificial intelligence to anticipate degradation trends before they become operational concerns," he tells Aerospace Innovations.

Aero NextGen's Founder and CEO, Monica Badra expands. "In practice, it means pulling real-time telemetry from sources like ACARS, FADEC (full authority digital engine control), EGT (Exhaust Gas Temperature) margins, oil debris monitoring, and vibration signatures, then running that data through algorithms trained on failure patterns to estimate remaining useful life (RUL) of critical components."

She says that the distinction from other strategies matters. "Preventive maintenance operates on fixed TBO (Time between overhauls) intervals — effective but wasteful, because you're replacing parts based on calendar time, not condition. CBM (condition-based maintenance) is reactive to current state: you act when readings fall outside tolerance. Predictive maintenance goes a step further, it identifies degradation trajectories before limits are breached, giving you a planning window rather than an emergency response."

And she says the operational advantages are real. "Reduced

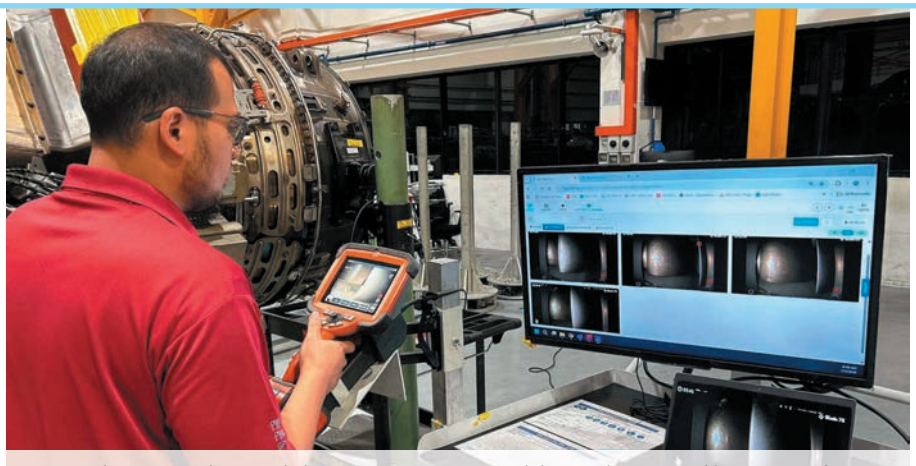


LEAP engines now representing a significant and fast-growing share of the global narrowbody fleet. (Credit: CFM International)

unscheduled removals, better parts inventory positioning, fewer AOG events, and more efficient shop scheduling. For engine MROs specifically, the ability to sequence work against predicted shop visits rather than reactive inductions is a significant throughput and cost lever. The transition from time-based to RUL-based (Remaining Useful Life) thinking is the core shift," Badra states.

From Awiros' perspective, the missing layer in today's maintenance ecosystem is inspection intelligence. "Every manufacturing image, borescope inspection, assembly photograph, configuration verification record and overhaul image contains valuable engineering knowledge that often remains locked inside disconnected systems," says Gupta. "Vision AI transforms these visual records into structured, searchable intelligence that can be compared across years of engine operation.

Rather than replacing engineers, Gupta says Vision AI augments them by retrieving similar historical cases, highlighting subtle progression patterns, and providing explainable recommendations supported by historical evidence. "Over time, every inspection contributes to



Pratt & Whitney recently expanded its engine inspection capabilities with AI-assisted borescope software through the acquisition and integration of Amsterdam-based Aiir Innovations. (Credit: Pratt & Whitney)

a continuously growing digital memory of each engine, enabling more informed maintenance planning, greater consistency, reduced unplanned events, and improved asset availability while ensuring certified engineers retain responsibility for all airworthiness decisions," he comments.

A coming of age

According to Badra, predictive engine maintenance has moved from a research-grade capability to an operationally deployable one, though maturity varies sharply by organisation and asset class.

"Early implementations, largely in the 2010s, were concentrated at OEMs and Tier-1 carriers with the data infrastructure to support them. The tooling was expensive, proprietary, and difficult to integrate outside of new-generation platforms. The broader MRO community, particularly independent shops and mid-sized operators, had limited access.

"The shift over the last five years has been meaningful. Cloud-based analytics platforms have dramatically lowered the cost of entry. HUMS adoption has expanded beyond helicopters into fixed-wing applications. The volume of labelled historical failure data available for model training has grown substantially, improving prediction accuracy. ACARS data is now more widely parsed and acted upon, not just logged. And vendor ecosystems have matured enough that purpose-built solutions exist for specific engine types, CFM, V2500, RR Trent families, rather than generic condition-monitoring tools requiring heavy customisation.

"The gap that still exists is between pilots who can collect the data and organisations who can turn it into decisions. Data capture has scaled faster than analytical capability within MRO operations. That's the frontier: operationalising the insight, not just generating it."

The Delta TechOps Predictive Technology and Innovation team focuses on on-wing predictive/health monitoring to identify engine degradation that could lead to in-flight effects or operational disruptions.

A Delta TechOps spokesperson explains that Delta TOC has been utilising tools across its fleet of engines for over 20 years – "always enhancing our analytics and data sources to provide more insight into the performance of our engines."

Agile learning

The spokesperson continues that predictive maintenance can provide meaningful value when it is continuously measured, validated and improved. "This is why Delta TechOps evaluates predictive models using performance metrics that measure their precision and effectiveness, and we regularly assess whether the analytics are accurately identifying emerging issues," they state.

"It's important to note," they emphasise, "that the industry does not treat algorithms as static tools. We can refine and retrain models based on new operational data and real-world outcomes. Predictive maintenance is an iterative process, where every success and every missed prediction can help improve future performance. Our objective is a disciplined process that continuously increases the reliability and value of the insights being provided.

"As predictive maintenance capabilities continue to evolve, a common engine health monitoring platform, or a true "single pane of glass," will be critical to providing a comprehensive view of engine performance across Delta's large and diverse fleet. Combined with prioritised access to our operational data and a deeper understanding of how our engines operate, this foundation will help improve reliability, accelerate insights and support more informed maintenance decisions."

As an example, its APEX MRO program, which is utilised by Delta Airlines, collects and analyses real-time data throughout an engine's lifecycle. This capability enables Delta TechOps to optimise material planning, shop visits, and production control, reducing repair turnaround times, improving operational efficiency, and generating substantial cost savings while keeping more aircraft flying.



Aero NextGen's Founder and CEO, Monica Badra

"Data capture has scaled faster than analytical capability within MRO operations. "

Aero NextGen's Founder and CEO, Monica Badra

At MTU Maintenance, Dr Christian Keller from the Engine Trend Monitoring Program says predictive maintenance is a central part to the company's strategy to further evolve engine services from reactive or interval-based maintenance toward proactive, data-driven decision-making. Its predictive maintenance capability is primarily a digital and engineering-intelligence capability. "That means, we include operational engine and aircraft data, full-flight data, engine models, neural-networks, digital twins and AI-assisted fleet simulation," he states.

As Dr Keller explains, MTU has been working in this field for many years. Our proprietary Engine Trend Monitoring was introduced in 2006 and has evolved from "just" monitoring into a key pillar of our digital services that includes diagnosis, prognosis and real-time insight, as well as feeding vital information into our fleet management software."

myETM is MTU's engine trend monitoring environment. It tracks parameters such as exhaust gas temperature, fuel flow, shaft speeds, oil parameters and bleed settings. If the system detects a trend deviation, MTU experts assess the data and provide qualified recommendations. These can range from a simple watch item to on-wing action, urgent repair or earlier preparation of a shop visit. "This data can also feed into our wider fleet-management tools, where it supports optimised removal planning, material forecasting and scenario analysis," he says.

As a lever amongst a range of strategies to help avoid delays and optimise maintenance costs across an entire fleet, predictive engine maintenance is not without its challenges.

Predictive pickle

Whilst these challenges are well understood; the difficulty is in solving them at scale inside real MRO operations, claims Badra.

"Data quality and completeness remain the most persistent barrier. Predictive models are only as good as the data they consume. Missing ACARS reports, inconsistent borescope documentation, or gaps in oil debris monitoring logs introduce noise that degrades prediction reliability. Many shops are working with partially digitised records that weren't captured with analytics in mind," she says.

Dr Keller agrees, adding that predictive maintenance also has to recognise the limits of prediction. "Even with strong data, the final workscope can only be fully determined once the physical engine is inspected," he states.

For Gupta, much of the enormous volumes of visual inspection



Dr Christian Keller, Engine Trend Monitoring Program, MTU Maintenance

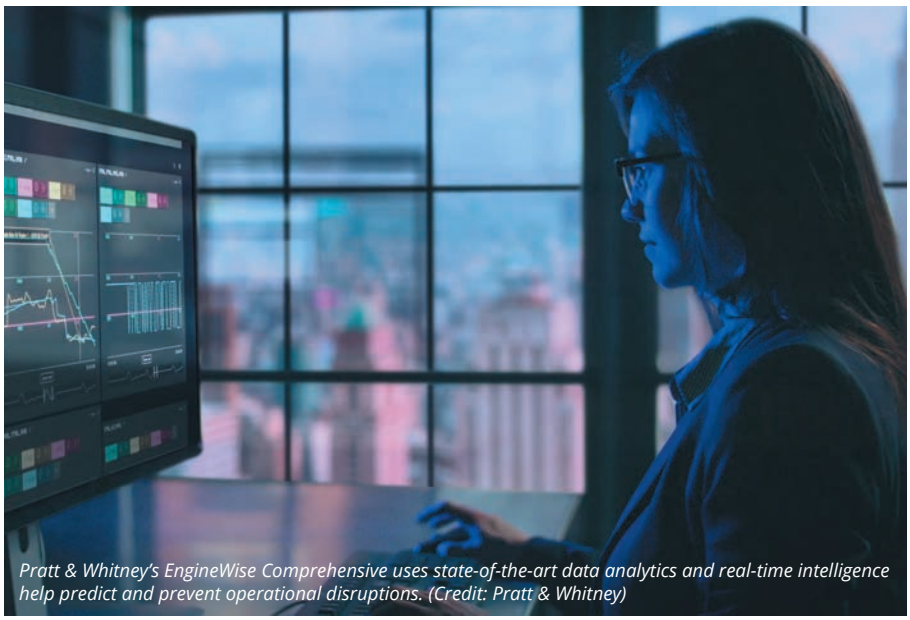
generated by the aerospace industry remains fragmented across OEMs, MROs, suppliers and airlines. He credits the difference in image quality, inspection methods, data formats and documentation practices as making large scale analysis challenging.

Legacy system integration is closely related. Most MRO environments run a mix of ERP, MES, and engineering systems that don't communicate natively says Badra. Getting sensor data, shop findings, part traceability, and maintenance history into a unified data layer is therefore a significant integration project before any predictive algorithm can run.

An enthusiastic supporter Gupta believes Vision AI addresses these challenges by standardising visual interpretation, creating digital traceability and converting unstructured imagery into engineering knowledge. "Combined with domain expertise and robust governance, this creates the foundation for future predictive maintenance without compromising regulatory compliance or engineering oversight," he says.

Regulatory acceptance is a real constraint. Airworthiness authorities require documented evidence that a predictive-driven maintenance decision meets or exceeds the standard established in the MRB. Getting that approval pathway defined adds time and cost to deployment says Badra.

"Model interpretability matters for maintenance engineers. A black-box prediction that says "remove in 200 cycles" gets challenged unless



Pratt & Whitney's EngineWise Comprehensive uses state-of-the-art data analytics and real-time intelligence help predict and prevent operational disruptions. (Credit: Pratt & Whitney)





Delta TechOps APEX MRO program collects and analyses real-time data throughout an engine's lifecycle. (Credit: CFM International)

engineers understand the driving indicators. Explainability isn't just a technical feature, it's a change management requirement," Badra says.

"Organisations we work with through Aero NextGen's Solution Finder — a free, vendor-neutral matching tool that connects MROs with vetted predictive maintenance technology providers — consistently cite integration complexity and data readiness as their top blockers, ahead of cost."

Multi-layer approach

The technology stack for predictive engine maintenance has several interconnected layers.

Awiros believes Vision AI will become a foundational layer of future aircraft maintenance. "Our visual inspection capabilities transform images into structured engineering intelligence through anomaly detection, configuration verification, inspection documentation, historical comparison, and digital traceability," asserts Gupta.

At the data acquisition layer, Badra says the foundation is IoT-enabled sensor networks feeding continuous telemetry — EGT trends, vibration signatures, oil debris particle counts, and FADEC parameter outputs. ACARS

remains the primary air-to-ground data pipeline for in-service monitoring, supplemented increasingly by onboard HUMS where installed.

At the analytics layer, machine learning models — specifically anomaly detection, regression models for RUL estimation, and classification models for failure mode identification — process the telemetry against trained baselines. Digital twin frameworks are emerging as a structuring approach: building a virtual representation of the engine that updates against real operational data and surfaces deviations before they manifest as physical symptoms.

Delta TechOps uses engine parameter data collected in-flight, physics-based performance analysis to identify deviations from expected engine behaviour, and machine learning models that evaluate engines against fleet performance. It also uses domain adapted large language models to draw information from unstructured sources such as maintenance records and shop findings. These capabilities are being consolidated onto a common engine health monitoring platform.

AI-assisted borescope analysis deserves specific mention. Computer vision tools trained on thousands of labelled inspection images are now commercially available and reduce inter-inspector variability significantly, an important data quality input to predictive workflows.

"Our experience working with leading global aerospace organisations demonstrates that consistent, AI-assisted visual inspections can improve quality, reduce variability and establish the digital foundation required for predictive maintenance," remarks Gupta. "As the ecosystem matures, this visual intelligence will integrate with operational, sensor, and maintenance data to create a holistic view of engine health."

Several threads are converging in a way that will materially change how engine maintenance is planned and executed over the next decade.

Looking ahead, Dr Keller sees the industry moving toward larger data sets, full-flight data analytics, predictive digital twins, AI-assisted inspection and more prescriptive maintenance planning. "We do not expect a single moment when this future suddenly arrives. It will be a gradual progression from better monitoring to better prediction, then to more integrated and eventually more automated decision support," he opines.

For Delta TechOps, condition-based maintenance is another key area of focus, where engine data is used to determine the optimal time to perform maintenance rather than relying solely on fixed intervals. This approach has the potential to support maintenance decisions based on actual engine condition, improving efficiency while maintaining safety and reliability.

"As these capabilities evolve, we are focused on expanding our analytics from snapshot-based engine data to full-flight data, providing richer insight into engine performance across all phases of flight. Achieving this vision will require technology platforms capable of processing significantly larger and more complex data sets," a spokesperson says.

This evolution underscores the importance of data quality, consistency, and reliability. Predictive maintenance programs are only as effective as the data that supports them, making a strong data foundation critical to delivering accurate, actionable insights.

Embedded diagnostics and self-reporting engines are the most significant structural shift. As Badra notes, new-generation platforms, and retrofitted sensor packages on legacy platforms, are moving toward engines that continuously report their own health state, narrowing the gap between what the engine knows and what the MRO sees. "The vision of a truly self-inspecting engine, where internal sensing replaces scheduled borescope access for routine assessment, is technically plausible; the certification path is what determines the timeline," she says.

Badra also highlights autonomous maintenance decision support —AI systems that generate a recommended maintenance action, not just a flag — which is already deployed in limited forms. "The near-term evolution is less about full autonomy and more about integrating predictive outputs directly into work order generation and parts procurement, eliminating the manual translation step between data and action," she remarks.

A final observation from Badra, is the growth of fleet-level predictive models that aggregate data across operators to train better predictions, enabled by OEM data-sharing frameworks and third-party analytics providers. The network effect here is powerful, each additional engine in the dataset improves prediction accuracy for all.

By 2035, every aircraft engine could have a continuously evolving visual digital twin that learns from manufacturing through retirement. That's the belief of Gupta, who says engineers will work alongside AI copilots capable of retrieving historical evidence, comparing inspection findings across fleets, and identifying degradation trends long before they become operational issues.

"Awiros envisions a future where every inspection strengthens the intelligence of the next one," he says. "Vision AI will not replace human expertise; it will amplify it, enabling safer operations, more efficient maintenance planning, improved sustainability through optimised component life and a continuously learning aerospace ecosystem."

When does this fully arrive? For Badra, the technology is ahead of the operational and regulatory infrastructure needed to exploit it. "For leading organisations, meaningful predictive-driven maintenance is operational now. For the broader MRO market, the 2028–2032 window is realistic for widespread adoption, driven by platform refresh cycles, regulatory clarity on data-driven airworthiness, and a generation of digital-native maintenance engineers entering the workforce."

By Alex Preston

AVIONICS AND TESTING INNOVATIONS

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- Min (not charging): 500mW

MAX OUTPUT POWER PER PORT
- Dual USB Type-C: 27W

REQUIRED CIRCUIT BREAKER SIZE
7.5A

DIMENSIONS
- Side Connector: 1.50" x 1.55" x 0.84"
- Rear Connector: 1.50" x 1.50" x 0.92"

WEIGHT
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Boeing *737-7 MAX approval in progress*

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