Q2 MAY 2025

AEROSPACE INNOVATIONS

News, views and analysis of the commercial and defence sectors

MULTICORE: SETTING THE STANDARD IN AVIONICS

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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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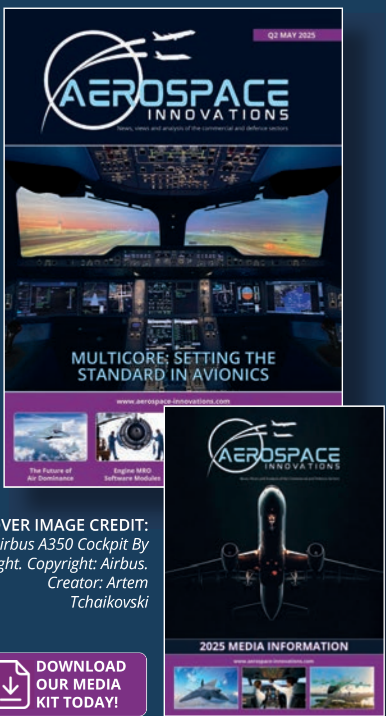

COVER IMAGE CREDIT: *Airbus A350 Cockpit By Night. Copyright: Airbus. Creator: Artem Tchaikovski*

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Tariffs, Supply Chains, and the F-47

Since April 2nd ("Liberation Day") the world has witnessed wild swings in global stocks markets and huge uncertainties still remain regarding what impact levels the increased tariffs will have on global trade. We will see in the coming weeks and months how many countries can manage to do deals with the U.S. administration to get them to agree to lowering the tariffs for them.

Aerospace and defence supply chains and tariffs are of course global and interconnected, and tariffs are already causing some alarm. A recent case in point being the recent return of two newly built Boeing 737 MAX 8 aircraft destined for China. Related to supply chains, Spirit AeroSystems is divesting of certain assets and sites to Airbus, while concurrently finalising the broader acquisition of Spirt AeroSystems by Boeing.

In our packed Q2 (May 2025) edition, Alex Preston spoke with several companies about the ongoing challenges the aviation industry battles with regards to supply chains, and how AI can help streamline manufacturing and MRO processes. In his second article, Alex talked to some of the leading Advanced Air Mobility companies about the developments with their eVTOL programmes.

James Careless interviewed several experts in his article about Multicore processors and discovered how they are setting the standard in modern avionics. In his second article, James spoke with some leading MRO software companies about engine-specific maintenance modules. In his third article, James revisited his experience from his recent tour of CAE's facilities in Canada and shines a light on their innovative and varied products and services.

Ian Harbison interviewed several leading connectivity companies about advances being made in downloading and analysing data for flight operations and maintenance, while Mark Robins investigated the world of NDT and examined how regular NDT checks help keep aircraft flying safely.

Our first guest article in this issue is from AdaCore and is about Rust, which is a systems programming language designed for safety, speed and concurrency, and aims to empower the aerospace industry. Our second guest feature in this issue is from Troy Medeiros at Alderman & Company. Troy talks about the future of air dominance, with the integration of manned and unmanned aircraft, and looks at Boeing's MQ-28 and the recent award of the NGAD next-generation fighter platform (F-47) to Boeing.

We look forward to meeting those of you who will be participating in our forthcoming Avionics & Testing Innovations Conference in London in May. We also look forward to seeing those of you who will be attending the Paris Air Show in June. Aerospace Innovations is proud to have two of our journalists nominated for Awards at the prestigious Aerospace Media Awards, ahead of the Paris Air Show.

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 or suggestions for us about our publication.

Best wishes,
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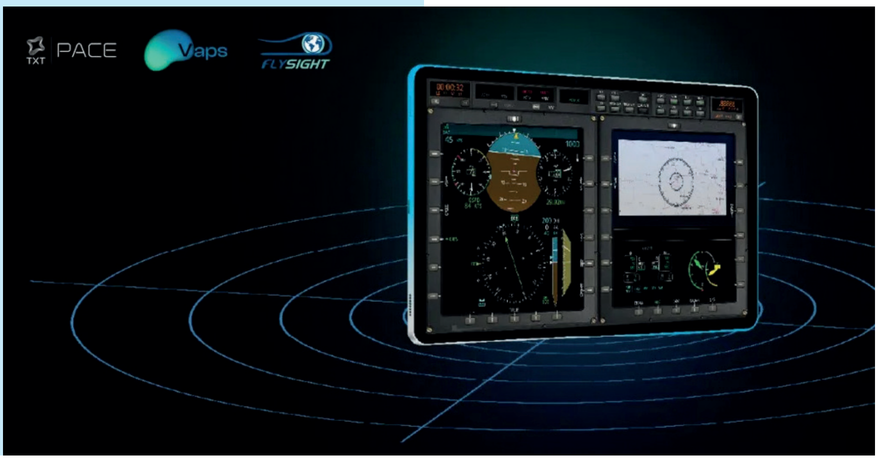
PACE and FlySight Announce Strategic Partnership for Tool Integration

PACE Aerospace & IT and FlySight are excited to announce a strategic partnership aimed at integrating their advanced tools to enhance the capabilities of mission and safety-critical applications.

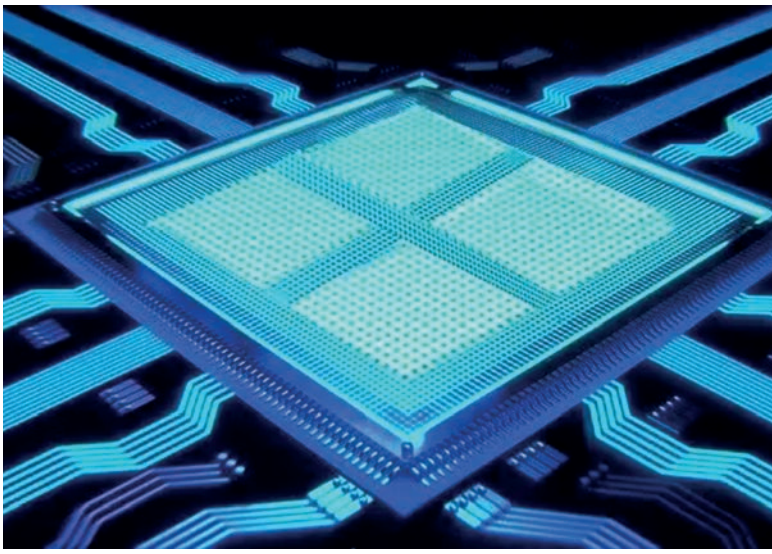
This collaboration will bring together PACE's VAPS XT, a state-of-the-art tool for creating dynamic, real-time graphical Human-Machine Interfaces (HMIs), with FlySight's OpenSight an advanced PED (Processing, Exploitation and Dissemination) platform. The result will be a powerful synergy that improves the efficiency, performance and situational awareness of next-generation avionics systems.

By combining VAPS XT expertise in the development of interactive and certifiable HMIs for complex safety-critical environments with OpenSight's geo-exploitation SDK – designed for comprehensive mission data analysis and visualization – this partnership introduces a new standard in mission computing technology.

Together, PACE and FlySight aim to deliver robust, reliable, and high-performance solutions that support seamless operation and enhanced user experience across the aviation industry.



Wind River Supports First-Ever FAA Technical Standard Order for Fully Enabled Multi-Core Processor by RTX's Collins Aerospace



In Collins Aerospace's multi-core processor, cores can simultaneously execute applications across all design assurance levels. With the U.S. Federal Aviation Administration granting the company a Technical Standard Order — the first for such a system — new capabilities can be incorporated into future aircraft without recertifying flight-critical applications.

Collins Aerospace — a Wind River customer — has earned a key authorization for its new multi-core processing platform that, among other achievements, provides a significant performance increase without sacrificing power consumption.

VxWorks 653 v3.0.1.1 played a critical role in enabling Collins Aerospace to achieve the FAA's first Technical Standard Order certification for a multi-core avionics system. This milestone marks a significant leap forward in software-defined avionics, as it allows manufacturers to harness multi-core processing for performance; reduce size, weight, and power (SWaP); and prepare for future mission capabilities. It aligns with the principles of the modular open systems approach (MOSA), enabling significant cost savings over the certification lifecycle.

Built to meet DO-178C DAL A requirements and FAA AC 20-193 multi-core guidance, VxWorks 653 delivers MOSA conformance, hard-real-time determinism, ARINC 653 partitioning, and multi-core interference mitigation, all of which support safe, scalable, and high-performance avionics applications. This technology is foundational to Wind River Helix Virtualization Platform, which enables customers to seek AC 20-148 Reusable Software Component credit and use DO-297–compliant integrated modular avionics platform features on the latest hardware.

A modular platform approach, such as one based on VxWorks 653 or Helix Platform, makes it easier to add capabilities without requiring the entire platform to be recertified. Support for multiple guest operating systems, from various vendors or open source distributions, enables flexibility and reuse of existing applications. This also helps avoid vendor lock-in, a key tenet of a MOSA.

Boeing to Sell Portions of Digital Aviation Solutions to Thoma Bravo for $10.55 Billion

Boeing has entered into a definitive agreement to sell portions of its Digital Aviation Solutions business, including its Jeppesen, ForeFlight, AerData and OzRunways assets, to Thoma Bravo, a leading software investment firm. This all-cash transaction is valued at $10.55 billion.

Boeing will retain core digital capabilities that harness both aircraft and fleet-specific data to provide commercial and defense customers with fleet maintenance, diagnostics and repair services. This digital expertise will continue to provide predictive and prognostic maintenance insights.

"This transaction is an important component of our strategy to focus on core businesses, supplement the balance sheet and prioritize the investment grade credit rating," said Kelly Ortberg, Boeing president and chief executive officer.

The transaction is expected to close by the end of 2025 and is subject to regulatory approval and customary closing conditions.

Honeywell Advances Technology for the European Defense Sector – Two New EU-Funded Projects

Honeywell has received two research grants to execute projects aimed at advancing avionics and cybersecurity capabilities for the European defense sector.

The multi-year projects will be carried out by Honeywell International s.r.o. – a subsidiary of Honeywell International based in the Czech Republic. The work will be conducted at the company's advanced engineering center in Brno.

The New Generation Military Integrated Modular Avionics (NG-MIMA) project and the Artificial Intelligence Deployable Agent (AIDA) project have been awarded under the European Defence Fund (EDF), which supports the development of European defense innovation.

The selection of Honeywell International s.r.o. as a consortium member highlights the company's commitment to fostering domestic innovation in Europe and its support for the European Defence Industrial Strategy.

The NG-MIMA project, coordinated by Spanish company Indra Sistemas, aims to develop next-generation European military avionics in the form of an integrated, modular system for aircraft. The AIDA project, led by CR14 – a foundation established by the Estonian Ministry of Defence – focuses on the development and modernization of cyber defense technologies.

Leonardo Selects Wind River VxWorks to Deliver Software-Defined Advancements for Aerospace and Defense Safety System

Wind River®, a global leader in delivering software for the intelligent edge, today announced that Leonardo, one of the world's leading players in the aerospace, defense, and security sector, has selected VxWorks real-time operating system (RTOS) to deliver software-defined advancements for its state-of-the-art safety-related radio frequency (RF) system on multicore processor architectures.

To address the challenge of using different multi-core processor architectures for individual system functions within the Leonardo RF system, the company is using VxWorks to provide a common application runtime environment across processor architectures. Leonardo is developing applications to run on VxWorks and will undergo DO-178C DAL C certification.

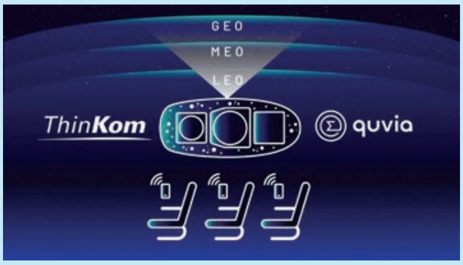
VxWorks provides flexible single-core and multi-core support on different architectures, enabling individual systems to be configured depending on application performance requirements and safety certification requirements. Proven in the most challenging safety-critical applications, Wind River technology makes it easier and more cost-effective for organizations to meet the stringent safety certification requirements of EN 50128, IEC 61508, ISO 26262 and DO-178C / ED-12C.

The first and only commercial RTOS to support Open Container Initiative (OCI)–compliant containers, VxWorks OCI container implementation uses a lightweight minimal footprint combined with VxWorks Real-Time Processes (RTP). This enables the development of containerized applications on VxWorks and can enable Leonardo to rapidly deploy new software-defined capabilities.

ThinKom and Quvia Team Up for Multi-Link In-Flight Connectivity Experience Boost

The future of in-flight connectivity (IFC) is multi-band, multi-beam and multi-constellation. ThinKom Solutions (ThinKom) and Quvia, the first AI-powered QoE platform for commercial aircraft, are teaming up to make that a reality. Through this partnership, the companies will integrate ThinKom's best-of-breed satcom antenna hardware and Quvia's network management software to optimize quality of experience (QoE) in the commercial aviation market.

The resulting solution combines ThinKom's ThinAir® Plus terminal with Quvia Grid, an AI-powered network management solution, to ensure airlines can support multiple concurrent data links with full visibility and control of the IFC experience. Airlines can now get future-ready with technologies designed to orchestrate and optimize hybrid connectivity across multiple links and satellite orbits, enabling robust, reliable, and affordable connectivity for their customers.



ThinAir Plus serves the multi-orbit demands of today while enabling the multi-band, multi-beam, multi-constellation needs of tomorrow. The field-proven, highly efficient ThinAir Ka2517, supporting GEO, MEO and LEO connectivity, is augmented by an integrated LEO-only ESA in a standards-compliant mounting. The multi-aperture solution supports concurrent connectivity across multiple constellations.

ThinKom's ThinAir Plus solution will be packaged with Quvia Grid as a fully integrated solution. Grid's intelligent traffic management functionality sits between the aircraft and ground networks. It uses AI and machine learning to classify traffic types and route data across multiple available networks based on latency sensitivity, link capacity, bandwidth costs, application requirements and other factors to deliver an optimal QoE for passengers.

Pegasus x Microsoft: Strategic Alliance Boosts Satisfaction with AI at Its Core

Pegasus Airlines has significantly enhanced customer and employee satisfaction through its collaboration with Microsoft, leveraging Azure AI Services. Microsoft has praised the airline's AI transformation, calling it a "prime example" of how technology drives strategic value. The integration of AI-powered solutions doubled customer satisfaction with Pegasus' FlyBot virtual assistant as well as boosting employee satisfaction by 20% for the human resources virtual assistant.

Ümit Şener, Data and Artificial Intelligence Specialist at Microsoft, said: "Our AI transformation project with Pegasus Airlines is a prime example of how technology drives strategic value in business processes. By implementing one of the best AI use cases both in Türkiye and globally, Pegasus has established a pioneering position in the aviation industry. As Microsoft, we are proud to be part of this transformative journey."

The success includes enhancements like real-time customer support through FlyBot and personalized travel recommendations via ChatGPT, along with AI-powered solutions improving employee workflows.

Embraer to Offer Intelsat's Factory Installed High Speed WiFi System

Embraer, a global aerospace industry leader, has finalized an agreement with Intelsat to install its high-speed in-flight connectivity (IFC) system on E-Jet E2s during aircraft production. The system, with transmission speeds up to 275Mbps, gives passengers in the sky a similar streaming and surfing experience to their home networks. The Intelsat product is the first multi-orbit satellite system to incorporate an Electronically Steered Array (ESA) antenna, which for passengers means wider coverage, faster transmission, and greater reliability. The Intelsat ESA, which is offered as an option, will be available for line-fit by the end of this year.

"Intelsat is the first multi-orbit satellite inflight connectivity system with an electronically steered array (ESA) antenna to be installed at the Embraer factory, allowing passengers access to reliable, streaming connectivity starting immediately when aircraft enters revenue service," said Rob Baird, Director of OEM Programs at Intelsat. "Passengers on Embraer E2 aircraft will soon enjoy the same high speed internet access from the clouds that they enjoy at home, thanks to our wide coverage and low latency."

Intelsat's LEO network has low latency (the delay between sending and receiving data) and covers the entire Earth, including the polar regions. The GEO network is ideal for more densely populated areas, like big cities. The ESA antenna itself is lightweight. Its low profile (less than 3 inches) generates less drag compared to other designs. This helps minimize fuel consumption in keeping with Embraer's commitment to ensuring the E2's sustainability characteristics.

GKN Aerospace Secures Three-Year Contract with Boeing for C-17 Fan Blade Repairs

The contract represents a significant milestone in GKN Aerospace's ongoing expansion of Maintenance, Repair, and Overhaul (MRO) capabilities for both military and civil aero-engine components. The new 150,000-square-foot San Diego facility, equipped with state-of-the-art automation and robotics, enhances product reliability, increases efficiency, and reduces turnaround times. Supporting over 400 customers, the facility is capable of repairing 80,000 fan blades annually ensuring the highest standards of performance, reliability, and customer support across the industry.

Gerald Coste, Senior Vice President for the Engines MRO Business said: "This contract further strengthens our long-standing partnership with Boeing. With our deep expertise in fan blade repair and a highly skilled team in San Diego, we are proud to support the C-17 Globemaster fleet. This agreement reinforces our commitment to delivering world-class, innovative repair solutions for both military and commercial customers."

Airbus welcomes Collins Aerospace as new member of the Digital Alliance

Airbus recently welcomed Collins Aerospace, a leader in integrated and intelligent solutions for the global aerospace and defence industry, as a new member of the Digital Alliance for Aviation. Collins joins the existing Digital Alliance members including Airbus, Delta TechOps, GE Aerospace and Liebherr.

The Digital Alliance focuses on the joint development of digital solutions for airline operations powered by the Airbus Skywise platform, which supports structured data management for maintenance and repair operations.

Collins Aerospace brings additional expertise for predictive maintenance solutions for a wide range of components and aircraft types, covering areas such as avionics, aircraft interiors, enhanced communication and navigation systems and innovative solutions for flight landing systems and gears. More specifically, Collins complements the predictive value proposition of the Digital Alliance by providing significant analytics for Airbus and non-Airbus fleets. This includes air conditioning supplemental cooling, electrical power distribution centre, hydraulic power or engine bleed air supply.

“Within the Digital Alliance, it is all about joining forces with key industry players, providing their strong expertise in system and component design and repair to best serve our customers. Our aim is to provide reliable predictive maintenance solutions to ensure stable and cost-effective operations,” said Claude Houver, VP Innovation and Digital Solution at Airbus.

“In this fifth year of the Digital Alliance, and welcoming the fifth member, Collins Aerospace, we look forward to working on reinforcing our existing product portfolio. We are also assessing expanding our services for non-Airbus aircraft for customers with mixed fleets to further accelerate the deployment of predictive maintenance in the industry, starting with health-monitoring solutions.”

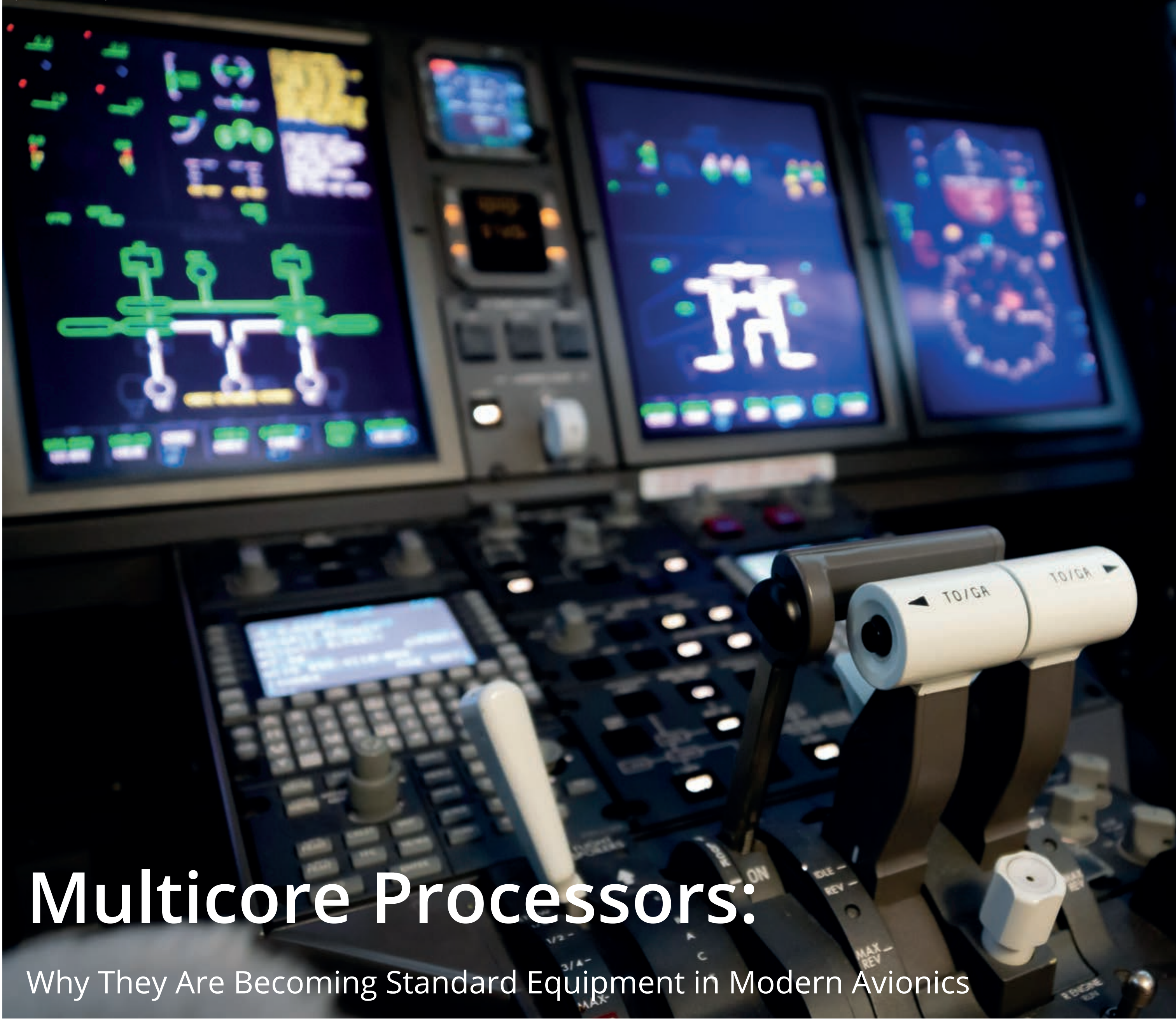
Norwegian based Norse Atlantic Airways achieves Operational Approval for ULTRAMAIN® ELB™

Norse Atlantic Airlines (Norse Atlantic) has received Ops Approval from the CAA Norway to operate ULTRAMAIN ELB, and is in live production use of ULTRAMAIN ELB across their Norwegian fleet.

Norse Atlantic selected Ultramain Systems electronic logbook, ULTRAMAIN ELB on iPads, to fully replace the aircraft paper technical log, cabin log, journey log, and fueling logs on their fleet of 15 Boeing 787 Dreamliners.

This transition from paper to digital line maintenance operations marks a significant step forward for Norse. Real-time Flight and Cabin Crew reports, selected from ULTRAMAIN ELB’s on-device B787 tailored fault repository, will enable enhanced planning and defect clearance. This will lead to lower deferral rates, increased operational service levels and lower maintenance costs across their Dreamliner fleet.

(Credit: SYSGO)



Multicore Processors:

Why They Are Becoming Standard Equipment in Modern Avionics

Originally designed for the high-performance computing industry, multicore processors are now becoming standard equipment in modern avionics. However, the transition from single-core processors to today's multicore processors is not without its challenges. To understand what these challenges are and what is being done to address them, Aerospace Innovations magazine spoke to the experts.

What Are Multicore Processors?

Let's start with first principles: What exactly are multicore processors?

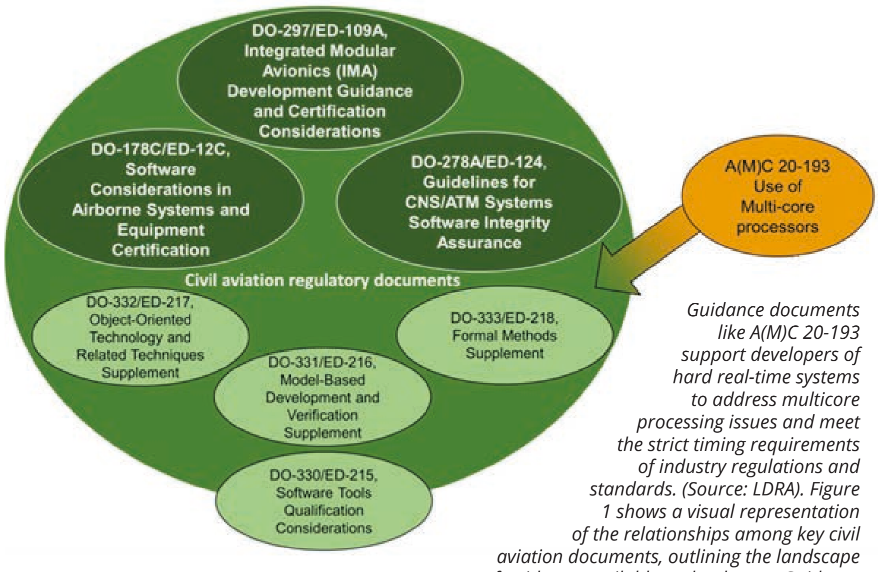
"Multicore processors incorporate more than one processing core; this allows them to execute more than one stream of instructions in parallel," replied Dr. Sam Thompson, Rapita Systems' Senior Multicore Analysis Engineer. (Rapita Systems provides software verification tools and services primarily to the aerospace and automotive industries.) "This, in turn, means that more functionality can be hosted on a single processor."

In plain language, a multicore processor is a computer chip with two or more independent central processing units (CPUs) on a single integrated circuit chip. If 'two heads are better than one' when it comes to humans solving problems, two CPUs (or more) on an integrated circuit are better than one when it comes to computers solving problems.

That's not all: "Multicore processors integrate multiple processing units (cores) within a single chip, enabling simultaneous execution of multiple tasks," explained Amani Karchoud, Technical Product Marketing Manager with SYSGO, a developer of real-time operating systems. "This parallelism enhances performance, improves multitasking capabilities, and increases energy efficiency compared to single-core processors."

"Physically, multicore processors

> "Multicore processors incorporate more than one processing core; this allows them to execute more than one stream of instructions in parallel."
>
> Dr. Sam Thompson, Rapita Systems, Senior Multicore Analysis Engineer



Guidance documents like A(M)C 20-193 support developers of hard real-time systems to address multicore processing issues and meet the strict timing requirements of industry regulations and standards. (Source: LDRA). Figure 1 shows a visual representation of the relationships among key civil aviation documents, outlining the landscape of guidance available to developers. Guidance documents like A(M)C 20-193 describe acceptable means for showing compliance with industry reliability specifications for aspects related to multicore-based systems. In this example, A(M)C 20-193 places significant focus on developers providing evidence that the allocated resources of a system are sufficient to allow for worst-case execution times. Such evidence requires that developers adapt development processes and tools to iteratively collect and analyze execution times in controlled ways that help them to optimize code throughout the development lifecycle. (Credit: LRDA)

are multiple cores of the same processor architecture packaged in a closely coupled configuration," noted Gary Gilliland, Vice President of Marketing at DDC-I, another developer of real-time operating systems. "For example, they can have multiple ARM Cortex A-72 cores sharing cache, memory bus, memory controller and RAM. They offer increased computing power without significant increases in size, weight and power, which makes them appealing to the developers of embedded avionics applications."

It is this last set of points that make multicore processors attractive to the designers and builders of avionic systems. "In the context of avionics equipment renewal, for example, it is important to be able to consolidate several existing systems into a single system," SYSGO Field Application Engineer Stephane Le Merdy said. "Using multicore systems allows this approach to be met. Furthermore, avionics now have the desire to develop complex systems. The pursuit of performance is a major area of work where the use of multicore platforms is entirely appropriate.

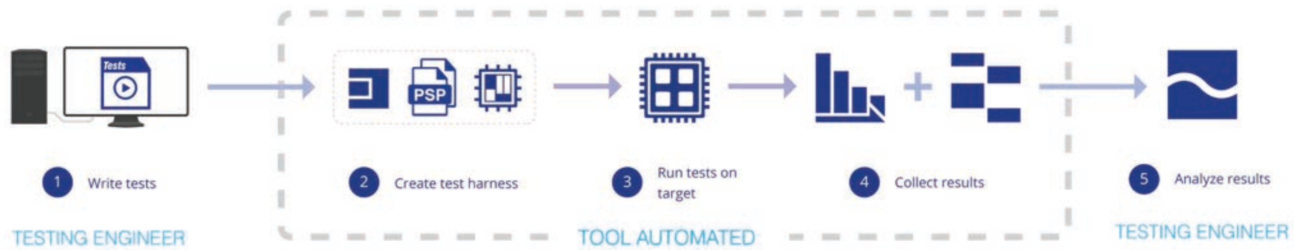
Solid Advantages

The advantages of multicore processors over single-core processors described above are just the start of the list. Many of these were enumerated for Aerospace Innovations magazine by James Coleman, Principal Engineer with Intel Corporation, the renowned computer chipmaker.

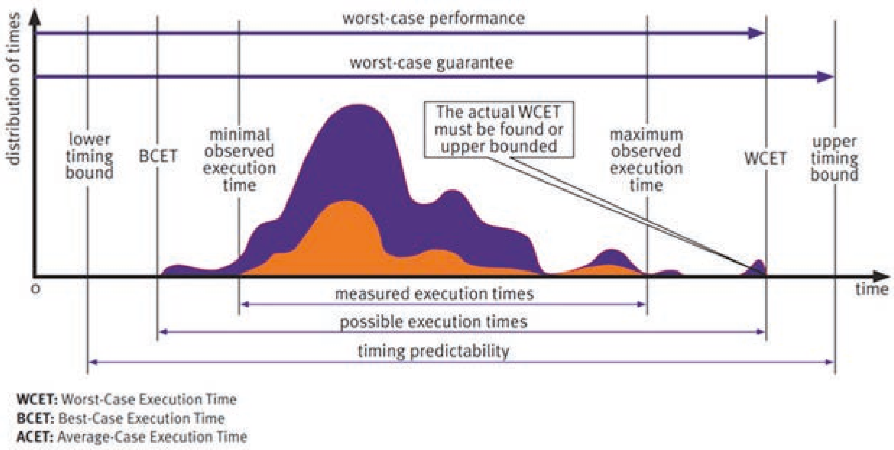
For instance, "each core can execute tasks independently, allowing for true simultaneous processing," said Coleman. "This is essential in environments where multiple operations must occur at once without delay. As well, by distributing tasks across multiple cores, multicore processors can manage more processes faster without overloading a single-core, leading to better system responsiveness and efficiency."

In fact, the fundamental difference between multicore and single processors is akin to the difference between a team doing a range of tasks at the same time versus a single person trying to do everything by themselves. "In critical systems, the ability to run multiple tasks on different cores means that time-sensitive tasks can be prioritized and handled without waiting for other tasks to complete," Coleman said. "This capability minimizes delays and enhances the performance of real-time applications."

"Compared to single-core processors, multicore processors



(Credit: Rapita Systems)



Measured execution times (orange) are but a subset of the possible execution times (purple). To ensure that the worst-case execution time (WCET) can be met, developers use the measured execution times to estimate the WCET. To assure safe and reliable execution, developers can choose an upper timing bound that guarantees the actual WCET will be met. Figure 2 shows execution times for a particular mission-critical task. The upper curve in the diagram depicts the set of all possible execution times and their distribution, which will vary naturally. Calculation of the WCET must consider all possible inputs and dependencies, including specification violations. The more contention there is among tasks, the greater potential variability, leading to a higher WCET. (Credit: LRDA)

offer major performance improvements, especially in tasks that can be divided into smaller, concurrent workloads," agreed Stefan Harwarth, Specialist Systems Architect with Wind River, a provider of real-time operating systems. "These processors enhance processing speed, improve efficiency, and allow systems to handle more complex and data-intensive applications with greater responsiveness and reliability."

One final advantage, briefly touched on earlier, deserves a closer look. "One aspect of leveraging multicore processors is consolidating multiple applications onto a single multicore processor," Coleman said. "Consider the size, weight, and power requirements of each single purpose module on an aircraft: Each time we combine multiple applications into one module, we reduce the total weight and power required and conserve the resources required during flight. This contributes to

Jay Thomas (Credit: LRDA)

> **"In the single-core world, you could get very exact and specific timing. In the multicore world that exactness is gone."**
>
> **Jay Thomas, LDRA's Director of Field Development**

a more sustainable future for the aerospace industry." It also reduces weight, which saves fuel, while drawing less electricity from the aircraft's total reserve.

How Are Multicore Processors Being Used Today?

With these advantages in mind, it's worth asking: How are multicore processors actually being implemented in real-world avionics systems today?

"In aviation, multicore processors are employed in avionics systems to manage concurrent operations such as flight control, navigation, and communication," said Karchoud. They are also being used to support flight management systems, autopilot controls, onboard sensor data processing, engine monitoring, and collision avoidance systems, among others.

Collectively, "these processors enable the simultaneous execution of multiple critical functions," said Olivier Charrier, Wind River's Principal Technologist of Solutions Engineering. "Their key advantages include enhanced computational capacity, improved system responsiveness, and the ability to consolidate several functions onto a single hardware platform."

Given how complex modern aircraft systems have become, multicore processors have become integral to today's onboard aviation systems precisely because they can handle complex, high-performance computing tasks more effectively than single-core processors.

"These functions include safety-critical and non-safety-critical tasks, real-time and isochronous operations, and secure and non-secure processes within the same SoCs [system-on-chip]," Coleman said. "This integration allows for a more streamlined and efficient architecture, reducing the need for multiple discrete controller modules and thus minimizing system complexity and improving reliability. With the advent of the AC/AMC 20-193 to clarify acceptable means of demonstrating compliance of multicore processors, certification authorities acknowledged the benefits and inevitability of multicore technology, leading to its increased adoption across avionic systems."

One practical reason why multicore processors are becoming prevalent in avionics systems is simply because they are in widespread use in desktop computing and server systems. Because the aviation market is relatively small compared to the overall computing marketplace, avionics developers have to work with whatever is available to them commercially. When it comes to CPUs, what's available are multicore processors.

"After all, it doesn't cost that much more to print two or more processors on a single chip than it does to print a single processor," said Jay Thomas, Director of Field Development at LDRA, a software analysis and testing firm. "Factor in the other advantages associated with multicore processors, and you can see why they are dominating the marketplace."

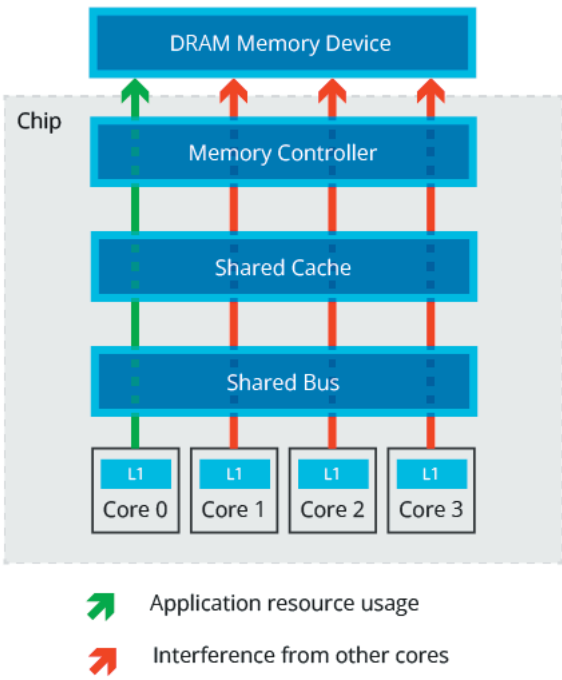
As a result, "most new avionics projects are now based on the use of multicore processors," Le Merdy said. "Thus, the aviation industry uses these SoCs just like the automotive and railways industries do."

Challenges of Multicore Processors

Despite all the advantages that multicore processors bring to aircraft systems, they are not a perfect solution to the challenge of onboard data processing.

The biggest concern is a problem commonly referred to as 'interference'. When an aircraft avionics system has more than one core of a multicore processor operating simultaneously, there is the potential for one or more of these processor operations to affect the ones being executed by the others.

To be precise, "since software executing on different cores will contend for usage of an avionics system's shared data resources, an multicore processor (MCP) greatly increases the potential for



(Credit: Rapita Systems)

interference patterns whereby software on one core can impact the execution time of software on another core," Gilliland said. "Consequently, unless managed and bounded, this multicore interference could impact software to miss deadlines that may result in unsafe failure conditions. This is why guaranteeing that every application in an avionics platform has the time it needs to perform its intended functions (system timing analysis) is part of the DO-178C certification of these systems. Developers of certifiable, safety-critical software must design for worst-case behavior, and show that there is time available to meet all deadlines."

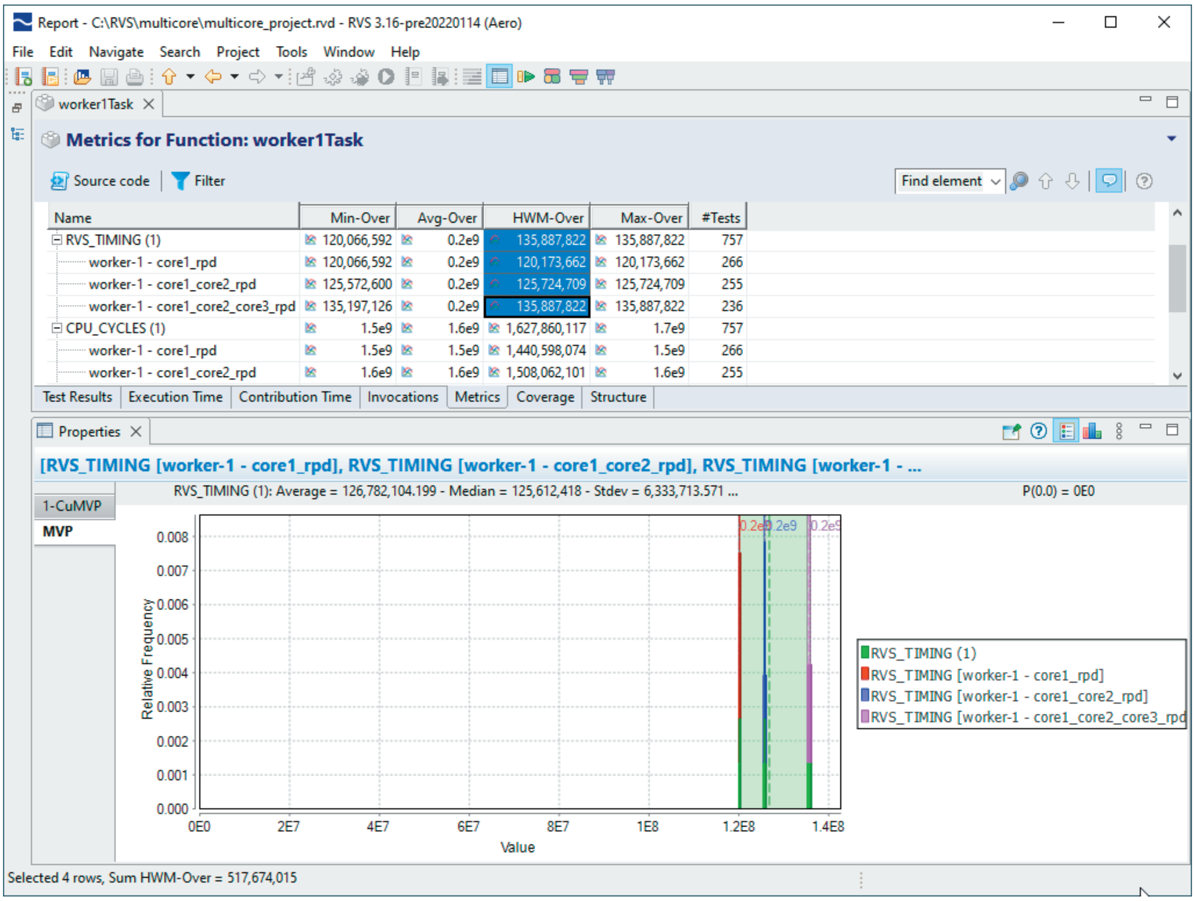
Worth noting: Because of this potential for interference, "most multicore processors in use in aviation today are either hosting low-criticality functionality or are running with only one core active (which allows them to be certified like their single-core counterparts)," said Dr. Thompson. However, thanks to improvements in multicore processor technology, RTOS technology and certification authority guidance, "avionics vendors are now using multicore processors as they were intended with all cores enabled," Gilliland noted.

A second issue associated with multicore processors is known as 'variance'. In plain language, one can think of this as 'actual processing speed'. Simply put, just because two multicore processors have the same architecture and same operating specifications doesn't mean that they will process data at precisely the same speed.

In the desktop computer and server space, variance is not a big issue. After all, the units of time we're talking about are almost infinitesimal, and certainly beyond the ability of a human observer to detect unaided.

"When you're running Windows on a 32-core processor, there's a lot of variance in terms of how long it takes each core to do a specific task," Thomas said. "That is okay because that's how those applications were designed: They can forgive a degree of variance. But when it comes to avionics, we need our CPUs to obtain their inputs, perform their calculations, and output their data within a very specific, narrow window of time. The first generations of multicore processors with their desktop roots weren't ideal for that."

Back in the days of single-core processors, the hosting of several independent functions on a single processor was controlled using a management concept known as IMA (integrated modular avionics). "IMA



(Credit: Rapita Systems)

Dr. Sam Thompson
(Credit: Rapita Systems)

Stéphane Le Merdy
(Credit: Sysgo)

was based on very exact time slicing where you'd run multiple applications on a single-core and you would make sure that you knew exactly how much time each application would take," said Thomas. "That was the state-of-the-art for many flight control systems. You were able to run multiple flight control applications one after another taking turns on the same CPU, which incidentally avoided interference issues."

If a single-core processor operating in this mode was akin to a single person switching between two or more tasks sequentially, then a multicore processor can be likened to a group of people doing multiple interconnected tasks at once. In this situation, variance is like assigning tasks to a group of people with different skill levels — the overall speed is limited by the slowest performer. And just like a chain is only as strong as its weakest link, the speed and successful interactivity in a multicore processing system is only as good as its least efficient core.

"In the single-core world, especially in those IMA applications, you could get very exact and specific timing on how much time it took to do your algorithm," Thomas observed. "But in the multicore world that exactness is gone, at least for the time being."

Finally, "from a regulatory perspective, the key challenge is the relatively new guidance in the form of A(M)C 20-193" said Dr. Thompson. "While the aviation industry is very familiar with more established standards like DO-178C/ED-12C and DO-254/ED-80, there is no corpus of experience of meeting A(M)C 20-193 objectives, and organizations do not yet have internal processes available to address the multicore certification objectives."

Addressing the Challenges

Given the issues cited above, certifying multicore processors for safety-critical applications is more complex than for single-core processors. This is why "aviation authorities have added some additional objectives to address multicore usage in the form of the AC/AMC 20-193 (as an update of the previously called CAST-32A guidance), as a complement to DO-178C and DO-254 guidelines," said Charrier.

As for the issue of multicore processor interference and variance? Coping with these issues proactively requires on-the-ground testing and software fixes before such systems can be allowed to go aloft. "It's all about aligning your systems and your resources so that different parts of your application running on different cores don't conflict and/or be degraded by variance," said Thomas. "That's something that LRDA has been doing for some time, but that's not all. We've also been working with chipmakers to get variance down on the hardware side. The fact that the chipmakers have taken this challenge seriously has made the problem a lot easier to address."

Intel's James Coleman is sympathetic to this point of view. "Avionics manufacturers need vendors to provide comprehensive chip reliability and characterization information, including evidence demonstrating adherence to AMC 20-152A and AMC 20-193 objectives," he said. "These resources should be designed to help system designers effectively identify and mitigate potential interference channels. This support should also address design assurance and certification issues, to ensure that multicore systems meet stringent aviation standards."

This being said, "we find that there can be a lot of concern whenever the topic of multicore pops up with a hyperfocus on interference overlooking the values for MCP architectures," Gilliland said. "This is especially the case as each hardware, software, and tool vendor puts their spin on what is the right solution for MCP for safety critical operations. Nevertheless, the issues that multicore processing create are not new. There are means to resolve these MCP issues and make them less of a challenge or burden — but the approach and solution set can differ greatly amongst processor architectures and operating system environments. Such differences include the level of effort it takes to develop and certify a safety-critical MCP system, which can result in performance advantages in one vendor's solution compared to the next."

A Time for Extinction

In this article, we have covered the progression of multicore processors into aircraft systems, the issues that can sometimes arise in their usage aloft, and the solutions to those issues. This begs one last question: Are single-core processors doomed?

Apparently, the answer is 'yes'. According to Olivier Charrier, multicore processors are expected to become the standard for aviation systems as the demand for more powerful and efficient avionics continues to grow.

"Advances in processor architecture, software tools, and certification processes will help overcome current challenges, enabling broader adoption of multicore systems," he said. "As avionics systems become increasingly complex, the use of single-core processors on new aircraft is likely to diminish, with multicore processors offering the performance and scalability necessary for future aviation applications."

"Over time, the aviation industry is expected to increasingly adopt multicore processors, phasing out single-core processors in new aircraft designs," agreed Amani Karshoud. "This shift is driven by the need for enhanced performance and the obsolescence of single-core technologies."

"Multicore processors are becoming increasingly prevalent across various industries, and aerospace is no exception," Intel's James Coleman said. "Given the intense computational demands of modern aviation systems, the shift towards multicore technology is inevitable. Their substantial benefits for handling complex, compute-intensive workloads make multicore processors a key component in future aircraft designs. As aerospace technology continues to evolve, the reliance on single-core processors is expected to diminish, marking a significant shift towards more advanced multicore architectures in new aircraft."

Granted, the interference and variance issues associated with multicore processors still continue to cause concern. As Dr. Thompson observed, "multicore processors are widely seen as being novel, and it's fair to say that they currently carry greater certification risk than their single-core counterparts. However, it's important to bear in mind that not too many years ago, fly-by-wire systems occupied a similar space: there were clear advantages from embracing the new technology, but there was additional risk associated with deployment. I expect that the deployment of multicore processors will follow a similar trajectory, until certification of high-criticality multicore systems becomes a completely unremarkable achievement."


Amani Karchoud (Credit: Sysgo)

"Multicore processors are employed in avionics systems to manage concurrent operations such as flight control, navigation, and communication,"

Amani Karchoud, SYSGO's Technical Product Marketing Managers

In conclusion, while multicore processors bring unique challenges, they also offer unmatched potential. So, as avionics systems grow ever more complex and performance-driven, the shift toward multicore is not just logical — it's essential. Granted, the path to certification may be longer, but the destination is clear: Multicore processors are here to stay.

By James Careless

Rust - The language to empower the Aerospace Industry?

There is a valuable ecosystem developing around the Rust programming language for aerospace applications because it "empowers everyone to build reliable and efficient software". But it is not the only choice. Let us explore other language alternatives to Rust and the features of each language to better explain the value of Rust for the future of the aerospace industry.

C/C++ - a risky default solution

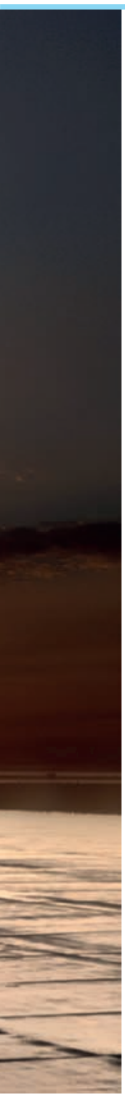
In the embedded domain, you're more likely to look at C/C++ than anything else. This is the option "by default". A large portion of your software is likely to already be in C/C++. Your staff is trained in this language, tools, and processes are in place, and development costs are known and deterministic. Why change?

There is a growing body of evidence, both qualitative and quantitative, that shows that C/C++ is making the production of safe and secure software more difficult than it should be. Decades of research and investment have still not yielded a "safe C/C++" that is cost-effective, flexible, and reliable. The White House Office of the National Cyber Director (ONCD) released a seminal document in 2024, "Back to the Building Blocks: A Path Toward Secure and Measurable Software." This report provides strategic recommendations, including using memory-safe programming languages to mitigate vulnerabilities and improve resilience.

Rust and Ada - improving traditional development processes

Teams that are looking at alternative programming languages have two options today: Ada and Rust. Both languages raise the bar in terms of safety and security compared to C/C++; each has unique strengths.

Consider ecosystems and communities. Rust has a vibrant community that has developed a huge amount of resources over a short period of time. However, its commercial ecosystem is still in the



process of organizing itself. There is work underway, but filling all the gaps will take some time. Ada has a smaller community - it has been growing over the years but much more slowly. However, Ada has a complete and mature ecosystem both in terms of toolchain availability and certification documentation.

Or consider language capabilities. Rust pushes memory safety very far and provides a more flexible memory model than most programming languages today. Ada has an unmatched specification language that allows one to express and check software and hardware constraints at various levels.

SPARK - industrial-strength formal methods

If you're prepared to look at alternative programming languages to avoid the costs and risks of C/C++, SPARK offers an opportunity to go much further than Ada or Rust. SPARK, which is based on Ada, offers industrial-strength formal methods: an opportunity for you to prove mathematically that your software is safe and secure. This paradigm shift in software development methodology offers significant cost savings for high-integrity software.

So what's the best choice?

Choosing between Ada, Rust, and SPARK is a complex discussion. The questions are, what is the team looking to achieve, and what is the potential appetite for change? The chart below provides some elements that can serve as the basis of a discussion. Different companies may allocate different weights to different elements.

As there is so much buzz and chatter about Rust in the press and when attending events, let's explore this language a little deeper and answer some of the questions we often get asked.

Why Rust?

There are several reasons why Rust would be valuable for the development of reliable software in the Aerospace industry. We have selected a few that are most often talked about.

Community

One of the big strengths of the Rust programming language is its large and vibrant community. It's easy to find resources on the language, and get questions answered by people who have a true passion for it.

Memory safety without sacrificing performance

One of Rust's most powerful capabilities is its ability to avoid

	Ada		SPARK
Community	Small	Large	Small
Toolchain Embedded Ecosystem	Mature	In development	Mature
Certification	Off-the-shelf	In development	Off-the-shelf
Libraries available	Limited	Large	Limited
Programming paradigm	Imperative system-level	Imperative system-level	Imperative system-level
Mitigation of programming errors	Yes	Yes	Yes
Strong Typing	Yes	Limited	Yes
Data constraints, hardware / software data consistency	Yes	No	Yes
Guaranteed absence of run-time errors	Run-time checks	Run-time checks	Static, via Proof
Contract language (pre- post- conditions, invariants, predicates...)	Yes, checked at run-time	No	Yes, checked statically, via Proof
Memory safety	Pointer avoidance Accessibility checks Dynamic checks	Borrow checker Lifetimes	Borrow checker Pointer avoidance Accessibility checks
Cost of adoption	Language change	Language change	Methodology change
Expected benefits	Mitigation of programming errors Constraint checks	Mitigation of programming errors Memory safety	Mitigation of programming errors Memory Safety Guarantee of absence of run-time errors Guarantee of formal properties Guarantee of constraint checks Testing reduction

(Credit: AdaCore)

memory errors through its ownership model of memory. This eliminates the most significant source of security vulnerabilities in software simply by adopting Rust, following the ownership model, and satisfying the borrow checker.

Libraries

There are a large number of libraries available for Rust through its cargo package manager. Pretty much anything that you can think of is covered one way or another. However there is a word of caution here, a number of these libraries are developed by hobbyists and many of the most popular libraries have yet to reach version 1.0 and publicly available libraries are usually not suitable for safety - or security-certified embedded development.

Strong Typing

Strong typing ensures that you can determine at compile time the specific type of an object and that you can check the integrity of its values throughout its usage. C is notably weakly typed: while variables are typed, implicit conversions allow you to mix numbers with different representations without the developer's oversight (for example, when adding integers and floats). This may result in various issues such as overflow, underflow, or rounding errors. Treating arrays like pointers is another example of an issue that arises from weak typing.

Rust's typing is stronger in this regard (albeit not as strong as Ada). Different types can't be mixed together without explicit conversion, and arrays are first-class citizens. This allows programmers to avoid a number of common programming mistakes.

So, where does this leave us regarding the question of which language to invest in?

As previously stated, both Rust and Ada have advantages, and it will come down to the development teams' preference. Antoine Colin is the CTO at Rapita and has recently started some work with Rust and is finding it beneficial as a language alongside Ada,

"Rust complements Ada in ways that align perfectly with how we see the future of our tools. With GNAT Pro for Rust, we gain access to an industrial-grade Rust toolchain backed by AdaCore's expertise and a proven Ada ecosystem.

Where Ada offers unmatched reliability and maturity, Rust brings memory safety and a developer experience that encourages clean, robust code.

GNAT Pro for Rust allows us to integrate both languages into a unified workflow. This empowers our engineering teams to choose the right language for the right task. It will let us evolve our toolchain with the best of both languages, helping us build the next generation of RVS with confidence and agility."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NDT plays a vital role throughout an aircraft's lifecycle. (Copyright: Evident)

The ABCs of NDT for Aircraft

Seeing the unseeable: NDT checks keep planes in the air safely

Quality and verification are requisite to determine and validate an aircraft's airworthiness, and keep personnel and passengers safe. Aircraft undergo numerous scheduled maintenance routines, as well as unscheduled inspections following unexpected events such as lightning strikes, bird strikes or other incidents.

Non-destructive testing (NDT) plays a vital role throughout an aircraft's lifecycle—from raw material selection and manufacturing to assembly and in-service maintenance. NDT methods help detect defects or imperfections that could compromise structural integrity, preventing failures and extending the aircraft's operational life.

NDT extends service life of parts by catching issues early, preventing unnecessary replacements and maintains compliance with strict aviation regulations and standards from FAA and EASA.

Aircraft safety is non-negotiable, even a tiny crack or flaw could lead to catastrophic failure. "NDT is vital to aviation because it identifies hidden flaws without damaging aircraft parts," explains Peter Pelayo, Product Manager and an NDT Level III for Met-L-Chek, Cleveland. "Modern airplanes can have more than 6,000 moving parts, and NDT ensures that even the smallest components are safe and reliable. This practice underpins what many call the 'impossible infrastructure' of flight, where huge, complex machines can remain airborne. NDT enables a proactive maintenance approach, ensuring aircraft remain safe and airworthy throughout their service life."

"All parts of an aircraft can be verified with NDT methods from wings to fuselage, engine but also windows, wheels," says Angélique Raude, Global NDT Application & Market Development Director in the Test & Measurement Division at Evident, France. "For each assembly, material, defect type a suitable inspection technique is being deployed limiting the need for repairs, change of part, etc."

Larry Culbertson, CEO/RL3 at NDT Solutions (NDTS), Signal Hill, California, stresses that NDT is not just a maintenance task, it is an essential life-or-death safeguard that must be completed, sometimes even daily. He cites the following common aircraft structures and parts tested with NDT:

- Fuselage (main structure): Check for cracks, corrosion, fatigue near doors, windows and joints.
- Wings: Monitor for stress cracks, especially near attachment points and fuel tanks.
- Landing gear: Inspect for cracks, corrosion, and stress fractures—takes heavy impact loads.
- Engine components: Blades and turbine parts are inspected for micro-cracks and overheating damage.
- Control surfaces (ailerons, elevators, rudders): Inspect for cracks, corrosion and bonding failures.

The new 72DL PLUS ultrasonic thickness gauge delivers precision thickness measurements. (Copyright: Evident)

- Composite structures: Test for delamination, impact damage that isn't visible on the surface.
- Blades and propellers: inspected for cracks and corrosion, especially at the blade roots.

NDT Testing Methods for Aircraft

Hürth, Germany-based Waygate Technologies, a Baker Hughes business, offers a comprehensive suite of NDT equipment, software and services. Ben Linke, CEO at Waygate Technologies explains the three primary NDT methods to ensure the integrity of aircraft components are remote visual inspection (RVI), ultrasonic testing (UT) and industrial radiography and computed tomography (CT). "These inspection technologies are applied across the entire lifecycle of aircraft components, from verifying the quality of initial materials to assessing the condition of finished parts and supporting in-field maintenance and repair. The choice of which technology to use depends on the specific inspection requirements."

Culbertson explains that, "When it comes to modern aircraft design, there is a damage tolerance philosophy that assumes that some cracks might form during service, but that the important thing is detecting them early enough. This philosophy depends heavily on regular, reliable NDT. No single NDT method finds every defect. That's why multiple techniques are often required."


The selection of an NDT method depends on the aircraft structure, component material and expected defect type. (Copyright: Evident)

He cites the following aircraft NDT methods, applications and rationale:

Ultrasonic Testing (UT): Used for thick structures like wings, fuselage skins and composite panels. It's great for detecting internal cracks, delaminations and corrosion. Ultrasonic resonance can be used for bonded structures.

Eddy Current Testing (ECT): Used for surface/near-surface cracks in fuselage, landing gear and fastener holes. It's fast and highly sensitive to tiny cracks, especially in conductive

The Powerscan HE industrial CT scanner can inspect large high-density parts and additive components. (Copyright: Waygate Technologies)

metals like aluminum.

Mag Particle Testing (MT): Used for landing gear and engine shafts (ferromagnetic parts). It's good at detecting surface and shallow subsurface cracks however only works on ferromagnetic materials.

Penetrant Testing (PT): Used for surface crack detection in non-porous materials (engine parts, landing gear). It's good at finding surface-breaking flaws, even tiny hairline cracks, and is dependent on cleanliness.

Radiographic Testing (RT): Used for internal defects in critical engine parts, composite layers and thick structures. X-rays see inside components to detect voids, cracks or inclusions.

Visual Inspection (VI): Used for all accessible surfaces such as fuselage, wings, control surfaces and engines. It is a quick and first line of defense and is often used with borescopes for inside views. VI requires trained technicians with good visual acuity.

Raude believes each NDT method has its advantages and limitations, depending on the structure being inspected. "Factors such as material type, manufacturing process, expected defects and component geometry influence the choice of NDT technique. However, when used in combination, NDT methods allow for the inspection of nearly the entire aircraft structure."

The NDT Technician

"There is a common misconception that one NDT method is inherently best for all aircraft inspection needs," Pelayo says. "In reality, choosing the right method depends on the material, the type of defect, accessibility, and—most importantly—the skill and intuition of the NDT technician. Ultimately, no single method reigns supreme; it's the technician's expertise—knowing which approach suits each application and interpreting the results accurately—that truly keeps this impossible infrastructure safe in flight."

Culbertson agrees that NDT technicians make a difference. "NDT technicians are like detectives with superpowers. They require technical knowledge and hands-on skill. Plus, certification standards (like NAS 410 or EN 4179) are strict. It's not just about knowing how the equipment works; it's about interpreting sometimes subtle signs that others would miss."

While aircraft NDT technicians do indeed make a difference, one critical issue facing the aircraft NDT field is the growing shortage of qualified technicians. As aircraft fleets expand and advanced materials become more common, the demand for skilled inspectors far outstrips the supply. Pelayo explains this shortfall can lead to maintenance bottlenecks, increased costs and potentially longer aircraft-on-ground (AOG) times. "The work itself requires a blend of technical expertise, hands-on skill and analytical thinking—qualities that take time and mentorship to cultivate. Well-trained NDT professionals are in high demand. As the industry moves toward more automated, data-driven methods and advanced inspection technologies, the need for skilled personnel who can interpret results and adapt to emerging challenges will only become more pressing."

Aircraft NDT Innovations and Improvements

Aircraft NDT is getting more accurate and innovative. Linke explains that while the aerospace industry is generally conservative with innovation due to rigorous safety and quality standards, the need for increased productivity and longer component lifecycles continues to drive new NDT inspection technologies.

As aircraft structures have evolved with increased use of composite materials, new assembly processes (e.g., bonding over rivets and welds) have introduced different damage mechanisms. Raude adds that consequently, NDT methods are adapted accordingly. "Bond testing provides a rapid screening solution for detecting disbonds and delaminations in composites."

Raude adds that in recent years, "Both ECT and Ultrasonic testing techniques have advanced to enhance inspection capabilities while reducing inspection time. Advanced Ultrasonic methods such as Phased Array Ultrasonic Testing (PAUT), Total Focusing Method (TFM), and the emerging Phased Coherence Imaging (PCI) are increasingly used in aircraft inspections, offering superior defect detection, positioning and sizing accuracy. Eddy Current Array (ECA) technology is also gaining traction for efficiently inspecting large areas. These advanced NDT techniques provide deeper insights into structural health, facilitating better integration with digital twin technologies—ushering in a new era of predictive maintenance and data-driven decision-making."

Culbertson cites the following aircraft NDT innovations:

Automated Robotics for NDT Drones: Crawling robots and robotic arms can perform inspections on fuselage, wings and hard-to-reach areas. This provides faster, safer and more consistent inspections, especially for large aircraft and tight spaces.

Phased Array Ultrasonic Testing: Advanced ultrasonic method using multiple beams at once can scan more area and create detailed 3D images. Accurate for detecting complex cracks and corrosion, it's a big upgrade over traditional UT.

3D Computed Tomography (CT) Scanning: Using advanced X-ray imaging can create full 3D models of internal parts. Engineers can see inside parts, like turbine blades, in detail.

Augmented Reality (AR) Assisted Inspections: Technicians wear AR glasses that overlay inspection steps, defect locations or schematics onto real-world parts. This reduces errors, speeds up inspections and improves technician training.

Machine Learning and AI Defect Recognition: AI algorithms automatically detect and classify defects from images e.g. cracks, delaminations or corrosion. This speeds up diagnosis, removes human bias and improves early detection.

Pelayo explains that over the past five years—and looking ahead to the next five—one of the most exciting developments in NDT for aircraft has been the introduction of permanently installed sensor networks. "They provide real-time structural health monitoring. These sensors track crack initiation and growth, detect corrosion or delamination and relay data to maintenance teams without requiring major disassembly or extended aircraft-on-ground (AOG) downtime."

Another emerging innovation is the use of AI-powered drones for full exterior inspections, particularly after events like lightning strikes or hail damage. Instead of manually checking the aircraft's skin and fasteners, these drones autonomously scan the surface and use machine-learning algorithms to pinpoint and categorize damage. By reducing the need for time-consuming, hands-on inspections, both of these technologies significantly streamline the maintenance process and help ensure aircraft remain safe and operational.

Recent NDI innovations with significant impact include those that deliver superior imaging for enhanced defect detection and digital or AI-powered solutions like assisted defect recognition (ADR). "These advancements have dramatically sped up inspection and reporting, while also enabling a wider range of personnel to perform inspections, reducing the dependence on extensive training and certifications," Linke says. "Waygate Technologies has developed the Mentor Visual iQ+ (MViQ+) video borescope. This innovative tool builds upon Real3D Phased Measurement and incorporates advanced AI analytics to automate tasks such as blade counting and defect recognition, significantly improving data quality and streamlining inspections."

The Mentor Visual iQ+ is an advanced video borescope for engine inspection. (Copyright: Waygate Technologies)

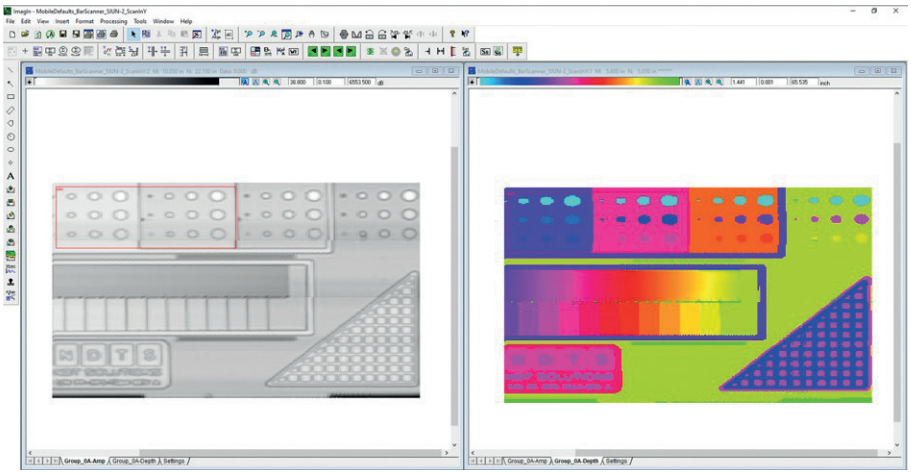
NDT is an integral aspect of aircraft maintenance. (Copyright: Waygate Technologies)

Aircraft NDT Challenges

Despite its benefits, NDT limitations and challenges exist. "Certain NDT techniques may struggle with complex geometries, multi-layered structures or detecting deeply

The AUSS Mobile seamlessly integrates multiple NDT modalities all in a single device. (Copyright: NDT Solutions)

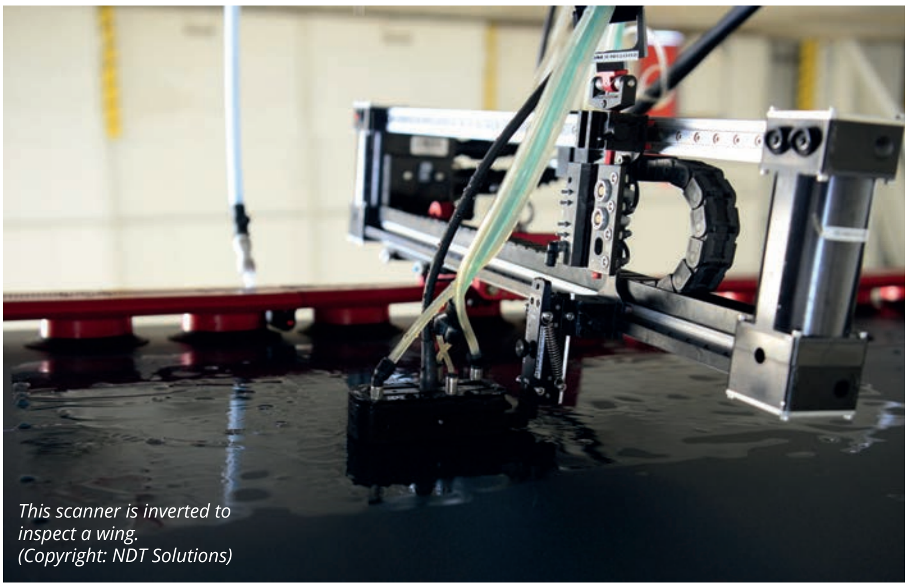
Below: Results from a NDT test. (Copyright: NDT Solutions)



embedded flaws," Raude says. "Additionally, access restrictions in confined areas of the aircraft may require alternative inspection methods or partial disassembly."

Some methods require direct contact or specific surface preparation, making them impractical for inaccessible areas or components with intricate geometries. Material properties may constrain others: for instance Pelayo explains magnetic particle testing is only suitable for ferromagnetic materials, while radiography can be less effective on thick or highly dense parts without specialized equipment. Also, "The emergence of advanced materials—especially composites and additively manufactured (3D-printed) components—presents new challenges and opportunities. These newer manufacturing methods and materials can introduce unique defect types (e.g., porosity in 3D-printed metals or delamination in high-performance composites) that may not be well-suited to traditional inspection methods."

Culbertson explains, "Some very small, tight cracks, especially deep inside materials, can be missed, depending on the method used. Parts must often be reachable for the inspection tools or probes; hidden/internal areas can be tricky without disassembly. Many methods need a clean, prepared surface because dirty, painted or rough surfaces can hide defects. Some NDT methods, like radiographic testing or phased array UT, require expensive equipment, highly trained personnel and longer setup times."



This scanner is inverted to inspect a wing. (Copyright: NDT Solutions)

Linke believes the biggest NDT challenge does not lie in a particular part, but rather in adapting to new materials while further streamlining time- and cost-efficiencies without compromising on safety and quality. "And, as aviation and space exploration advance, sophisticated inspection technologies will only become more critical. New materials and propulsion systems will necessitate continuous adaptation of inspection methods. The evolution of artificial intelligence (AI) and machine learning (ML) promises to unlock new levels of efficiency and thoroughness in inspections. We can anticipate advanced technologies providing more insightful data from connected inspection equipment, enabling assisted and automated workflows, and fostering integrated platforms and collaborations."

By Mark Robins

The Future of Air Dominance:

The Integration of Manned and Unmanned Aircraft

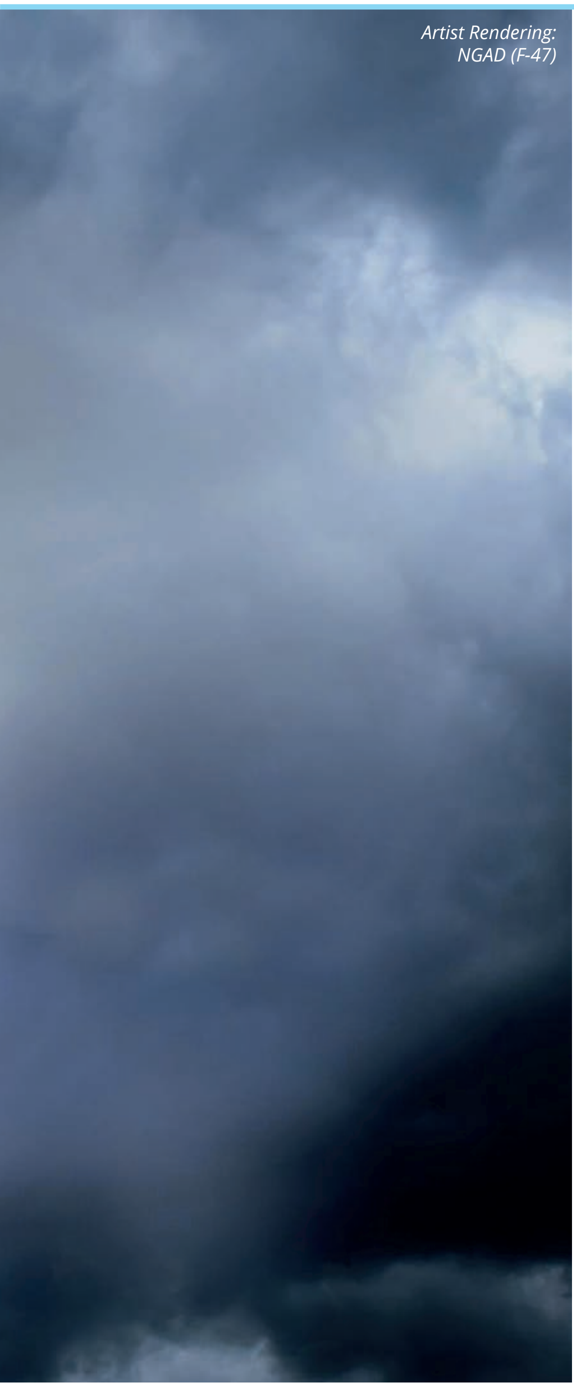
For the past 24 years, Alderman & Company has served as sell-side M&A Bankers in the middle market of Aerospace & Defense. Approximately half of our engagements during this time have involved companies within the U.S. defense industrial base. Drawing on our industry perspective, this article explores how middle-market firms that are aligned with the development of next generation military networks are well positioned for the coming years.

Military aviation networks are undergoing a generational shift, moving from centralized commands to distributed communication networks of manned and unmanned systems. This change is being achieved through the development of modern communication technologies that enable interaction between sixth-generation fighters, UAVs, and retrofitted legacy aircraft.

This shift is evident in the evolution of the fighter jet. Fifth-generation platforms like the F-35 and F-22 introduced stealth, sensor fusion, and network-centric warfare. Sixth-generation programs are expected to go further. Programs such as the NGAD are incorporating decentralized networks, artificial intelligence, directed energy weapons, and UAV integration through advanced avionics.

To bridge the gap between legacy and future systems, retrofitting existing fighters with modern avionics and electronics will also be required to utilize legacy aircraft in these emerging networks. This enhances interoperability and extends the operational relevance of older platforms within a networked battlespace.

UAVs are rapidly expanding their roles within the future of warfare. As low-cost, and in many cases disposable, UAVs offer an efficient



Artist Rendering: NGAD (F-47)

solution for Intelligence, surveillance and reconnaissance (ISR).

Middle-market aerospace and defense companies supporting next-generation technologies—such as AI-driven avionics, secure communications, energy weapons, UAV platforms, and retrofit solutions—are helping shape the future of defense. As the defense industrial base evolves, these firms are well-positioned for long-term growth.

Current Trends in 5th-Generation Fighters

5th-generation fighter aircraft, such as the Lockheed Martin F-35 Lightning II and Lockheed Martin/Boeing F-22 Raptor, have become the mainstay for modern air combat with advanced stealth, sensor fusion, and networked warfare capabilities. As of January 2025, Lockheed Martin has delivered more than 1,100 F-35 aircraft all time, including 110 in 2024 . 195 F-22 aircraft have been delivered all time. The F-22 stopped production in December of 2012 .

The supply chain for these platforms is extensive, with Lockheed Martin leading the F-35 program, supported by Northrop Grumman (sensor systems), BAE Systems (electronic warfare components), and Pratt & Whitney (F135 engine) . The F-22, developed by Lockheed Martin and Boeing, integrates avionics from Raytheon and Northrop Grumman, with Pratt & Whitney supplying its F119 engines.

The supply chain complexity has extended beyond the primes. Stealth and survivability requirements, achieved through composite materials, radar-absorbent coatings, and low-observable airframes that reduce detection by enemy radar and infrared sensors rely on specialized middle market suppliers. Many of these companies are small, privately owned enterprises with 50-500 employees. Of note, these are the primary clientele of Alderman & Company. These companies provide critical materials, precision manufacturing and sustainment services that enable these aircraft' capabilities. The demand for such support has continued over recent years as these aircraft remain central to U.S. air dominance .

While more than 1,100 F-35s have been built, the 5th generation fighter F-22 had only 200 units produced, and current plans are for the United States to build just 200 F-47s

Demand for 6th-Generation Fighters

Boeing recently won the US 6th generation fighter program with its F-47, also known as the Next-Generation Air Dominance (NGAD) program. The NGAD marks a critical leap forward in air superiority, pushing the boundaries of fighter aircraft well beyond the capabilities of 5th-generation platforms like the F-35 and F-22. The NGAD program is set to introduce groundbreaking technologies, including artificial intelligence (AI), directed energy weapons, and connectivity with unmanned aerial vehicles UAVs (referred to in this context as Collaborative Combat Aircraft – CCAs) and ground assets. The introduction of these advanced systems will change the way combat is fought, with 6th-generation fighters and their CCAs playing a central role in future multi-domain operations and maintaining U.S. air dominance.

Of note, another major demand signal for sixth-generation fighters and their associated UAVs outside the U.S. is the Global Combat Air Programme (GCAP), a joint initiative between the United Kingdom, Japan,

Tempest (GCAP) 6th Gen Fighter Jet Programme

(Copyright: Boeing MQ-28)

(Copyright: Boeing MQ-28)

and Italy. The program combines the UK's Tempest and Japan's F-X projects into a unified sixth-generation fighter development effort. Like the U.S. CCA, GCAP will include uncrewed aircraft designed to perform support functions alongside manned aircraft. BAE Systems, Mitsubishi Heavy Industries, and Leonardo are leading the initiative.

Opposed to its 5th generation predecessors, which typically rely on a single platform's capabilities, the F-47 is envisioned as part of a highly networked system, where human-piloted aircraft and CCAs work together in coordinated operations. The F-47's design incorporates advanced stealth features, next-generation propulsion systems, and a flexible sensor suite that can quickly adapt to emerging threats. The aircraft will enhance operational efficiency by providing a seamless interface between few manned aircraft and many unmanned systems. Boeing is driving the development of the F-47, while Lockheed Martin plays a complementary role in advanced stealth technologies and sensor integration for the program .

While the capabilities of the 6th generation fighter will maintain U.S. air dominance, the supply chains that previously supported the large quantity of F-35 and F-22 aircraft will likely shift to include new demand for the 200 6th generation fighters and the associated 1,000 CCAs projected to be produced. We have worked with many clients who have worked on both the F35 program and F22 programs and as a result we have a deep appreciation for the differences between being a supplier on a 200-unit program versus a 1,000-unit program. While the cost per unit for the F-47 will dwarf that of each associated CCA, we expect suppliers will be as keen to win work on the CCAs as they will be on the F-47.

The Role of UAVs in NGAD and 6th-Generation Operations

UAVs are already a significant component of modern warfare. These systems have grown in sophistication and versatility, supporting missions that range from intelligence, surveillance, and reconnaissance (ISR) to targeted strikes. As part of the NGAD program, CCAs, under development, will dramatically enhance the capabilities of the F-47. We expect these new CCAs will be designed based on recent lessons learned from such systems as Anduril's Fury and General Atomics' GA-ASI XQ-67 . We expect these CCAs will be in very high demand in the future, because of the command capabilities of the 6th generation aircraft and the fraction of fighters that will be required, compared to these CCA systems that enable the achievement of air dominance at much lower total cost.

From FY2025 to FY2029, NGAD funding is projected to rise from \$2.75 billion to \$5.72 billion—a 108% increase. Contemporaneously, CCA is expected to grow from \$557 million to \$3.11 billion, marking a more than 450% increase over the same period. This rapid acceleration reflects the Department of Defense's emphasis on fielding large numbers of cost-effective, autonomous systems to complement a small fleet of sixth-generation fighters. As a result, CCAs are expected to drive greater unit volume and sustained demand across the defense industrial base. This provides significant opportunities for middle-market suppliers that provide critical components, manufacturing, and integration services to support this expanding UAV and CCA ecosystem .

As the NGAD program accelerates, tier 1 suppliers (such as Raytheon Technologies and L3Harris Technologies) will start building subsystems that will enable NGAD's electronics, communications and networks. For middle-market suppliers already supporting these OEMs, the increasing demand for high-performance defense electronics and secure communications points to a clear, sustained growth opportunity. We are seeing this firsthand, as Alderman & Company is currently in the process of selling companies in this exact niche. The supply chains involved in the development of these CCAs will push to design for greater efficiency and endurance. These next-generation CCAs under the NGAD program will feature advanced engine technologies that reduce fuel consumption while improving performance at higher altitudes. This integrated platform (F-47s with CC will allow precision strikes with fewer resources, reducing the risk to human pilots, and save both lives and money, while pushing US air dominance into the next level.

The Shift in Production and Retrofitting Trends

The modernization of military aircraft has become a priority for many air forces around the world, not just the US, as they seek to extend the lifespan of their existing fleets rather than producing all new and expensive platforms (such as NGAD). This shift toward retrofitting older aircraft with next generation avionics, communications, radar systems, and electronic warfare (EW) capabilities allows military forces to maintain the operational relevance of legacy platforms at a fraction of the cost of purchasing new aircraft .

State-of-the-art in this context refers to the integration of cutting-edge technology into both new and existing aircraft. These kinds of upgrades can provide enhanced capabilities in areas like radar, communication, and navigation, which are essential for successful multi-domain operations. These updates enable older platforms to engage in more advanced combat scenarios and better integrate with next-generation systems, such as the NGAD F-47 and its associated CCAs'.

Demand for retrofitting legacy aircraft is evident in programs like the B-52 Commercial Engine Replacement Program (CERP), which has transitioned from mid-tier acquisition to a Major Capability Acquisition. The Air Force has requested $3 billion for B-52 procurement through 2028, including over $1.1 billion annually in 2027 and 2028. Within that, the Radar Modernization Program (RMP) accounts for $845.9 million, with procurement peaking at $271.95 million in 2027 to fund 74 radar kits and related systems. Alderman & Company is keenly aware of the impact these legacy upgrades can have on middle market suppliers. We are currently selling a company that manufactures components in this market. These upgrades not only enhance the B-52's capabilities but also drive sustained demand for middle-market suppliers specializing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(Copyright: Boeing MQ-28)

(Copyright: Boeing NGAD F-47)

in state-of-the-art retrofits—highlighting a broader industry trend as modern avionics, communications, and radar technologies are increasingly integrated into legacy platforms to ensure interoperability with NGAD .

How Future Military Networks Will Operate: Lessons from Ukraine and Gaza

The ongoing conflicts in Ukraine and Gaza have showcased the evolving nature of UAV warfare strategies, particularly in asymmetric warfare situations.

Ukraine's use of UAVs has been significant, with various drones deployed for ISR, strike, and electronic warfare. UAVs like the Turkish Bayraktar TB2, developed by Baykar Technologies, have played a crucial role in Ukraine's efforts against Russian forces. The Bayraktar TB2 is capable of precision strikes with guided munitions, and its ability to perform at long ranges has made it an effective tool for Ukraine in disrupting Russian operations .

In addition to the Bayraktar TB2, Ukraine has also deployed Switchblade drones, a type of loitering munition made by AeroVironment, which are used to target Russian vehicles and artillery. These UAVs have proven effective in disrupting supply lines and command posts, showcasing how smaller, more cost-effective UAVs can challenge superior air forces .

For suppliers in aerospace and defense industrial base, these conflicts provide a critical signal about the future of warfare. They reflect a broader transformation, where UAVs are reshaping how military operations are conducted. As the U.S. defense industrial base responds to these changes, there will be sustained demand for the technologies that make this shift possible—advanced communications, secure and fast networks, and cost-effective UAV platforms. The operational lessons from Ukraine and Gaza highlight the importance of UAVs in future combat. As we are seeing in our practice, middle market suppliers are becoming keenly aware of this shift and are focusing their resources on supporting both traditional aircraft platforms as well as these as up and coming UAV and CCA platforms.

New Players in Military Aircraft

In this evolving market, we see new entrants. Palantir and Shield AI developed a secure technology package demonstrated on the unmanned V-Bat and MQM-178 Fire Jet and manned F-16. This technology, based on Shield AI's Hivemind autonomous flight software, combined with Palantir's battlefield intelligence system, has proven its capability in enabling manned aircraft to control autonomous uncrewed systems (CCAs) .This exactly the kind of technology that the US Department of Defense is looking for, to facilitate the NGAD program and enable the F-47 manned aircraft to control a fleet of CCAs .

The growing investment in this kind of on-board technology for defense is another clear signal to middle market suppliers: the future of military air dominance will include computing and networking capabilities like those emerging from the Palantir–Shield collaboration

Conclusion

In the near future, military air dominance will require large numbers of CCAs and UAVs. These unmanned aircraft will require secure, high-speed data sharing between different military assets to ensure coordinated and efficient air dominance. The future of air dominance will not be dictated by individual aircraft capabilities alone, but by how effectively manned fighters and unmanned aircraft (CCAs and UAVs) can communicate and operate as a single, unified force.

And regarding older/legacy manned aircraft, modernization (to enable those aircraft to be "in the network") will require substantial investments into cutting-edge avionics, fast computing and secure communication. These retrofits are becoming a core strategy for the US and other military forces looking to maximize combat effectiveness and cost efficiency. By making these upgrades legacy aircraft can be integrated into modern battle networks, extending their operational life and maintaining their relevance in the age of future warfare.

The US DoD's budget priorities for NGAD (and its CCAs) and legacy aircraft upgrades present a significant opportunity for middle market companies in the defense industrial base. With only about 200 NGAD aircraft expected to be built, the initial plan is to build 1,000 CCAs and we expect there may be many more, as their cost effectiveness is realized. Middle-market suppliers should pay attention to these evolving changes in DoD priorities and take advantage of the substantial opportunities that lie ahead.

By Troy Medeiros, Vice President, Alderman & Company

DOWNLOAD NOW

Aircraft data is generally assumed to be maintenance data but it is now being used increasingly across all aspects of an airline's operations. Ian Harbison looks into how it is acquired, downloaded and processed.

Edward Gorman, Vice President, Engineering at Avionica, says there has a steady growth in the type and amount of data that can be downloaded from aircraft.

The Aircraft Condition Monitoring System (ACMS) and Aircraft Communications Addressing and Reporting System (ACARS) are the primary data sources for operational awareness, fault detection, and predictive maintenance. usage for operational and maintenance reporting. In addition, there is the (Flight Data Recorder (FDR) , mandated by regulation; and limited to post-event recovery and fixed parameter sets; the Quick Access Recorder (QAR), defined by the OEM and used by operators for routine analysis but often lacking completeness; and the Defined Access Recorder (DAR), a QAR derivative, modified by large airlines to meet custom needs but often cost-prohibitive for smaller carriers (for example, more than $100,000 to add high precision GPS).

The growth in the amount of data is exemplified by the Boeing 737 NG and the MAX, the latter generating eight times more ACARS traffic and QAR data.

One restriction to downloading more data is ARINC 717, which is limited to around 256 words per second (WPS), reducing resolution and analytical depth. It provides no

Modern aircraft like the Airbus A350 can generate massive amounts of data during flight. (Copyright: Airbus - Photo by H GOUSSE/Master Films)

support for integration or timing alignment with modern data buses such as ARINC 429, Ethernet, or other digital sources. He explains that Avionica's approach bypasses this limitation by capturing data using ARINC 429 at its native speed and timing of 8,192 WPS. This ensures complete and accurate capture and exact timing. This done without modifying the existing ARINC 717 wiring or architecture. After download, the data is delivered to the customer in ARINC 717 format for ease of use.

He says all recording starts with the DAU but OEMs are trying to lock down the documentation that controls inputs to it. In addition, where airlines could previously select their own supplier, the OEMs are pushing them towards a single supplier. In the case of Airbus, there is a data output channel that only goes into the Ground Flight Operations & Maintenance Exchanger (FOMAX) from Collins on A320 and A330 aircraft. This part of the aircraft manufacturer's Skywise data analytics service.

All aircraft data originates from centralised units: such as the Data Acquisition Unit (DAU), (Flight Data Acquisition Unit (FDAU) and Flight Data Interface Management Unit FDIMU). He says OEMs are increasingly restricting access to documentation, parameter definitions and third-party access, .steering airlines into closed ecosystems with mandatory single suppliers. For example, Airbus routes key outputs into the Ground Flight Operations & Maintenance Exchanger (FOMAX) from Collins on A320 and A330 aircraft. FOMAX (Collins), which only connects to the aircraft manufacturer's Skywise data analytics service, blocking integration with alternate platforms. This has created what Gorman describes as a "data gold rush", with OEMs and platform providers racing to control analytics value chains, not to create open ecosystems. He says this behaviour prioritises commercial monetisation over operational flexibility and undermines airline autonomy in managing safety and performance due to data bottlenecks and integration barriers.

He also points out that that the OEMs' have a poor track record in keeping up with rapidly changing progress. Boeing still ships legacy Wi-Fi systems on the 787 platform while Airbus was delayed in transitioning connectivity on the A350 from 3G to newer standards, with many operators having to revert to manual processes.

Edward Gorman, Vice President, Engineering (copyright: Avionica)

In contrast, Avionica is vertically integrated and has a Hardware-as-a-Service (HaaS) business model. It actively engages with third-party partners to integrate customer-requested applications and services. These are standardised and repeatable, which accelerates deployment for new customers with similar needs. This focus on service promotes continuous improvement, with development driven by customer feedback.

In summary, he says, the OEMS work at the speed of aviation, not at the speed of technology.

Avionica has cybersecurity certifications that allow it to link to other systems in the cabin for real time monitoring, with several customers showing interest and a possible product launch next year. Engines are the most important application. It will be offering bespoke integration. That means additional ARINC 429 ports and outputs can be added but the data is delivered to customers in their preferred format, again providing freedom from OEM dominance. Eventually, he would like to see an FDAU/FDIMU that acts as a comprehensive data source and forwards all content to an Avionica aviONS onboard network server.

The company also has a partnership to develop live telemetry streaming for operational analytics and predictive systems.

The company serves the commercial, regional and business aircraft markets. Commercial has the biggest fleets, so there is more competition, but operators are

The Avionica aviONS onboard network server (Copyright: Avionica)

looking for cost-effective and flexible alternatives to legacy OEM systems. Regional carriers operate like commercial airlines but face tighter cost constraints. They often fly aircraft that share avionics with business jets, creating synergy for tailored solutions. For business jet operators, availability is paramount as downtime is expensive and unacceptable to the owners, who invest in reliability and low-footprint upgrades.

Murray Skelton is VP Weather Solutions and Business Development at FLYHT Aerospace Solutions. In December 2024, the Calgary-based company was acquired by Firan Technology Group Corporation, an aerospace and defence electronics product and subsystem supplier.

The company's' Automated Flight Information Reporting System (AFIRS) has been around for about 20 years, and can use 5G and satcom for download, along with backwards compatibility with 3G and 4G/LTE. Three years ago, it was a pioneer of edge computing with the introduction of AFIRS Edge.

He says there are two types of data. ACMS/AMH data needs to be offloaded quickly and acted on and then there is the huge amount of routine data that can analysed with AI or algorithms for predictive maintenance. Cost is the barrier to downloading this in flight, he also says, so cellular is the cheapest

AFIRS Edge (left) and AFIRS Edge+ (Right) (Copyright: FLYHT)

way to do this and 5G is the most effective and will be around for some time - AFIRS can offload terabytes of data within seven minutes of landing.

He says ACMS software is extremely difficult and expensive to change on an aircraft as it is controlled by the OEM, and also very expensive to purchase, along with need for experienced personnel to use it. AFIRS Edge can be loaded remotely across an entire fleet. It can also be used to monitor a specific problem. For example, LEAP engines need to run for three minutes before shutdown. If there is a rise in engine problems, it is easy to remotely ask the ACMS to download whether the pilots followed the rules.

He compares AFIRS Edge to Amazon's Alexa – a small local unit that can connect to the whole of Amazon Web Services, which is constantly evolving, developing new capabilities. For AFIRS Edge, the equivalent is the development of extremely complex rules that select the data parameters to be recorded and how the data can be used most effectively for problem solving. This is important, he says, it is the quality of the data, not the quantity, that now makes it a differentiator between airlines – those with fewer technical delays and cancellations because they can pre-empt problems have a competitive advantage in terms of costs savings and, of course, passenger loyalty.

An ARINC 717-standard Data Acquisition Unit (DAU) is used to collect the information from all the aircraft systems, including the flight data recorder, which is then fed to the QAR. Within those data streams, there are different levels, depending on the DAU software and the age of the aircraft. For a Boeing 737, it is maybe a few hundred parameters, measured a few times a second. For a Boeing 737 MAX, it is tens of thousands of parameters being measured up to 40 times a second. It is the same data but the higher sampling rate means there is less chance that something significant will be missed.

Airlines want more data for their AI and predictive maintenance models, indeed, need more data, to make the models work more effectively. Interestingly, engines, perhaps the most complex components, are not monitored by the QAR. Instead, huge amounts of data are downloaded at regular intervals for analysis. AFIRS EDGE has additional ports beyond ARINC 717, so could be used to record performance in real time for download at the end of the flight. This could be used by the models. Early detection of performance degradation or impending failures seem to offer enormous potential benefits.

Another reason for some airlines being interested in this is their own very capable and experienced engineering teams – they do not want to be beholden to the OEMS, he explains, although in some cases the data is shared by both sides but used differently.

If the airline wants to pay for it, it is possible to send short message bursts to report location and altitude, engine temperatures, fuel load, fuel burn, as well as any exceedances that might occur - essentially inflight telemetry.

He adds that AI is going to make a huge difference, although it is still very early days. In a demonstration last year, he used it to determine heavy landings by four aircraft at three Canadian airfields. Having been fed invented weather conditions, the AI predicted one heavy landing (about the law of averages). The next step was to add data about previous heavy landings at the airfields, which resulted in a forecast of two events at an airport that was known to have wind shear issues at certain times. Adding more extreme weather data produced a prediction of five heavy landings, all at the affected airfield.

Murray Skelton is VP Weather Solutions and Business Development (copyright: FLYHT)

Another likely AI application is in other of company's products, such FuelSense, which analyses flight data based on eight industry recognised fuel savings initiatives that include: Single Engine Taxi, Reduced Flap Takeoffs, Reduced Acceleration Altitude, Low Drag Approaches, Reduced Flap Landings, Idle Reverse, and APU Monitoring. It compares how the aircraft was flown to how it could be flown in order to maximise efficiency and fuel savings.

However, he comments that moving more computing capacity and AI is unlikely to happen in the foreseeable future because AI results are undeterminable, so will not be permitted by the regulatory authorities.


More ways to
train better.

(Credit: IFS)

The Power of Engine MRO Modules

Rob Mather, IFS, Vice President of Aerospace & Defence Industries (Credit: IFS)

Esa Tuokko, Engagement Director, QOCO (Credit: QOCO)

Saravanan Rajarajan AVP and Head of Consulting for Aviation, Aerospace & Defence, Ramco (Credit: Ramco)

Aircraft engines are both essential and extraordinarily complex. This is why MROs pay particular attention to these engines during servicing, and why the makers of MRO software have created 'Engine MRO Modules' to assist them in this work.

A Truly Complex Process

Rob Mather is Vice President of Aerospace and Defence Industries at IFS. Its MRO software solutions cover airframe heavy maintenance, component repair, OEM aftermarket services, and engine maintenance, which it delivers through its IFS Complex Assembly MRO (CAMRO) module.

"Gas turbine engines are extremely complex machines," said Mather. "What separates engine maintenance from airframe and component maintenance is the need to disassemble, inspect, and reassemble each of the thousands of components in these engines."

"It is the orchestration of this incredibly complex process that sets engine MRO modules apart," he continued. "This software must also successfully mitigate the cost risks from disassembly through reassembly and testing, while ensuring the delivery of high performing engines within a minimized turnaround time and complying with all regulatory requirements." As well, engine MRO modules need to align the lifespans of an engine's various components, to maximize the overall useful life of the engine.

Sophisticated Solutions

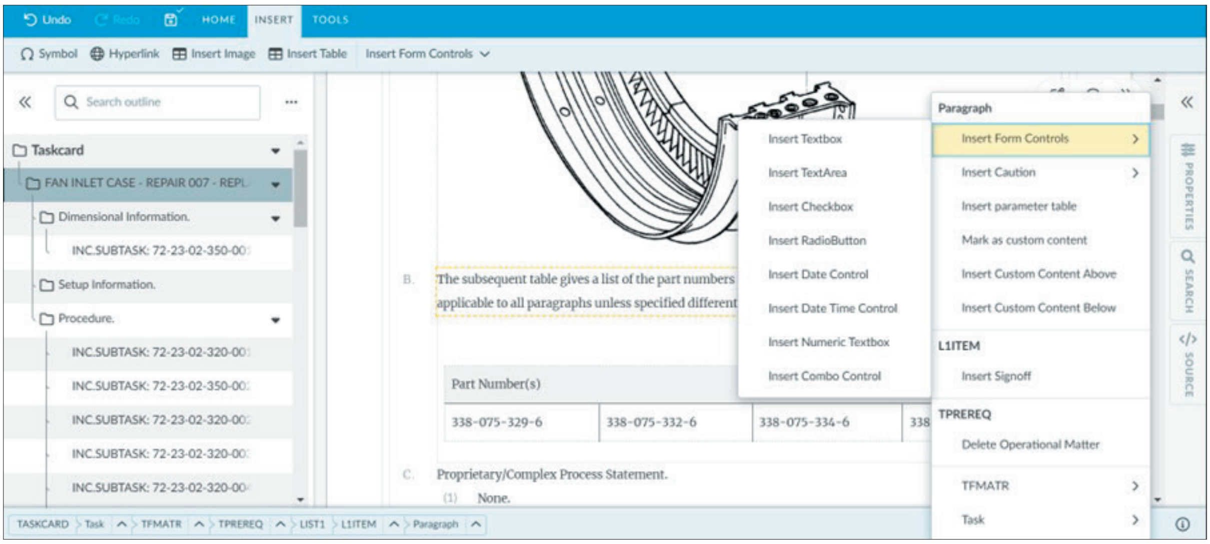
To address this wide range of engine servicing needs, MRO software suppliers have developed some truly sophisticated solutions.

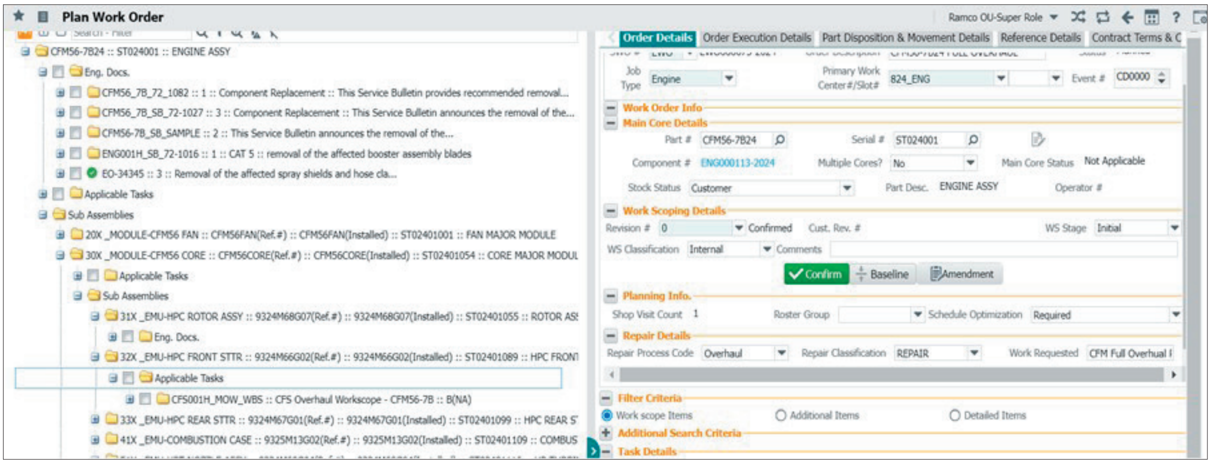
A case in point: "IFS has an industry-tailored CAMRO solution that deals with all these requirements while providing end-to-end support from shop visit work scoping through to redelivery and all supporting processes in one complete package," Mather said. Hence, by using the IFS CAMRO software module, MROs are able to identify potential problems, manage material flow, and maintain complete control over the engine servicing process.

Ramco Systems takes a different approach. Its Ramco Aviation Software 6.0 "addresses the end-to-end business requirements for engine MROs," said Saravanan Rajarajan, the company's AVP and Head of Consulting for Aviation, Aerospace & Defense. "The key engine-specific modules of Ramco Aviation Software include the digitized MRO Contract module, the Engine Engineering module, the Engine Workscoping module, the Work Execution module, and the Kitting and Sourcing module."

Then there's QOCO Systems. Their SaaS (Software-as-a-Service) products are designed to connect

Digital Task Card Ingestion from OEM and Customization. (Credit: Ramco)





Engine Work Planning for Both Tracked and Non-tracked Parts. (Credit: Ramco)

airline operators M&E systems to engine MROs' own ERP/M&E-systems. This feature allows airlines to check the progress of their aircraft engine repairs in real time. "Our main product for this is Aviadex," said Esa Tuokko, the company's Engagement Director. "Aviadex provides a granular overview of an engine's duty cycles, and calculates which parts, LLPs and rotables need to be changed during shop visits. This allows an MRO to buy the parts they need before an engine comes into their facility."

Finally, we turn to Ultramain Systems. This company's ULTRAMAIN MRO software platform comes with a suite of engine-specific MRO software modules. "These modules — Engine Planning, Engine Scheduling, and Engine Execution — are designed to manage the full lifecycle of engine maintenance within a fully integrated system," said John Stone, Ultramain Systems Vice President of Product Management. "The Engine Planning module ensures that maintenance activities are executed efficiently while optimizing resource utilization. The Engine Scheduling module in ULTRAMAIN provides a structured and interactive approach to managing maintenance tasking, shop flows, and repair activities. And the Engine Execution module serves as the core environment for performing maintenance tasks, enabling a fully digital and streamlined workflow."

The Many Benefits of Engine MRO Modules

The product descriptions above give a sense of the benefits provided by engine MRO modules to aircraft operators and repair facilities alike. However, to ensure that we didn't miss anything of importance to our readers, Aerospace Innovations asked each of the four companies we interviewed to provide their own benefit assessments.

Let's start with IFS' Rob Mather. "With the IFS CAMRO module, MROs are able to achieve three key benefits," he said. "The first benefit is Operational Visibility: The solution enables proactive identification of process bottlenecks, allowing users to drill down into task details and take corrective actions in real-time to improve efficiency and service levels."

The second key benefit associated with the IFS CAMRO module is consistent fast turnaround times. "This is because the solution helps manage material flow with detailed parts tracking, global warranty support, and detailed engine configuration status accounting, which helps to minimize material delays and risks to final delivery dates," said Mather. And the third benefit is what he describes as "Total Control: The IFS CAMRO solution allows users to maintain complete control over work scopes, parts, maintenance planning, inventory, ownership, and engine configuration through comprehensive process management."

The engine MRO benefits of Ramco Systems' Ramco Aviation Software 6.0 are next.

According to Saravanan Rajarajan, "our engine-specific software can deliver value at each stage of the business process. For example, in Gate 0, the time taken by the engineers to process the technical records of the incoming engine to arrive at the workscope for exit configuration can be reduced by 60%. There is also the potential to reduce 20% of material costs in gate 2 through forecasting and decision-assist capabilities. As well, the time to process the invoice to the customer can be reduced from weeks to days through automated and progressive invoicing."

As for QOCO Systems' SaaS (Software-as-a-Service) engine MRO products? "Benefits are typically measured by cost efficiency (better transparency and visibility of assets prior to shop visit, improved capability to execute spare part procurement and supply chain), and increased throughput capacity of engine shop slots (leading to higher net sales)," Esa Tuokko replied. "Two of our most important benefits are greatly shortened turnaround time, and optimized procurement and supply chain processes related to spare parts."

We conclude the benefits' list with Ultramain Systems John Stone. "ULTRAMAIN delivers ready-to-use and highly flexible engine planning, scheduling, and execution capabilities, eliminating costly modifications," he said. "It natively connects maintenance planning, execution, labor management, inventory, and billing — ensuring real-time visibility and efficiency. ULTRAMAIN supports real-time scheduling changes, dynamic task tracking, and workflow automation, keeping maintenance operations flexible and responsive. And ULTRAMAIN enforces FAA/EASA compliance with built-in electronic task cards, audit trails, and certification tracking. It also enables mobile access, so mechanics can manage tasks and order parts on the go."

AI is Driving Change

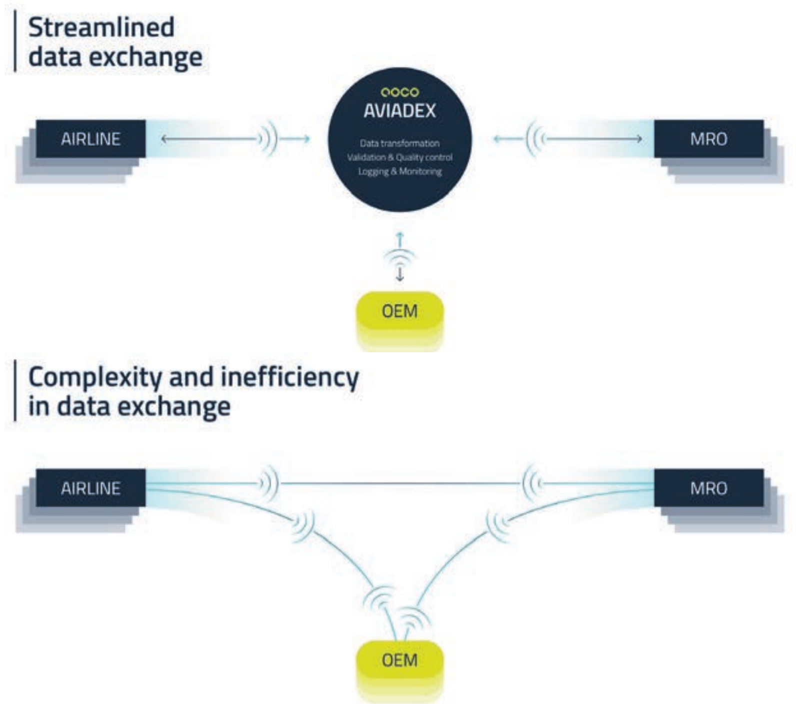
According to the experts, artificial intelligence (AI) is driving change and performance improvements in engine-specific MRO modules.

"AI is playing a critical role in workflow optimization, particularly in task sequencing and component routing," said Stone. "By analyzing historical data, AI can dynamically adjust schedules, ensuring that parts, tools, and manpower are available precisely when needed. This minimizes delays and optimizes shop flow efficiency. AI-driven routing logic can also adjust work assignments in real-time, prioritizing critical-path tasks and automatically reassigning technicians based on skill sets, availability, and certification requirements."

"It is the orchestration of this incredibly complex process that sets engine MRO modules apart."

Rob Mather, IFS' Vice President of Aerospace and Defence Industries

(Credit: IFS)



Top Image: Complexity and inefficiency in data exchange. Most collaborators in the aviation industry still share data manually or by point-to-point integrations, causing complexity, increased delays, manual data entry work and human errors. (Credit: QOCO)

Bottom Image: Streamlined data exchange. Aviadex streamlines data exchange, allowing collaborators to integrate once and choose which data is shared, and to whom. It eliminates manual data entry work and complexity for users. (Credit: QOCO)

As a result, engine-specific MRO software is evolving rapidly, "with advancements in AI, automation, and intelligent workflows transforming how maintenance is planned, executed, and optimized," he said. "Robotic Process Automation (RPA) is already enhancing ULTRAMAIN's paperless maintenance environment, reducing manual tasks like data entry, approvals, and compliance tracking. AI-driven predictive analytics are also being integrated to anticipate failure patterns, optimize maintenance intervals, and improve resource allocation, reducing downtime and maximizing engine life."

"AI is already heavily used and will be an increasingly utilized tool in product innovation and development processes," added Tuokko. "The automation of laborious operational tasks such as workforce planning, improving models for optimized forecasting and predictive maintenance from large datasets, parsing unstructured data (e.g. mechanic work reports) and improving the accuracy of reading data from PDFs are all benefiting from AI-enabled platforms."

IFS is one of these 'heavy users' of AI. "IFS has been well ahead of the curve in incorporating increased automation and AI in its solutions with developments such as support co-pilots, simulation, forecasting, and advanced optimization," Mather said. For instance, "AI-based optimization engines can be used to optimize task sequencing, shop routings, task assignments, and even optimize supply chains," he noted. "AI can be applied to predict when engines will come in for maintenance and what type of maintenance will be required allowing organizations to plan ahead and take a strategic approach – shifting from a reactionary model to a pro-actively managed model – planning your material procurement and making use of your resources to their utmost."

Looking ahead, future engine MRO workflows will combine "Digital OCR [optical character recognition] to automate data inputs, RPA [robotic process automation] to replace manual tasks, machine learning models to interpret the data, and agentic AI to make decisions and execute tasks," said Rajarajan. "Areas that Ramco is working include the prediction of scrap rates for an engine during the bidding and work scoping stage; part-sourcing recommendations based on technical and commercial parameter; conversational chatbots for engineers that accept input queries in plain text and generate insights in an easily explained and interpreted way manner; the automated selection of suppliers within an MRO's approved list; and the autonomous detection of spurious parts based on paperwork and web searches."

Challenges to be Overcome

Despite the many benefits associated with engine MRO modules, there are still challenges that have to be overcome in the aviation industry to ensure their widespread adoption and optimal usefulness.

In particular, "many engine MRO shops are still using inefficient disparate systems, and manual record keeping so the usual change management challenges around the adoption of modernized processes exist," Mather said. "The shift from paper-based to digital processes is challenging and the shift from a largely reactionary model to a model built on forecasting is also a significant organizational shift. In addition, compared to other types of aviation maintenance, it can be tricky to drive new process adoption in engine MRO. For example, an engine can stay at a given station for a long time with processes (e.g. disassembly) that require minimum interaction with other departments — as in they don't need to order parts frequently. This means that the execution of the process alone does not force adoption inherently. In turn, this means that new process adoption and enforcement can be tricky and buy-in from the technicians needs to be an area of focus."

As well, "the information technology landscape within relevant ecosystems (airline operators, airframe MROs, engine MROs, OEMs) is very complex and there are several tens if not even hundreds of relevant stakeholders," said Tuokko. "Security and compliance policies are constantly evolving, and it is costly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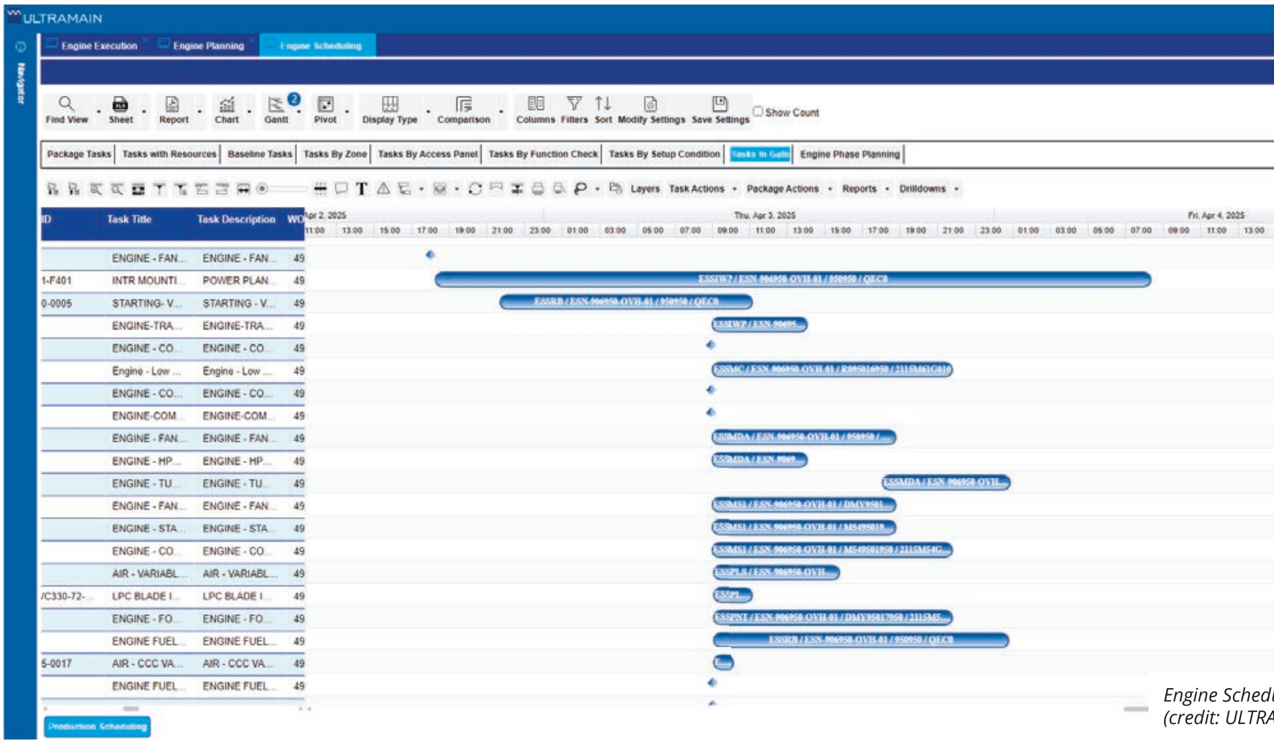

Engine Scheduling (credit: ULTRAMAIN)

and labor-intensive to keep all point-to-point solutions up-to-date."

"One of the biggest challenges in implementing new MRO software is ensuring seamless integration with legacy systems without disrupting operations." Stone observed. "Many solutions require costly middleware and extensive customization, which can delay deployment and introduce inefficiencies. AI-powered MRO solutions also rely on accurate, standardized data for predictive analytics, scheduling optimization, and automation: Poor data quality can lead to incorrect maintenance projections and inefficiencies. And MRO software must adhere to strict aviation regulations, especially as the industry moves toward fully digital operations."

Finally, engine OEMs as a whole are undergoing massive technological transformations, which has a cascading impact on engine MROs, said Rajarajan. "For example, most OEMs have established digital platforms, and technical documentation is served digitally to the end consumers, such as airlines and MROs," he said. "This shift forces engine MROs to upgrade their existing systems and processes, especially their backbone software. To achieve this, the engine MROs must redesign their processes." The good news is that cutting-edge engine MRO modules can assist in this upgrade.

The Next Industry Standard?

In the course of this article, we have witnessed just how powerful engine MRO modules are in supporting the effective, efficient, and safe servicing of aircraft engines. So does this mean they're about to become the next MRO industry standard? John Stone certainly thinks so.

"Yes, engine-specific MRO software modules are poised to become the industry standard in the coming years," Stone told Aerospace Innovations magazine. "As engine maintenance operations grow more complex and data-driven, the need for highly specialized, integrated, and automated solutions will only increase. Generic ERP systems and customized legacy software simply cannot keep pace with the real-time tracking, AI-driven optimization, and regulatory compliance required to operate efficiently in today's aviation environment. "

In fact, "the aviation MRO industry is already shifting toward paperless operations, predictive maintenance,

> **"Our engine-specific software can deliver value at each stage of the business process."**
>
> **Saravanan Rajarajan, Ramco Systems' AVP and Head of Consulting for Aviation, Aerospace & Defense**

and AI-enhanced scheduling, all of which demand purpose-built MRO software that can seamlessly integrate planning, execution, inventory, and compliance in a unified platform," he concluded. "As technology advances and regulatory bodies continue encouraging digital transformation, MROs will find that engine-specific software is no longer just an advantage, it's a necessity. Those who adopt specialized MRO platforms will see reduced turnaround times, lower operational costs, and improved compliance, making it an inevitable industry standard rather than just an option."

By James Careless


POWERING
INSIGHT
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In modern aviation, every second counts—and every insight matters.
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Boeing claims it has enough elasticity in its supply chain to weather current market conditions. (Credit: Boeing)

Targeting the Achilles heel of Supply Chain Management

AI is increasingly being deployed across the aviation sector, but to what extent can it help navigate the turbulent waters of the supply chain?

"2024 made it absolutely clear that people want to travel," proclaimed Willie Walsh, International Air Transport Association (IATA) Director General in January 2025, as he announced 2024 full-year and December 2024 passenger market performance. "Aviation growth reverberates across societies and economies at all levels through jobs, market development, trade, innovation, exploration, and much more."

After a series of testing years for Airbus and Boeing, both are reporting strong order intakes and increased deliveries as production stabilises and rates increase over time.

At Airbus, the A320 Family programme continues to ramp up towards a rate of 75 aircraft per month in 2027. The company is now stabilising monthly A330 production at around rate four. On the A350, Airbus continues to target rate 12 in 2028, whilst on the A220, it continues to target a monthly production rate of 14 aircraft in 2026.

Over at Boeing, the 737 program has gradually increased production and maintains plans to reach 38 per month this year. The 787 program continued to stabilise production at five during Q1 2025, and Boeing still expects to increase to seven per month this year.

On the surface, things seem to be going in the right direction. But look closely, and Airbus has a confirmed backlog of 8,651 aircraft as of December 31, 2024. Boeing has a backlog of more than 5,600 airplanes: that translates to over seven years of production.

Addressing this growth path is not easy. As a 2024 article from McKinsey & Company observes, commercial aerospace OEMs and suppliers are dealing with multiple challenges in parallel. These include quality control issues, new regulations, talent shortages, and an increasingly splintered geopolitical environment. One of the more pressing issues—and one frequently cited—relates to persistent supply chain constraints.

Corridors of uncertainty

"The current state of the MRO supply chain is characterised by high volatility and uncertainty in demand, making planning and stability particularly challenging," says Matt Porter, Head of Aerospace & Defence Industries, Sopra Steria UK.

"MRO managers are grappling with how to effectively manage these uncertainties to stabilise inventories and maintain service levels without escalating immobilised costs. This is a critical issue as traditional solutions have not proven to be entirely efficient."

Announcing its Q1 2025 financial results, Brian J. West, Chief Financial Officer & Executive Vice President-Finance, confirmed that Boeing continues to make adjustments as needed and manage supplier by supplier based on inventory levels. "Over the past year, our buffer inventory has grown to promote stability across our production

> "Over the past year, our buffer inventory has grown to promote stability across our production system. As production stabilises and rates increase over time, we plan to deliberately return buffer inventory to more normal levels."
>
> Matt Porter, Head of Aerospace & Defence Industries, Sopra Steria UK

system. As production stabilises and rates increase over time, we plan to deliberately return buffer inventory to more normal levels."

Porter says today's supply chain managers face numerous pinch points. These include planning under uncertainties, where the unpredictable nature of demand and supply makes it difficult to create stable and reliable plans. "Managers must constantly adjust to new information and changing conditions," he says.

Additionally, there's disruption root cause analyses. "Identifying the root causes of disruptions is often complex," says Porter. "Understanding where and why supply flows are blocked or delayed requires sophisticated analytical tools and processes."

He also highlights end-to-end visibility and anticipation. "Achieving full visibility across the entire supply chain is a significant challenge. Managers need to see the state of all flows within the end-to-end supply chain to make informed decisions." Lastly, he raises the issue of optimisation. "Making good recommendations for resource allocation, production capacities, and logistics re-routing is essential. This requires advanced optimisation techniques and tools."

West says that Boeing has enough inventory for it to achieve the production rates mentioned. "We've got really good alignment with our key suppliers, fuselages, engines, everything looks pretty good." West said the company would have to get through some "discrete moments" surrounding the current tariffs and ensuring the continuity of delivery. "But as we look a little further out, good alignment, plenty of inventory, feel pretty confident about the supply chains side of it."

Digital deliveries

Aviation's supply chain is a turbulent beast, characterised by the complexity of managing thousands of parts, each with its unique regulatory and compliance requirements. Boeing's response to this daunting challenge is indicative of the current trends in MRO.

As exemplified by Boeing, Porter says that companies are increasingly focusing on agility and responsiveness to improve efficiency. This involves adopting flexible strategies that can quickly adapt to changing demands and supply disruptions. In such turbulent times, enhanced collaboration between suppliers, manufacturers, and service providers is becoming essential. Integrated systems that provide real-time data sharing and communication are being adopted to improve overall supply chain visibility and coordination.

And then there's digital transformation, which Porter says is a growing trend for the MRO supply chain. This includes the use of advanced analytics, IoT, and AI to enhance predictive maintenance and inventory management.

At this year's MRO Americas in Atlanta, ePlaneAI marked its appearance by unveiling its evolution from a digital marketplace to a full-suite provider of AI-powered aviation solutions.

"Our transition from a marketplace to AI-powered aviation solutions is a direct response to what the industry truly needs: efficiency, accuracy, and real-time automation," said Meir Rozolio, CEO.

Writing in a company blog, Angel Marinov, Head of Innovation, said that "We've built a purpose-driven aviation intelligence platform designed to optimise procurement, inventory management, and maintenance workflows in real-time."

The AI suite now includes AeroGenie, an intelligent enterprise resource planning (ERP) assistant that makes aviation data searchable and accessible in plain language. Essential metrics and reports can be instantly retrieved through simple commands, available at any moment.

Other features include Inventory AI, which predicts parts demand to optimise stock levels, minimise shortages, and reduce carrying costs. It provides real-time vendor integration for seamless ordering and analyses stock movement and usage rates. The suite also includes Document AI, which automates the review and validation of critical aviation documents, helping organisations strengthen compliance. Document AI dramatically reduces search and data retrieval time by extracting, analysing and indexing information from both structured and unstructured aviation documents.

Additionally, the platform includes Email AI, which automates request for quotation (RFQ) processing, speeding up response times and streamlining supplier communications. Email AI leverages advanced Large Language Models (LLMs) to intelligently read, categorise, and respond to email RFQs in 60-120 seconds. Using clustering models like K-Means and hierarchical clustering, it segments customer requests to prioritise high-value opportunities. It can also optimise pricing based on real-time market trends and customer data.

Agentic AI gets active

In an EY insight, Gaurav Malhotra, Supply Chain Technology Leader and

Like others, Airbus has suffered from constraints in the supply chain but believes it can still improve production rates. (Credit: Airbus)

EY Global Alliance Executive Sponsor, and Ayoub Abielmona, EY Global GenAI Supply Chain Leader profile how agentic AI is expanding the capabilities of demand forecasting, supply planning, inventory management, logistics optimisation and predictive maintenance. Looking ahead they say, agentic AI help organisations predict and mitigate future supply disruptions with limited human intervention.

They explain that while agentic AI also relies on an LLM, it primarily uses the LLM as a central coordination module or a decision-making tool that interprets complex, goal-oriented requests and then autonomously plans and controls the execution of internal or external tools to achieve the desired outcome. The overarching focus is on autonomy, with the LLM taking ownership of understanding requests, planning actions, executing tasks and optimising processes, with limited human oversight.

Making a difference

Porter says there are a number of benefits from using AI, including cost optimisation. Here, Porter says AI can help identify areas where costs can be reduced without compromising service levels. This includes optimising inventory levels, reducing waste, and improving operational efficiency. AI can also create digital twins of the supply chain to simulate various scenarios and predict outcomes. This helps in making data-driven decisions and preparing for potential disruptions.

Other benefits include continuously monitoring demand patterns and provide real-time insights, enabling better forecasting and planning. AI models analyse historical data to identify trends and forecast future demand. This enables airlines and suppliers to adjust their inventory levels proactively.

Further advantages are automated learning, whereby machine learning algorithms continuously learn from new data, improving their predictive capabilities over time. This adaptability is essential in the dynamic aviation industry, where demand can fluctuate rapidly. With natural language processing AI can process vast amounts of unstructured data, such as customer feedback and market reports, to extract insights that inform demand forecasting.

To this list, Porter adds virtual assistants which can be used for exogenous risks management and flows re-routing and automatic analyses.

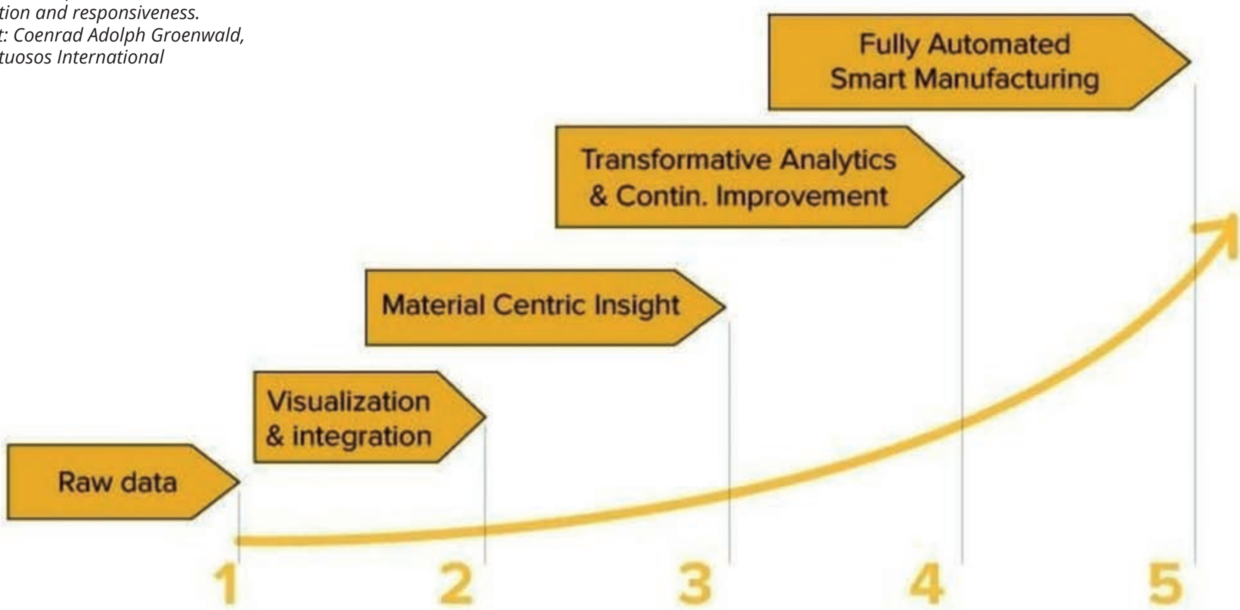
AI-powered virtual assistants can help manage risks that are external to the supply chain, such as geopolitical events or natural disasters, by providing early warnings and recommending mitigation strategies. AI can also automate the re-routing of supply flows and perform automatic analyses to identify bottlenecks and optimise logistics.

Lufthansa Technik is collaborating with Microsoft in the use of artificial intelligence to optimise entire maintenance processes, as part of Digitize the Core", a comprehensive initiative by Lufthansa Technik to drive forward the digitisation of the company's core operational processes.

The initiative includes over 50 context-sensitive AI use cases based on Microsoft Azure AI Services and Microsoft Azure cloud. By using LLMs provided via Azure AI Services and a memory-enabled cognitive architecture, Lufthansa Technik aims to distill knowledge from vast amounts of data, including unstructured data such as work instructions. Much of the information is also hidden in sources

AI-powered optimisation algorithms can lead to improved resource allocation and responsiveness. (Credit: Coenrad Adolph Groenwald, SG Virtuosos International

AI driving the smart supply chain management:



such as code, folder structures, images, or charts. To answer complex questions effectively, this knowledge must be made accessible and linked to other data.

According to Florian Deter, Managing Director at Microsoft Germany, "AI is the pivotal technology of our time. It not only enables incredible breakthroughs that could hardly have been imagined before. In its development, security and data protection have the highest priority for us and for Lufthansa Technik."

Dushyant Mohanty, Head of Consulting & Advisory for North America Aerospace and Defense at TCS, and Bhaskar Sharma, Aerospace & Defence Executive at TCS Switzerland cite that in product development, AI and GenAI can accelerate a 'shift left' supplier collaboration approach, building on digital threads and cloud-based engineering platforms.

According to the pair, this leads to "smarter component choices, reducing long-tail supply chain risks and costly redesigns. AI and GenAI can also be used to predict material shortages and swiftly source alternatives from tier 1 and tier 2 suppliers, optimising production processes without inflating inventory costs."

Risk and challenge

In May 2023, the European Union Aviation Safety Agency (EASA) released the second version of its AI Roadmap which provides a comprehensive plan for the integration of AI in aviation, with a focus on safety, security, AI assurance, human factors and ethical considerations.

One chapter of the Roadmap identifies a set of common challenges that will require further consideration. This includes elaborating pertinent guarantees on stability and robustness of AI models and on the absence of 'unintended behaviour' in AI applications.

As the Roadmap draws attention to, due to the statistical nature of data-driven and statistical applications, they are subject to variability in their output for small variations on their input (that may even be imperceptible by a human). There is a need to investigate new methods to verify the stability and robustness of AI applications, as well as to evaluate the completeness of the verification. The use of formal methods as providing suitable verification means is further investigated. Such methods may as well be a means to compensate for the lack of coverage analyses, while observing closely and attentively the underlying scalability issues presented by these methods.

To the list of AI risks, Porter adds:

- Data Continuity and Visibility: AI systems require continuous and high-quality data to function effectively. Ensuring data continuity and visibility across the supply chain is crucial but can be challenging due to siloed systems and data inconsistencies.
- Change Management: Introducing new AI tools requires significant change management efforts to ensure adoption by employees. This includes training, communication, and addressing resistance to change.
- Data Quality Assessment: The quality of data is paramount for AI systems to provide accurate insights. Ensuring data quality and integrity is an ongoing challenge.
- AI Transparency: Making AI systems transparent and understandable to users is essential for building trust and ensuring adoption.
- Human in the Loop: AI should be used as a decision support tool rather than a replacement for human judgment. Ensuring that humans remain in the loop is crucial for effective decision-making.
- AI Ops: Implementing robust AI operations, including testing

pipelines and monitoring, is essential to ensure the quality and reliability of AI systems

In addition, generative AI can sometimes identify patterns or objects in data that are non-existent and yield results that are either nonsensical or altogether inaccurate—a phenomenon known as a "hallucination."

Introducing agents of change

With an awareness of these threats, those in the supply chain need to adopt best practices.

Porter says there are several strategies to implement. One surrounds AI Transparency. "Ensure that AI systems are transparent and explainable. Users should understand how AI recommendations are generated," Porter advises. He also recommends using AI as a decision support tool, keeping humans in the loop to make final decisions.

Further best practices embrace data quality assessment. Porters says there is a need to regularly assess and improve data quality to ensure accurate AI insights. He also advises to implement robust AI operations, including testing pipelines and monitoring, to ensure the quality and reliability of AI systems.

Consideration should also be given to change management. "Invest in change management efforts to ensure employee adoption of new AI tools. This includes training, communication, and addressing resistance to change," says Porter, who likewise champions continuous improvement. "Regularly review and update AI systems to incorporate the latest advancements and address emerging challenges," he says. This helps maintain accuracy and relevance in predictions.

AI can help airlines better deal with their MRO strategies for improved outcomes. (Credit: Lufthansa Technik)

Thinking ahead

With AI now becoming a pervasive element within aviation, what future innovations can the industry expect over a five-to 10-year period?

Porter feels many will build upon those that currently exist.

"Generative AI and virtual assistants will become integral to operations management and decision support processes. These tools will help accelerate processes and improve efficiency," he states. "Each step of the supply chain process will also have dedicated AI agents to optimise operations, from procurement to delivery."

Porter believes that the use of advanced analytics and machine learning will become more pervasive, enabling real-time decision-making and predictive insights, while blockchain technology will be increasingly adopted to enhance transparency and traceability across the supply chain.

In addition, there will be a greater focus on sustainability, with AI and other technologies being used to reduce waste, optimise resource use, and minimise the environmental impact of supply chain operations.

Finally, Porter says that the deployment of autonomous systems, such as drones and robots, will become more common, further automating supply chain processes and improving efficiency.

AI has the possibility to benefit many aspects of the aviation industry, with supply chain optimisation just breaking the surface of possibilities.

By Alex Preston

CAE: An Innovative Company at the Cutting Edge of Cool

In a recent edition of Aerospace Innovations, we covered the official opening of CAE's Air Traffic Services Training Centre (ATSTC) on its Montreal campus, adjacent to Montréal–Pierre Elliott Trudeau International Airport. But there was a lot more for this reporter — and other members of the global aerospace media — to see at the facility, which also happens to be where CAE designs and manufactures its Full-Flight Simulators (FFSs).

In this story, we'll take you inside that operation to show why CAE truly is an innovative company at the cutting edge of cool.

Humble Beginnings

Today, CAE is a dominant force in the simulator manufacturing and aviation training markets. For decades, its hyper-realistic, six-axis Full-Flight Simulators have been standard issue at the world's major airlines and aviation training facilities. Small wonder. Having personally taken their Bombardier Global 7500 simulator into a near-vertical climb during this media tour — and terrifying myself in the process, thanks to the simulator's realism — I can say that being in a CAE FFS truly is the next best thing to actual flight.

Yet the company started humbly in an empty hangar at Saint-Hubert Airport (now Montreal Metropolitan Airport) in Longueuil, Quebec, on Saint Patrick's Day, 1947. Back then, it was known as Canadian Aviation Electronics Ltd. and employed just 18 people. CAE was founded by retired RCAF officer Ken Patrick, who wanted to "create something Canadian and take advantage of a war-trained team that was extremely innovative and very technology-intensive."

In those early days, CAE took on whatever work it could to survive. This included installing antenna farms in Canada's far north for the RCAF and repairing ground-based communications equipment. But that's not all — CAE also built moisture detectors for grain storage, Geiger counters to detect radiation, and even, for a while, consumer television sets.

The company's big break came in 1952 when the RCAF hired CAE to build a simulator for the CF-100 Canuck, a Canadian twin-engine interceptor/fighter made by Avro Canada (which later designed the iconic Avro Arrow). CAE equipped this trainer with highly advanced technology to simulate radar targets

"Our goal was to create a virtual flight deck that allows students to train realistically, by making the same hand motions they'd use in a real aircraft."

Erick Fortin, CAE's Director of Incubation

From its humble beginnings in 1947 to today, CAE has become the global aviation training leader – its full-flight simulators known as among the most technologically advanced and trusted in the world. (Copyright: CAE)

CAE is the company that trains the most pilots - whether commercial, business, helicopter or military – in the world. Although it began making simulators in 1952, it is now also renowned for its innovative approach to pilot training, whether cadet training for aspiring pilots, type-rating for pilots wanting to fly a different aircraft, recurrent training, or advanced courses for those seeking career progression. (Copyright: CAE)

and score weapons discharges. That success led to a DC-6B simulator for Canadian Pacific Airlines, and later to F-104 Starfighter simulators for the RCAF in the 1960s—so good that five other NATO countries bought 26 of them. CAE was on its way to becoming a simulation powerhouse in both civil and defence aviation.

A Gigantic Factory Floor

CAE's Montreal campus is home to all things CAE — and a great place to watch planes landing and taking off at the adjacent airport. The heart of the site is the company's massive factory floor, which spans nearly half a million square feet.

Our tour guide that day was Steve Levesque, CAE's Vice President of Global Hardware Engineering, Manufacturing Quality, and Facilities. "We do everything here from fabrication to testing, logistics, shipping, and so forth," he told us. "We're starting from scratch: we even cut and bend our own metal."

About 550 unionized workers keep the floor humming, running three shifts on weekdays and a fourth on weekends. Their workflow is laid out in stages, from raw materials and basic fabrication through to the assembly and testing of sophisticated simulators.

The most jaw-dropping sights are the towering Full-Flight Simulators, whose glossy structures resemble a Martian invasion force from The War of the Worlds. "These are our CAE 7000XR Series Full-Flight Simulators," said Levesque. "From the outside, they all look the same. But the cockpits inside are totally customized for each customer. For instance, the FFS in front of us is for an Airbus A320, while the one down the line could be for a 737."

To increase efficiency, CAE builds its simulators in five separate modules and integrates them later, rather than assembling each one sequentially. "When we built the previous version, we did them one at a time," Levesque explained. "The problem with that was if one simulator took longer than expected, the whole line slowed down. That's why we moved to a modular approach, it gives us the opportunity to manage our production rate and meet customer demand."

The same approach applies to CAE's 3000 Series helicopter simulators, which can be configured for aircraft like the CH-47 Chinook, CH-149 Cormorant, or Sikorsky NH-60 Black Hawk.

Everything is tested on site, which accelerates production and eliminates the cost and delay of shipping parts elsewhere. At a time when cross-border tariffs are pushing up prices, this self-contained setup is good news for both CAE and its clients.

Apple Vision Pro + CAE Software = The Ultimate VR/AR Training Solution

Apple's Vision Pro headset is sleek, wireless, and powerful—just what you'd expect from the tech giant. Now, imagine what happens when CAE integrates this VR/AR marvel with its own pilot training application.

The result? A fully interactive cockpit where trainees can operate switches and instruments using hand gestures. The system can place students in a fully immersive environment or show a stripped-down cockpit with visibility into the classroom around them. It's flexible, responsive, and impressively realistic.

CAE's Director of Incubation, Erick Fortin, was my guide into this hybrid training world. "Our goal was to create a virtual flight deck that allows students to train realistically, by making the same hand motions they'd use in a real aircraft," he said. "We wanted to get away from handheld controllers—they're just not realistic."

The AR/VR trainer guides students through sequences to prepare for and execute a flight. What surprised me most was how quickly my brain accepted the experience as real. It took little time to master the hand gestures needed to interact with the cockpit. This wasn't a video game pretending to be a simulator—it was the real deal.

CAE was the first to develop an immersive pilot training app using the Apple Vision Pro goggles. The CAE app uses spatial computing to bring true-to-life precision to flight deck interactions, allowing pilots to remotely complete training activities that are currently only available in training centres. (Copyright: Gleb Gomberg for CAE)

Harnessing the Electric Revolution

CAE's training programs aren't limited to simulators. The company also provides hands-on flight instruction using a fleet of about 60 Piper Archer single-prop aircraft. Of these, 48 are based at CAE's Phoenix Aviation Academy in Mesa, Arizona, where many airline pilots begin their careers. The fleet also includes eight Piper Seminoles, seven Cirrus SR20s, two Cessna Citation CJ1s, and two Diamond DA20s.

Knowing that electric propulsion is the future, CAE is developing a retrofit kit for the Piper Archer, based on the EASA-certified Safran ENGINeUS 100 electric engine. Several of these aircraft, in various states of disassembly, can be found inside the Montreal facility.

Mukund Patel, CAE's Design Lead for Electric Aircraft, described the process. "We've taken out everything unnecessary for electric flight—gasoline engine, fuel tanks, related systems," he said. Batteries will be installed in the wings and behind the pilot, but they currently require so much space that CAE is converting the four-seater into a two-seater.

Once the battery layout is finalized, CAE will install the electric engine, a new propeller, a cowling, and supporting avionics. Everything must be safe, balanced, and efficient enough to fly. "We're still in the detailed design phase," Patel said. "We completed a preliminary design review last year. That helped define what we're trying to achieve."

Willing to Take Risks

If successful, CAE hopes to electrify a portion of its own training fleet—and eventually market an electric retrofit kit for the worldwide Piper Archer trainer fleet. The potential market is huge. If the performance is right and the price is advantageous, many piston-powered aircraft owners would likely consider switching to electric.

It's a bold leap. But then again, CAE has taken bold leaps before, starting with that first simulator in 1952. And their recent entry into air traffic control training with the ATSTC is another big one.

Risk-taking is part of CAE's DNA. Just ask anyone who remembers when the company tried to make TVs. That didn't pan out, but most of their risks have paid off—enough to turn CAE into one of the world's most successful aviation firms.

That's why I expect CAE to stay at the cutting edge of cool — whether in flight simulation, aviation training, electric aircraft, or whatever else they dream up next. I've seen the future on their factory floor, and I am impressed.

By James Careless

CAE is developing a retrofit kit for the Piper Archer, which it uses for its ab-initio training, to eventually electrify a portion of its own training fleet. based on the EASA-certified Safran ENGINeUS 100 electric engine.

Three key CAE electric aircraft team members. From left to right: Richard Alexander, Stella Filippatos, and Mukund Patel.

The enigma of eVTOLs

The eVTOL market is beset by claims and counterclaims but what is the current state of leading eVTOL programmes?

eVTOL programmes are progressing at different rates backed by innovative technologies, strong investments, and progress in regulatory approval activities. (Credit: Archer Aviation)

For some, the eVTOL market is a bed of technological innovation, offering the potential to disrupt transport through faster, more direct aerial pathways. One is Captain Fahad ibne Masood, a senior analyst at the Advanced Air Mobility Institute.

As Captain Masood expounds, "the commercial aviation market, especially urban air mobility and regional travel, will significantly increase in the long-term due to rising congestion in urban areas, as well as the need for faster and more eco-friendly modes of transport," he says.

"Cargo delivery also has substantial opportunity for near-term adoption, spurred by the growth of e-commerce and the high demand for efficient first as well as last-mile delivery in urban and remote areas. eVTOL technology will have immense early market effect in the defense industry for reconnaissance, troop and equipment transport, search and rescue, and medical evacuation missions."

Others are more sceptical, believing the eVTOL market is mired in unrealistic forecasts and timelines, which have obscured the reality of developing, certifying and delivering a new clean-sheet aircraft.

These commentators can point to the failure of Lilium, which has once again entered into insolvency, having failed to find further financing, due to "technical difficulties in accessing infrastructure funds."

But such divergent sentiment highlights the uncertainty surrounding the trajectory of the market, and its near-term volatility and long-term potential. It also begs the question, has the enthusiasm surrounding the eVTOL sector surpassed its actual development stage?

With so much fog surrounding eVTOLs, what is the reality?

A degree of transparency is provided by the Advanced Air Mobility Reality Index, a rating tool, based on a proprietary formula that uses publicly available information as well as expert knowledge to assess the industry entrants' progress toward the delivery of a certified product at mass scale production. The tool is un-biased and data-based and not meant as an endorsement or a critique of any specific company, but as a simple, easy-to-use guide to the complexities of the AAM industry.

It rates EHang, Joby and Archer as best placed on the path to commercialisation.

Certification momentum

EHang has made some important strides, becoming the first company in China to gain certification for autonomous eVTOL passenger flights.

At the end of March this year, EHang and Heyi Aviation and its joint venture company in Hefei, HeYi Aviation have been granted the first batch of Air Operator Certificates (OC) for civil human-carrying pilotless aerial vehicles by the Civil Aviation Administration of China (CAAC).

Under the definition by CAAC, passenger Transportation refers to airline operators using CAAC-compliant civil aircraft to engage in commercial flight services for transporting passengers. Conversely, human-carrying refers to airline operators using CAAC-compliant civil aircraft to carry individuals other than crew members and personnel essential to flight operations, engaging in commercial flight services that are not classified as passenger carrying.

The initial phase of autonomous EH216-S operations is primarily focused on air tourism, urban sightseeing, and flight experiences, as per the OC. Initially, these certifications cover flights that take off and land at the same location (Point A-to-A routes) for human-carrying tourism and flight experiences.

The OC categorises operations as "Hovering Flight", which includes hovering, circling, and return flights near the designated take-off and landing zones.

According to EHang, the two certified operators are prepared to offer paid human-carrying tourism and flight experience services along designated routes. Simultaneously, in coordination with the CAAC, relevant strategies are being formulated to synchronously apply for human-carrying sightseeing and experience flights from Point A to Point B. Building on the obtained OCs, the process will gradually be promoted to higher level of flight operations.

Archer has begun production of the first Midnight aircraft at its ARC facility in Covington, Georgia. (Credit: Archer Aviation)

Joby Aviation asserts it has made significant progress on the fourth stage of the type certification process to date, for its electric air taxi which is designed to carry a pilot and up to four passengers at speeds of up to 200 mph.

According to the company, during 2024, it saw a 12-percentage point increase on the Joby side and a 10 point increase on the FAA side, bringing the company to more than 53% complete on the Joby side and 31% on the FAA side. A further milestone was met with the completion of its first FAA 'for-credit' static load testing of the tail structure, and completion of a first Type Inspection Authorization (TIA) testing with the FAA, using Joby's flight simulation lab and conforming flight deck to perform human factors testing with FAA pilots.

The update was made in a Fourth Quarter and Full Year 2024 Shareholder Letter, posted in February this year.

"Completion of our first TIA testing is an acknowledgment by the FAA of the maturity of our certification program," Joby stated. The company is preparing for flight TIA, which is planned for within the next 12 months.

In June 2024, Archer Aviation subsidiary, Archer Air, received its Part 135 Air Carrier & Operator Certificate from the FAA, allowing the company to begin operating aircraft commercially to refine its systems and procedures in advance of launching Midnight into. Archer is now one of two air taxi manufacturers in the world to have announced receipt of a Part 135 certificate from the FAA.

In addition to its Part 135 certificate, Archer has also received its Part 145 certificate from the FAA allowing it to perform specialised aircraft repair services. The FAA has also issued the final airworthiness criteria for the Midnight aircraft. The completion of the Part 135 certification process involved five rigorous stages, which entailed the submission of extensive documentation of operational manuals and procedures, as well as Archer's pilots needing to demonstrate proficiency with those manuals and procedures under FAA observation.

Since finalising Certification Basis in May 2024, formally closing the FAA's second phase, Archer has placed its efforts on the safety of flight activities related to its piloted aircraft, as it works with the FAA to finalise the means and methods of compliance in third phase. Specific topics that were finalised include means and methods of compliance for safety and development assurance, electric engines, batteries,

Archer's says it is on track to deliver its first revenue-generating Midnight aircraft later this year. (Credit: Archer Aviation)

high voltage systems and structural loads. Archer says it has completed 700+ flight hours on its iron bird, testing numerous potential failure modes across many of Midnight's key systems in advance of planned for credit testing on the aircraft.

"With these activities finalised, we are now substantially complete with the compliance planning phase of the certification program," Archer says. "We continue to be largely focused on the fourth phase of our certification program with the FAA. We now have FAA approval for ~13% of the total compliance verification documents in this final phase before type certification."

In the UK, Vertical Aerospace has completed the second stage of piloted thrustborne testing of its full scale VX4 prototype. The company is now preparing for the VX4 to enter the penultimate phase of flight testing, wingborne flight, which can begin once the UK's Civil Aviation Authority (CAA) has expanded Vertical's Permit to Fly. Once approved, the VX4 will take off, fly, and land like a conventional aircraft, with lift generated by its wings rather than its rotors. Transitioning from a tightly controlled test environment to more dynamic, scalable operations is a major leap forward on the path to full certification and commercial viability.

Once the aircraft has completed wingborne flight, the aircraft will have, in effect, completed a mini-certification process with this prototype. While Vertical works with the CAA to expand its Permit to Fly, the company says it will continue to perform important system and component testing as well as progressing the development of an identical full-scale prototype which will accelerate the VX4's flight test programme and demonstration capability. Following wingborne testing, the VX4 will enter a final phase of transition testing to demonstrate its ability to switch between vertical and forward flight modes.

During Phase 2, the aircraft completed over thirty piloted test flights. Flight tests included completing successful hover and low speed flight manoeuvres, as well as executing handling and performance procedures including roll, yaw, and spot-turns.

Demonstration flights

Korea's K-UAM Grand Challenge was launched in 2023 by Korea's Ministry of Land, Infrastructure and Transport to support the commercialisation of air taxis in the Korean market.

Over the course of a week, Joby completed a range of missions demonstrating various flight profiles and conditions, including fully wing-borne flight. Joby also demonstrated its capability to collaborate on aircraft operations with potential Korean partners ahead of future commercialisation in the country.

"Completing our first flights in Korea marks a significant milestone towards launching operations in the Korean market, where our service has incredible potential to save people time and improve connectivity in densely populated cities like Seoul and more remote areas like Jeju Province, where natural barriers complicate ground transportation," said JoeBen Bevirt, Founder and CEO of Joby.

Korea is the third country in which Joby has received an airworthiness certification for demonstration and flight testing, following similar approvals in the US and Japan.

In recent months, EHang has successfully flown the first flight of EH216-S in Mexico, following the granting of a Special Airworthiness Certificate by Mexico's Federal Civil Aviation Agency (AFAC) and the successful the first urban flight of a pilotless eVTOL aircraft in Europe, in Benidorm, Spain. The flight was conducted as part of the European Union's U-ELCOME (U-Space European Common Deployment) project, one of the flagship Digital Sky Demonstrators of the SESAR 3 JU.

The year started with an inaugural demo flight in downtown Shanghai, officially launching the regular trial operation of the eVTOL sightseeing routes by the Huangpu River at Longhua Airport in Shanghai, in preparation for the future gradual implementation and realisation of regular commercial operations in the Yangtze River Delta region centred around Shanghai.

Manufacturing progress

Behind the scenes, EHang has

Beta has secured a market survey ticket, which allows the startup to fly with potential customers so their pilots can test and evaluate the aircraft. (Credit: BETA) been made further investment in its production capacity. The latest coming via an agreement with JAC Motors and Guoxian Holdings to establish a joint venture in Hefei to construct of a state-of-the-art manufacturing base. According to the parties involved, the three partners will collaborate on R&D, manufacturing, and sales, to accelerate the technological advancements, industrialisation and production capacity growth.

Joby claims it has reached its target of achieving the capacity to build parts equivalent to one aircraft per month. According to the company, a majority of these parts are destined for testing as part of the certification process.

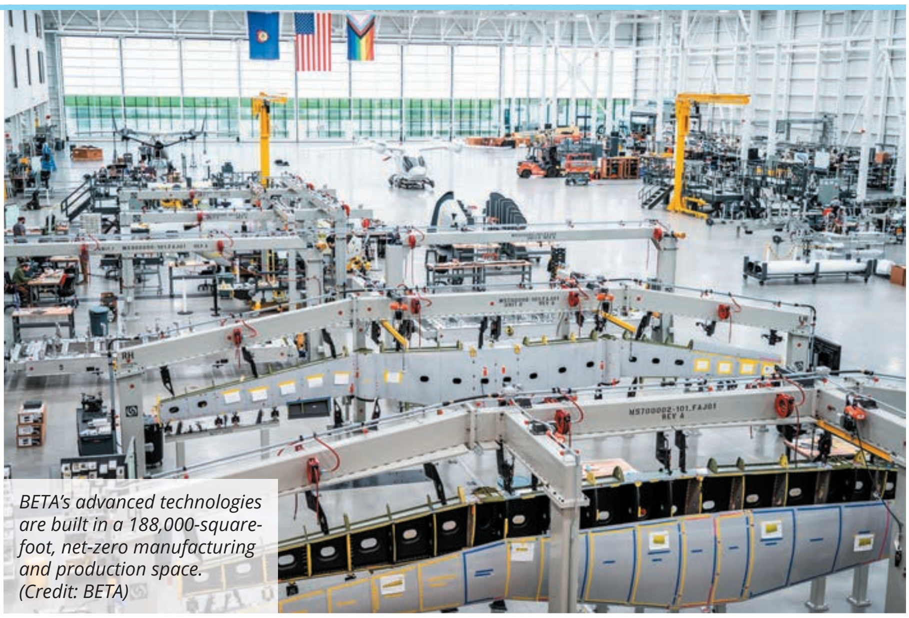
"We also rolled out and flew our fourth production prototype, bringing the total number of aircraft in our flight test fleet to five. Having access to a fleet of this size is unparalleled in our industry and allows us to rigorously test the performance of our aircraft while perfecting our production processes."

Joby says that over 95% of the composite components produced on its manufacturing lines are now fully conforming and the expansion of its Marina facility remains on track. The new facility will more than double its footprint in Marina, supporting expanded manufacturing and flight training. "We remain on track to deliver the first parts from our Ohio facility in mid-2025," the company says.

Archer has started production of its first Midnight aircraft at its 400,000 square foot aircraft manufacturing facility (ARC) in Covington, Georgia.

Archer plans to build up to 10 Midnight aircraft this year, ramping up production to a rate of two aircraft per month by the end of the year.

ARC was built in close partnership with automaker Stellantis (owner of brands including Abarth, Alfa Romeo, Chrysler, and Vauxhall). Stellantis is contributing capital, advanced manufacturing technology and expertise and experienced personnel with the goal of scaling this facility to 650 aircraft annually by 2030, as it looks to become Archer's exclusive contract manufacturer.



BETA's advanced technologies are built in a 188,000-square-foot, net-zero manufacturing and production space. (Credit: BETA)

Defence opportunities

According to Captain Masood, "eVTOL technology will have immense early market effect in the defense industry for reconnaissance, troop and equipment transport, search and rescue, and medical evacuation missions."

The US Air Force launched Agility Prime, a non-traditional program seeking to accelerate the commercial market for advanced air mobility vehicles. It operates AFWERX, a program office at the Air Force Research Laboratory (AFRL), which connects innovators across government, industry and academia.

One participant member is Archer.

"I believe the opportunity for advanced vertical lift aircraft across defense appears to be substantially larger than I originally expected," states Adam Goldstein, Founder and CEO of Archer. "As a result, we are raising additional capital to help us invest in critical capabilities like composites and batteries to help enable us to capture this opportunity and more."

Archer has launched Archer Defense to develop next-generation aircraft for defense applications in association with Anduril. with the first associated product planned to be a hybrid-propulsion, vertical-take-off-and landing aircraft that will target a potential program of record from the United States Department of Defense (DOD).

To support this initiative and for other general corporate purposes, Archer has raised $730 million in equity capital with participation from Stellantis, United Airlines, and institutional investors, including Wellington Management and Abu Dhabi investment holding company 2PointZero, a subsidiary of UAE'S largest listed entity, IHC.

Beta has two hybrid eVTOL aircraft in development – the MV250 and ALIA A250 VTOL, the latter flown multiple times since the autumn of 2023.

BETA's ALIA electric aircraft has a 50-foot wingspan, a range of 250 miles with a top speed of 138 mph and is 90% quieter than a helicopter. While ALIA has the capability to transport five passengers, the Air Force aims to demonstrate its potential to support agile combat employment logistics with its payload capacity of 1,000 pounds as part of Agility Prime.

Another program participant is Joby, which has delivered a second aircraft to Edwards Air Force Base as part of our work with the US Department of Defense. The company continues to engage further with the US Air Force, with its latest step the completion of a training program covering the inspection and maintenance of Joby's electric aircraft. The program included classroom instruction as well hands-on completion of inspections and pre-flight checks on Joby's production prototype aircraft.

Two years ago, Joby announced that four US Air Force pilots had completed pilot training and become

Joby says it is on track to deliver the first parts from its Ohio facility in mid-2025. (Credit: Joby Aviation)

the first Air Force personnel to fly an eVTOL as sole remote pilot-in-command through the full flight envelope, including transition from vertical to wingborne flight.

Commercial planning

"The appetite for eVTOL operations in the Middle East, especially in UAE and Saudi Arabia, is strong and quite proactive," says Captain Masood. "This is attributed to government policies and spending in these countries towards robust advanced mobility systems and innovation. The UAE specifically aims to spearhead leadership in advanced air mobility, as Dubai intends to operate air taxis within the metropolitan region by early 2026. Additionally, Archer Aviation also plans to commence commercial air taxi operations in the UAE by late 2025."

To establish a pragmatic and repeatable commercialisation playbook to deploy Midnight in dozens of early adopter markets, which includes the UAE, with Abu Dhabi Aviation (ADA) Archer's first Launch Edition customer.

Recently, the UAE's aviation regulator, the General Civil Aviation Agency (GCAA), approved the design for the planned transformation of the Abu Dhabi Cruise Terminal helipad into a hybrid heliport for both helicopter and eVTOL aircraft operations.

Under this guidance, Archer and its partners plan to add charging infrastructure and upgrade landing and safety systems to enable use by eVTOL aircraft. By upgrading an existing facility, Archer says it can capitalise on airspace regulations, zoning and structures that are already in place, without incurring the cost and time it would take to build a bespoke vertiport.

The goal is for this location to become the first site ready for eVTOL aircraft operations in the UAE, providing direct access to the Abu Dhabi Port, the Louvre Abu Dhabi, Saadiyat Island and the Corniche.

Archer is working to transform this helipad alongside its infrastructure partner Falcon Aviation in close coordination with the GCAA, with plans to complete this transformation in the second half of 2025.

"Tremendous progress within the Kingdom of Saudi Arabia is also evident as EHang is conducting unmanned air taxi trials in Mecca. As for the UAE, there is active mapping of urban aerial corridors including vertiport network within Abu Dhabi and Dubai which is expected to be augmented by mid-2025. Oman is also contemplating eVTOL, placing its focus on talent and research, indicating that Muscat's timeline is far more measured than the rapid acceleration expected in the UAE," adds Captain Masood.

Ethiopian Airlines is also working with Archer to bring an all-electric air taxi network to the region using Archer's Midnight aircraft. The duo will primarily focus on developing an air taxi network in the region using Midnight, the two are also exploring using Midnight for a broader range of use cases, including eco-tourism.

In 2022, Joby and Delta Air Lines announced a multi-city, commercial and operational partnership to pioneer community-to-airport transportation for customers. While the Joby/Delta partnership is mutually exclusive across the US and UK for at least five years following commercial launch, the partnership has been extended to include Virgin Atlantic in the UK.

The partnership will initially cover regional and city connections from Virgin Atlantic's hubs at Heathrow and Manchester Airport. According to Joby, journeys in the UK could include a 15-minute flight from Manchester Airport to Leeds, or an 8-minute journey from Heathrow Airport to Canary Wharf, instead of 80 minutes by car. Over time, Joby expects to build out a network of landing locations that offer rapid and convenient travel around cities and communities throughout the UK. Joby expects to offer prices that are comparable with existing premium ground ridesharing options at launch.

While much work is ongoing to bring eVTOLs to market, for passenger carrying applications, outside of tourist rides, is there real enthusiasm from the travelling public for electric air taxis? In competition with ground ridesharing options, eVTOLs face larger fleet sizes, greater choice and more flexibility on destinations. And can pricing remain competitive and attractive?

Developers of eVTOLs may see them as a further democratisation of air travel, but it remains to be seen if eVTOLs will curry favour with the few, rather than the many.

By Alex Preston


EHang is steadily advancing production and delivery of EH216-S pilotless eVTOL. (Credit: Ehang)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