



Meeting the Challenges of Next-Generation Advanced/ Urban Air Mobility Systems

Delivering Reliability, Safety, and Security



WNRVR

EXECUTIVE SUMMARY

From the Wright brothers' first flight off the sands of Kitty Hawk to supersonic jets and hypersonic vehicles, the aerospace industry has steadily advanced from one innovative technology to another. Over the years, experts have matured and leveraged new technologies and techniques to enable the development of air vehicles that would meet new flying challenges. Today, one of the most exciting opportunities is the application of electric vertical takeoff and landing (eVTOL) vehicles and other innovative propulsion and flight technologies to realize advanced/urban air mobility (AAM/UAM) in support of dual-use commercial and military missions.

To bring advanced eVTOL technology and innovation to the market faster and to meet AAM challenges, there must be a collaboration between aerospace companies, software innovators, and government regulation entities. Airspace management frameworks must evolve intelligently for the safe operation of eVTOL aircraft to support the commercial eVTOL industry and bring its players together to enable safety, security standards, and more. Wind River®, a software solutions leader in the aerospace and defense market, is committed to helping bring eVTOL to reality with its full portfolio of software products that deliver proven reliability, safety, and security to flight technology. In this white paper, Wind River will focus on meeting the challenges of the technology, solutions, and innovations that are required to make the next generation of AAM/UAM systems a reality.

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WIND RIVER: A STRONG AEROSPACE AND DEFENSE LEGACY

Wind River software has been a part of aerospace and aviation technology for 40 years. With VxWorks®, its real-time operating system (RTOS), it has delivered the real-time and deterministic technology to enable the Mars rovers, Boeing 787 Dreamliners, military jets, and helicopters.

Many of the projects that have leveraged VxWorks are also unmanned and include military systems such as the nEUROn in Europe and the MQ-4C Triton in the U.S. Wind River software is advancing state-of-the-art air mobility with companies engaged in this new aviation segment. Wind River partners with customers to deliver vertical lift innovation while its software continues to focus on reliability, safety, and security.

TECHNOLOGY CHALLENGES FACING ELECTRIC VERTICAL TAKEOFF AND LANDING

To make eVTOL a viable reality, the industry will have to overcome four major technical challenges.

Design

As eVTOL companies put their scientists and engineers to work, they need to focus on the aspects of the design and the use of technology that will enable successful vertical takeoff and landing and provide the greatest range of flight, making size, weight, and power (SWaP) considerations more important than ever. Currently, while a larger battery will provide electric power for flight, its weight can also shorten flight time and range. To get a design jump on this power and range challenge, some companies are looking at combining electric power with conventional engines, resulting in hybrid VTOLs, or hVTOLs. Overall, the successful design of eVTOLs needs to incorporate software solutions from the very start to address the range/ endurance and SWaP challenges.

Development

An intelligent compute system is a major component of modern aviation technology. Its development relies on DevOps, which uses agile practices to support constant integration and delivery of new or updated code. In its latest evolution, DevSecOps further incorporates security into the intelligent software platform from the outset. eVTOL software developers need to plan for a system development lifecycle (SDLC) that incorporates:

- Investigation
- Analysis
- Design
- Build
- Testing
- Implementation
- Maintenance, support, and upgrades

“The technical development of eVTOLs would not be feasible without leveraging the global trends of digitalization and electrification. The increasing capabilities of actuators, and sensors in particular, driven by the overall progress in digitalization, allow us to come up with new aviation concepts. In the long run, this process can also lead to autonomous systems.”

— The Economics of Vertical Mobility, Porsche Consulting, 2021

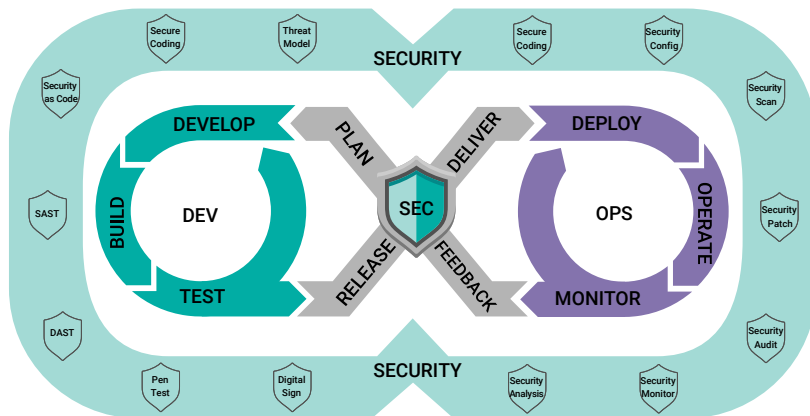


Figure 1. DevSecOps methodology

DevSecOps tools help secure the development workflow, ensuring that systems are free of vulnerabilities and that the eVTOL is secure during operation. To incorporate agile software development into the production of eVTOL systems, developers must build in software tools and technologies such as virtualization, containerization, orchestration, automation, commercial off-the-shelf (COTS) software, configuration management tools, and more. A constant flow of data via a digital feedback loop is imperative for the continuous updating, debugging, and improvement of the applications, systems, and operations of an eVTOL's avionics.

Safety

One of the most important challenges for eVTOL builders is safety. The National Transportation Safety Board (NTSB) found that Americans drove less in 2020 due to the pandemic, but the National Highway Traffic Safety Administration's early estimates show that an estimated 38,680 people died in motor vehicle traffic crashes — the largest projected number of fatalities since 2007. This represents an increase of about 7.2% as compared to the 36,096 fatalities reported in 2019. Meanwhile in air travel, the International Air Transport Association (IATA) 2020 Safety Report for the 2020 safety performance of the commercial airline industry reported some improved numbers. The report highlighted that the total number of accidents decreased from 52 in 2019 to 38 in 2020. Additional positive news was that the total number of fatal accidents decreased from 8 in 2019 to 5 in 2020. Yet there was some negative news as well: The all-accident rate was 1.71 accidents per million flights. This number is higher than the five-year (2016–2020) average rate, which is 1.38 accidents per million flights.

When planning for eVTOL safety, developers must consider flammable batteries, spinning rotors and propellers, navigation systems, reliable flight control systems, and the heavily populated areas over which these aircraft will often fly. Ensuring that the vehicle is operating safely and in compliance with federal regulations can be costly and time-consuming. However, using hardware and software components that meet safety certification standards will speed development time, require fewer resources, and ultimately cost less. Wind River focuses on safety in each of its products; understands the importance of safety certification; and, for its certified products, can deliver the required artifacts to support safety requirements certification processes in commercial and military environments.

Security

eVTOLs must have security planned and built into their systems from the start to prevent potential cybersecurity threats. Following a DevSecOps-compliant process, manufacturers can create a strong, secure system with built-in security features that can be easily and securely updated as new cybersecurity threats emerge. eVTOL system developers should take advantage of the real-time operating systems and open system software that have strong security features and functions. Additionally, the use of both virtualization and containerization technologies should incorporate strong security functions to protect the operation of the systems. To ensure cybersecure development and systems, cybersecurity testing should be conducted via DevSecOps processes throughout the product lifecycle. Simulation testing can allow developers to create the virtual equivalent of the eVTOL system and conduct security penetration tests (pen tests) to determine the vulnerability of the systems and their effects, all without incurring actual damage or needing to purchase expensive test systems. Simulation

“Many questions still remain for battery advancement, which leads to our additional concerns around the range of safety of urban aircraft. A key message to investors is that we believe the advancements in technology, manufacturing, form factor and cost that will be driven from the scale production of Battery Electrical Vehicles in the light vehicle market may very likely drive innovation that could be applied to electric aviation.”

— eVTOL/Urban Air Mobility TAM Update
Morgan Stanley Research, 2021

software can create a digital twin of the eVTOL to conduct ongoing assessments of the system. eVTOLs must meet stringent security standards based on NIST 800-53, classified data at rest, multilevel security, and anti-tamper requirements.

AN INTELLIGENT SYSTEM PLATFORM FOR EVTOL

The heart of a quality eVTOL is an intelligent system platform based on software that operates efficiently, cost-effectively, safely, and securely. Evolving artificial intelligence (AI) and machine learning (ML) technology will be critical to this intelligent system. The eVTOL system will need an RTOS that enables the flying vehicle’s rapid and deterministic operation and function. There will also be systems within the eVTOL that can run on open source software such as Linux.

Nevertheless, whether the system’s foundation is an RTOS or a general-purpose operating system, it must deliver reliability, safety, and security to vehicle operations. Furthermore, cloud computing is now a part of all areas of business, manufacturing, energy, transportation systems, and more. Because it combines AI, ML, and 5G communication, cloud computing will play a major role in eVTOL flight data and control systems.

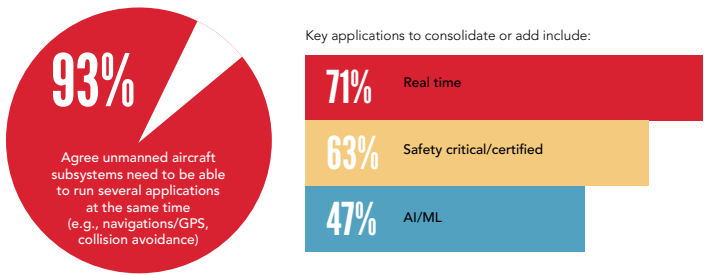


Figure 2. Responses about what is needed to make viable the UAS subsystems and key applications required (Source: 2019 Urban Air Mobility industry study commissioned by Wind River)

An intelligent system platform will be a part of each eVTOL vehicle’s functional components. Its software applications will provide the AI and ML intelligence that are key to the functional systems: They will manage, direct, and operate such functional areas as airspace deconfliction, aided navigation, flight safety, and terminal area operations. Beyond traditional avionics, the intelligent system platform will also encompass vehicle, mission, and communication management systems. Additionally, new cloud-computing technology will provide expanded systems development capabilities.

HOW WIND RIVER MEETS THE CHALLENGES

The Wind River software portfolio allows the eVTOL developer to design a software-defined architecture for vehicle operation. With a cloud-computing intelligent platform, virtualization technology, and containerization capabilities, a flexible and expandable intelligent platform can be built. Ultimately, Wind River software can offer the value of certifications that will help eVTOL builders meet security and safety requirements while also saving time, resources, and cost. The Wind River software portfolio offers future proofing and open architectures that allow seamless migration from prototyping to production and ultimately lifecycle maintenance, support, and upgrades.

VxWorks: Market-Leading Real-Time Operating System

The powerful capabilities of VxWorks, the industry-proven RTOS from Wind River, support modern development methods for building solutions that are secure, safe, reliable, and certifiable. VxWorks accelerates data-processing tasks in aviation system environments and ensures responsive operations in mission-critical deployments. VxWorks supports 32- and 64-bit and multi-core processors, including Intel®, Arm®, Power Architecture®, and RISC-V. VxWorks helps lower procurement and certification costs while meeting stringent industry standards such as DO-178C, ED-12C, ARINC 653, POSIX®, and FACE™ by using COTS standards conformance and safety certification evidence. VxWorks has an extensive history of safety certification including DO-178C DAL A, ISO 26262 ASIL D, IEC 62304, and IEC 61508 SIL 3. Additionally, VxWorks supports C11/C++17 programming language standards, Rust, LLVM, Python programming language, and Boost C++ libraries, helping application developers create efficient, portable applications. VxWorks is the only RTOS supporting IT-like application deployment with OCI container support.

Wind River VxWorks 653 Platform: Standards-Based Open Virtualization Platform

VxWorks 653 Platform is a safe, secure, and reliable RTOS that has FACE conformance certification and delivers an open virtualization platform that fully complies with the ARINC 653 specification with robust time and space partitioning on the latest Arm, Intel, and PowerPC multi-core processor platforms. It has high safety and security assurance with a multi-core scheduler using hardware virtualization assist. VxWorks 653 Platform provides COTS certification artifacts that can decrease the time required

to accomplish certification while reducing schedule risk. It offers support for a robust open architecture that enables suppliers to modify an application that is part of an existing certified system, then only retest the scope of the components that have changed, dramatically reducing the recertification costs and total cost of ownership (TCO). With independent build, link, and load (IBLL), VxWorks 653 Multi-core Edition is designed around a multi-supplier, role-based supply chain per RTCA DO-297, which allows application suppliers to asynchronously develop, test, and deliver software applications independently.

Wind River Linux: Linux for Mission-Critical Applications

Wind River Linux is a commercially supported version of Linux for embedded applications, cost-effective security, and access to prebuilt containers (with Docker and Kubernetes support). It plays a key role in cloud-native 5G environments, helping maximize server use by creating self-contained packages of applications that can be installed and run while sharing a common operating system kernel. Wind River Linux is FACE certified conformant and is ISO 9001-2015 certified. Wind River provides ongoing threat mitigation against emerging vulnerabilities. The Wind River security team constantly monitors security vulnerabilities, including specific security notifications from U.S. government agencies and organizations.

In addition, enhanced security and cyber system hardening capabilities are available via Wind River Linux cybersecurity subscription and, for certain aerospace use cases, Star Lab Titanium Security Suite. Wind River Linux is offered with options for validated community code, Wind River Long Term Support, Wind River Long Term Maintenance, and continuous delivery lifecycle services.

Wind River Helix Virtualization Platform: Flexibility Through Virtualization

Helix Platform reflects 40 years of Wind River experience in meeting the stringent requirements of A&D programs, consolidating workloads across multiple virtual machines, supporting container technology, and enabling operators to fully virtualize their industrial control systems. A real-time, embedded Type 1 hypervisor supports a diverse range of operating systems, delivering safety, performance, and flexibility. Helix Platform strengthens low-latency operations within an on-board aviation system. Helix Platform is designed to be certified and to simplify the certification of safety-critical applications according to the stringent requirements of aviation, automotive, and industrial safety standards. The Helix Platform hypervisor is OS agnostic, providing the ability to run any OS, unmodified, inside a virtual machine. Guest OS support includes the leading embedded RTOS, VxWorks; the leading commercial embedded Linux OS, Wind River Linux (and other Linux distributions); Microsoft® Windows®; Android; and other OSes.

Wind River Simics: Simulation to Reduce Risk and Compress Time-to-Market

Simics® helps create highly secure substation installations through elaborate simulations that can detect system vulnerabilities and streamline DevSecOps development projects. Simics provides a simulation environment to test systems and cybersecurity protections via secure virtual hardware in a safe and controlled environment and includes collaboration tools to improve development processes. This simulation tool lets a developer decouple work from physical aviation hardware while retaining the ability to connect physical hardware when required. Simics virtual hardware gives the developer on-demand access to a target eVTOL

URBAN TECHNOLOGY DEVELOPMENTS

Satellite Communication

- Launch costs falling dramatically
- Rising demand for bandwidth
- Significant levels of capital formation
- Estimate space economy to be \$1.1T by 2040

Compute Power/Availability

- Price of processing power and memory at all-time lows
- Increased speed and capacity likely coming from new 5G infrastructure
- Moore's Law

AI/Software

- Large amount of investment and development in autonomous driving
- AI derived business value is expected to reach \$3.9 trillion by 2022

Sensors

- Increased usability/cost efficacy of LiDar and other sensor technology
- Companies using sensors in a range of use cases, such as smart cities or autonomous driving/flying

Advanced Material Systems

- Becoming a cheap and practical method of manufacturing complex parts
- This technology can create lighter and more durable parts that are not possible with traditional metallurgical methods

Battery Technology

- \$/kWh coming down steadily – target of \$50/kWh by 2030
- Cost targets for 2022 below current prices by 50%

Electric Motor

- Cost, weight, and volume decreasing significantly with improved performance
- Cost targets for 2022 50% below current prices

Robotics

- Companies continue to develop different use cases for robotics, combining developments in AI/machine learning
- Allows for faster assembly of more complex mechanics systems

— eVTOL/Urban Air Mobility TAM Update
Morgan Stanley Research, 2021

system, supporting continuous integration and automated testing with members of the development team. With simulation using Simics, an eVTOL design team can test systems and operation of the vehicle to reduce risk and compress time-to-market to get the vehicle ready for flight.

Wind River Studio: Secure Collaboration at the Intelligent Edge

This cloud-native platform is a secure foundation for the development, deployment, operations, and servicing of vital intelligent edge systems. Optimized for DevSecOps, Studio enables application teams to employ continuous integration (CI) and continuous delivery (CD) workflows, drawing on agile development practices. These capabilities are paramount to the future of intelligent machines and responsive cloud-based infrastructures. eVTOL systems development teams can use the capabilities of Studio to accelerate their software development work and promote collaboration among geographically dispersed teams, while ensuring safety and security.

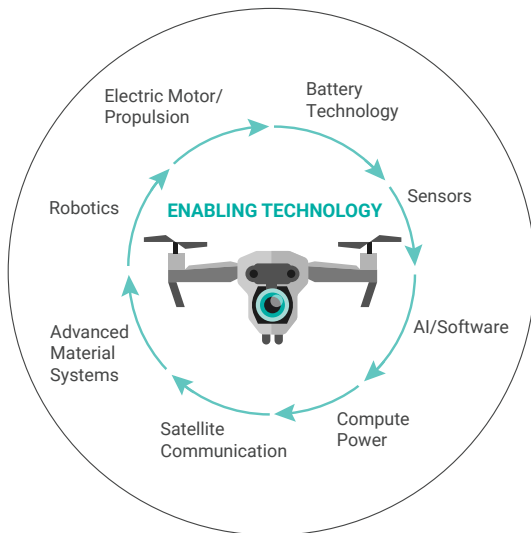


Figure 3. Enabling technologies

Wind River Professional Services: From Architecture Studies Through Development and Operations

Professional Services provides access to comprehensive knowledge and expertise to help Wind River customers unlock the full potential of Wind River products, dramatically reducing the risks and time associated with creating and integrating new technologies. Professional Services offers insights, expertise, and resources built from nearly four decades of leadership in the embedded software

industry. The Professional Services team works with customer development teams so they can focus on their core competencies and deliver market-leading devices, systems, and networks.

Professional Services helps design teams bring safe, secure, reliable, and compliant mission-critical products to market. Additionally, the team offers its Information Assurance (IA) Foundation to provide the APIs for the security devices within the QorIQ PPC processor family.

Wind River Titanium Security Suite

Star Lab, the Wind River Technology Protection and Cybersecurity Group, protects mission-critical embedded systems against cybersecurity and anti-tamper vulnerabilities in contested environments using a hardened Linux suite of security products. Wind River Titanium Security Suite (developed by Star Lab) specializes in tactical virtualization, operating system hardening, secure boot technology, and data-at-rest encryption with significant expertise and a long pedigree of success in developing tailored security solutions for military systems. Star Lab personnel have a demonstrated track record of operational excellence with no failures in the field and a 100% success rate in achieving certification, verification, and validation testing requirements. All employees are U.S. citizens with clearances, giving customers confidence and trust in the company and its staff.

CONCLUSION

Over the course of the next two to three years, the AAM/UAM industry will undergo a significant transformation as it matures concepts into prototypes, sub-scale air vehicles into full-scale models, and manually operated systems into highly automated – and in some cases autonomous – ones. Wind River, with its established and growing portfolio of software capabilities, looks forward to partnering with industry, government, systems, and academia to provide an intelligent systems platform that enables eVTOL vehicles to reliably, safely, and securely take flight.

As innovative development for electric vertical takeoff and landing vehicles continues, eVTOL designers will face a variety of challenges in design, development, safety, and security. To learn more about the Wind River portfolio, visit www.windriver.com or contact salesinquiry@windriver.com.

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