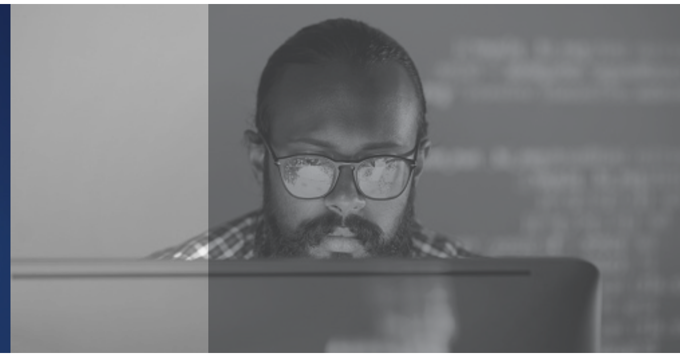
Intelligent Edge Technologies for Aviation

Strategies to Capitalize on Increasingly Software-Intensive Flight Systems

WNDRVR

A Strategic Model for Modern Aviation Systems



Shifting functionality of onboard aviation systems to software rather than using traditional hardware approaches makes them more cost-efficient, flexible, and future ready. Intelligent edge technologies are essential to take full advantage of this transition.

Longevity is critical to the cost-effectiveness of civilian and military aviation systems. To extend their lifespans, it must be possible to update those systems as needed, both to maintain and to add functionality. The inherently more dynamic nature of software-based versus hardware-based systems supports continuous updates and system modernization. As a result, the level of software-defined functionality in aviation systems has grown steadily over time. Maintenance based on installing code rather than system boards is simpler and more cost-effective, which makes incremental changes possible for more granular control and heightened cyber resiliency.

Growing software capability is accompanied by increased software complexity. The Aerospace Vehicle Systems Institute reports that, for decades, source lines of code deployed in both civilian and military aircraft have been doubling in number about every four years.[1] In the context of avionics for specific military aircraft, a recent steep growth trend is illustrated in Figure 1.[2]

Source lines of code (SLOC) in aviation systems double about every four years.

1 *"Exponential Growth of System Complexity," System Architecture Virtual Integration Program, Aerospace Vehicle Systems Institute, retrieved April 23, 2021*

2 *"Design and Acquisition of Software for Defense Systems," U.S. DoD Defense Science Board, February 2018*

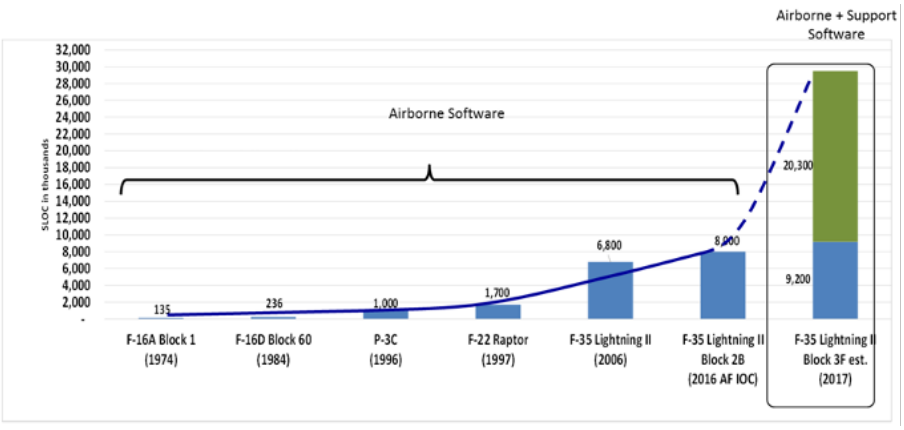


Figure 1. Growth of software complexity in DoD avionics software

Subsystems such as avionics have traditionally been software intensive, but mechanical subsystems also benefit from the incorporation of code. In addition to control software, mechanisms ranging from turbines to hydraulics incorporate sensors that continuously monitor health and other status. In fact, the steady flow of data from landing gear and other complex systems and subsystems can increase the dependability of physical equipment, potentially enabling lighter-weight designs and therefore fuel savings.

The intelligent edge, where onboard systems process data gathered in flight, is a critical strategic model for software-intensive aviation systems. Transmitting the massive amounts of data created in the software-rich environment back to a base station for processing is not always practical. Beyond the bandwidth considerations involved, transmission latency would interfere with real-time and near-real-time processes that respond to in-flight data.

Challenges in Bringing Software-Intensive Aviation Systems to Market

Developers for both civilian and military aviation share challenges that include security, cost, and time-to-market as they digitally transform aviation systems with software for the intelligent edge. As the complexity and sheer amount of software developed for embedded aviation systems continue to grow, so do these challenges.

> "Digitally transformed avionics will rely heavily on advanced software for motion planning, trajectory prediction, and predictive analysis integrated with sensor fusion."[3]
>
> **— Christine Stevens, Senior Director,** Aerospace and Defense Business Development, Wind River

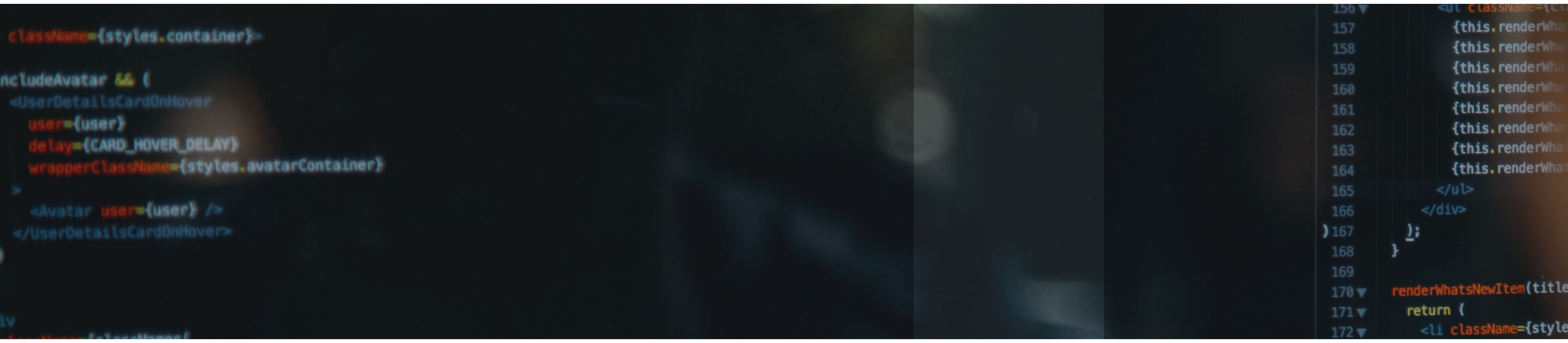
CYBERSECURITY THREATS

Each software component deployed on an aviation system represents a potential attack surface that must be hardened, monitored, and kept up to date. Even after a threat has been identified and mitigated with a software update, distribution of the patch throughout a fleet of aircraft generally depends on hands-on involvement by technical staff. This approach can prolong the update process and extend the duration of vulnerability to the threat, as well as dramatically increase the software's total cost of ownership (TCO). Enabling secure over-the-air software updates will be an important enabler for improved security and cost efficiency.

CERTIFICATION COST AND COMPLEXITY

As aviation systems have become more software intensive, the certification burden has grown dramatically in cost and complexity. To cite an example from a recent naval program, in order to demonstrate compliance with 70 DISA (Defense Information Systems Agency) STIGs (Security Technical Implementation Guides) for 150 software components, the team had to execute 120,000 test cases. Due to the manual nature of the process, that certification work cost $250,000, highlighting the need to streamline and automate testing.

3 *Christine Stevens, "Avionics and the Intelligent Edge," Wind River Blog Network, April 21, 2021*



AGILITY

The efficiency of software development depends on the capacity for rapid change to provide new functionality and accommodate new requirements. Deploying technology advances in the form of software allows them to be inserted more quickly than equivalent hardware upgrades. At the same time, highly complex aviation software systems can be challenging to maintain. The software itself and the surrounding ecosystem of development practices and tools must be architected for ongoing, continuous change with low overhead.

Intelligent Edge Technologies Enable Both Military and Civilian Aviation

On-board edge computing makes aircraft more capable, with benefits that are shared between civilian and military systems. For example, machine-to-machine in-flight communication enables distinct use cases such as the following:

- **Military missions** could increase their chances of success with boosted capabilities for weapons systems that are dynamically updated with the latest threat and target information, rather than depending on what was current when they took off.
- **Commercial fleets** can be operated more efficiently when more robust real-time information is available from the aircraft (for dynamically matching up crews, equipment, and routes, for example) to accommodate events such as weather delays and equipment failures.

Development Practices and Tools to Meet Today's Needs

As the role played by software-defined intelligent edge technologies grows in onboard aircraft systems, the overall efficiency of deploying and maintaining aviation systems increasingly depends on the efficiency of the software development lifecycle. Embedded software for aviation systems draws on modern development practices adopted from the enterprise to enhance security, cost-effectiveness, and agility.

> "The Department of Defense (DoD) and its defense industrial base partners need to adopt continuous iterative development best practices."
>
> — DoD Defense Science Board[4]

CONTINUOUS INTEGRATION/CONTINUOUS DELIVERY AND DEVOPS

In place of older, linear processes such as Waterfall, commercial software development has broadly adopted iterative approaches based on frequent code releases. Agile concepts such as rapid, closely defined development sprints have been refined into cyclical continuous integration/continuous delivery (CI/CD) pipelines, as illustrated in Figure 2. Here, development and operations activities are combined into DevOps practices, where continuously created code is merged into the shared repository several times per day, automatically checked for errors, and delivered into production. Using DevOps and CI/CD approaches makes development of aviation systems more efficient, while the small scope of individual changes helps isolate faults and accelerate remediation and code maintenance.

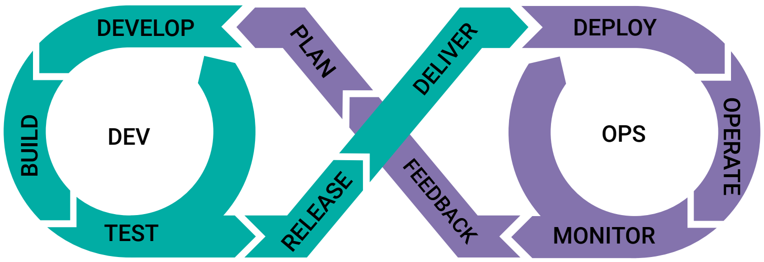


Figure 2. The DevOps continuous integration/continuous delivery (CI/CD) cycle

4 *"Design and Acquisition of Software for Defense Systems," U.S. DoD Defense Science Board, February 2018*

THE EMERGENCE OF DEVSECOPS

DevSecOps is an emerging discipline that adds to the depth of involvement by security professionals in the DevOps pipeline, as illustrated in Figure 3. Security protections such as code scanning and analysis, threat modeling, and penetration testing are woven deeply into the software lifecycle, rather than being bolted on afterward. DevSecOps is well suited to accommodating complex security needs of mixed-criticality and combined real-time and non–real-time workloads handled by aviation systems. The DoD has committed to the use of DevSecOps practices in 95% of all new software development by FY 2026.[5]

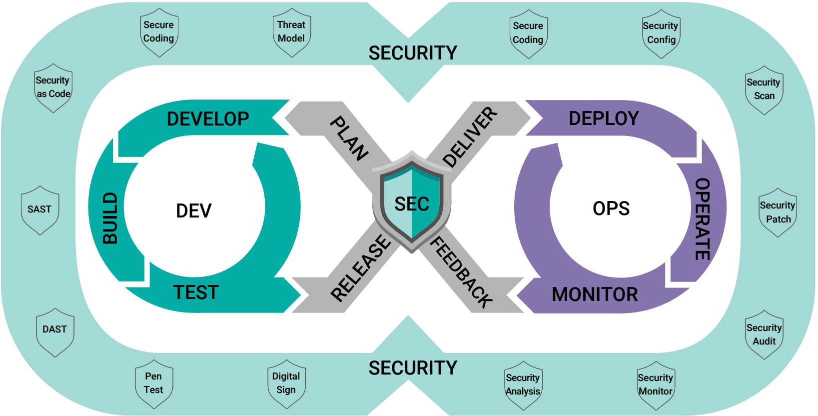


Figure 3. DevSecOps modifications of the DevOps CI/CD cycle.

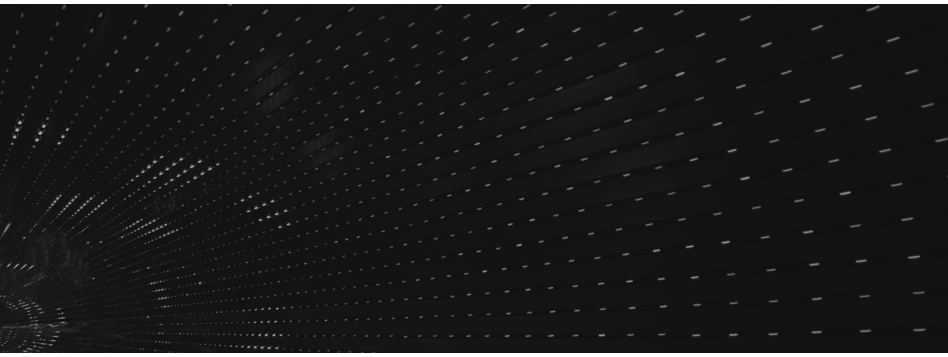
SIMULATION-DRIVEN, AUTOMATED TESTING

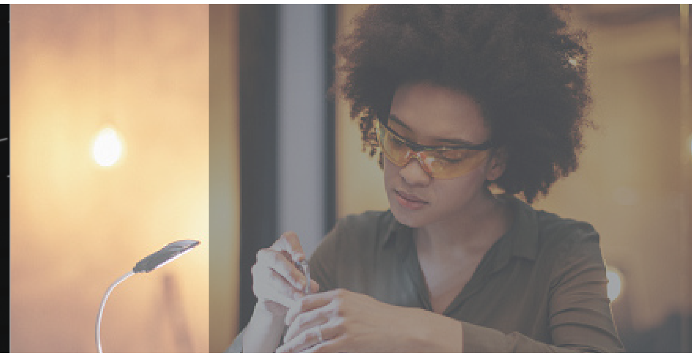
Particularly in the context of certifying software components, testing represents massive resource commitment and expense for development organizations, due to the high number of test cases involved and the need to obtain and dedicate target hardware for testing purposes. Simulation and automation address these issues by creating the target environment entirely in software

DevSecOps Software Factories: Highly Responsive to Changing Requirements

The U.S. Air Force's Platform One is a cloud-based development platform equipped with a secure Kubernetes environment built for hosting microservices. Applications can be updated as often as 20 times per day, with a lead time for changes of less than an hour and the ability to restore SaaS applications in about 15 minutes.

5 "Report to Congress on Implementation of Defense Science Board Report Recommendations, 'Design and Acquisition of Software for Defense Systems' Section 868 of the National Defense Authorization Act for Fiscal Year 2019 (P.L. 115-232)," U.S. DoD Office of the Under Secretary of Defense for Acquisition and Sustainment, April 16, 2020





and eliminating the need for operators to manually configure, execute, and document each individual test case. Particular effort is being applied currently to automate traceability and artifact creation during testing, to avoid the tremendous cost typically incurred.

CLOUD-NATIVE TOOLS

Operating a private cloud environment onboard aircraft drives efficiencies and agility by enabling modern approaches and intelligent edge technologies, based on containers, microservices, CI/CD, and DevSecOps. Legacy on-prem tools are poorly suited to cloud-driven development models, making cloud-native tools an essential prerequisite for modernization. Cloud-native tools and technologies are also ideal for use cases in which sensors attached to various aircraft subsystems create an onboard, cloud-based IoT network.

VIRTUALIZATION AND CONTAINERS

Containers and hypervisor-based virtualization work together to create flexible implementations. Hypervisors enforce hardware-based data isolation between virtual machines (VMs), while incurring overhead based on the fact that each VM must run its own full version of the operating system (OS). Containers are relatively lightweight and may share a single copy of the kernel, with partitioning based on software measures including Linux control groups and namespaces. They enable modular software architectures that lend themselves to CI/CD models and help reduce the scope and costs associated with certification testing. From a cybersecurity perspective, containers enable integrity checking by verifying against a known good container image from the container registry. Recent product updates allow the creation of real-time OS containers with OCI-compliant container support. (See the VxWorks® section to learn more.)

> "The global 5G in aviation market size was valued at $0.2B in 2019 and is projected to reach $4.2B by 2026, at a CAGR of 53.46% during the forecast period."[6]
>
> — Fortune Business Insights

6 *"Global 5G in Aviation Market Size, Share & Industry Analysis, by Platform (5G Airport and 5G Aircraft), Technology (FWA, URLLC/MMTC, and eMBB), Communication Infrastructure (Small Cell, Radio Access Network (RAN) and Distributed Antenna Systems (DAS)), 5G Services (Airport Operations, and Aircraft Operations), and Regional Forecast, 2019–2026," Fortune Business Insights, December 2019*

5G NETWORKING

As the emerging basis of short- and medium-range radio, 5G networking enables high-throughput, low-latency communications between aircraft as well as from aircraft to base stations and other installations. In addition to operational communications, 5G networks are a primary enabling factor for fast, secure, over-the air software updates, which are essential to efficiently keep onboard systems current throughout a fleet of aircraft. Expanded encryption and focus on machine-to-machine communication in 5G compared to 4G make it well suited to use in reimagined aviation use cases.

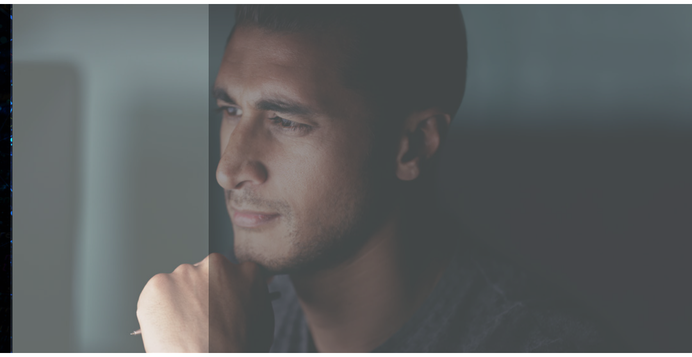
AI AND MACHINE LEARNING

As data sizes in aviation use cases reach beyond human scale, AI and machine learning prove increasingly valuable to help sort through massive data sets to identify trends and patterns that can yield insight. AI and machine learning are key forces in the future of how computer science is expressed at the solutions level. Current applications are focused on in-flight analytics related to equipment and situational data, while development toward goals such as autonomous flight also continues.

> "The Office of the DoD Chief Technology Officer lists AI as its first modernization priority[7] and the National Security Commission on Artificial Intelligence calls for at least 3.4% of the DoD budget[8] to be committed to AI."
>
> — Fortune Business Insights

7 *"Modernization Priorities," U.S. DoD Office of the Under Secretary of Defense for Research and Engineering, retrieved April 23, 2021*
8 *David Vergun, "Artificial Intelligence Key to Maintaining Military, Economic Advantages, Leaders Say," DoD News, April 9, 2021*

Realize Opportunity with Wind River and Intelligent Edge Technologies



Wind River® software development solutions draw on decades of industry leadership for aviation-related software, both civilian and military. As an integrated, comprehensive set of technologies, they improve solution quality and security while accelerating time-to-market.

WIND RIVER STUDIO

As the first cloud-native platform for development, deployment, operations, and servicing of mission-critical intelligent edge systems, Wind River Studio enables innovation for the aviation industry. Studio provides developers with an integrated, expandable set of tools that empower them to efficiently and cost-effectively develop aviation software built to high standards of security, safety, and reliability. The platform is architected to build solutions at cloud scale, accelerating transformation. This future-focused, cloud-delivered environment provides developers with always-available, always up-to-date Wind River tools to power aviation's future.

VXWORKS

As the market-leading real-time OS, VxWorks is in service aboard more than 80 types of civilian and military aircraft, particularly for safety-critical applications such as flight controls. VxWorks provides robust built-in support for both containers with OCI-compliant support and hypervisor-based virtualization with VMs. Its standards-based architecture builds business efficiencies by allowing software components to be shared across diverse airborne platforms. Additionally, conformance to standards such as POSIX® and FACE™ have been leveraged in the certification of VxWorks to DO-178C, IEC 61508, IEC 62304, and ISO 26262 safety standards.

> "At Wind River, we partner with our clients to help them accelerate their digital transformation efforts, realize the benefits of the three Digital Building Codes[9] (a.k.a. the "digital trinity") — digital engineering, agile software, and open systems architecture — and ultimately achieve their desired business outcomes."
>
> **—Roberto Valla,**
> Aerospace and Defense Field Digital Transformation Officer, Wind River

9 *"Memorandum for the Acquisition Enterprise: Guidance for e-Program Designations," U.S. Department of the Air Force, Office of the Assistant Secretary, May 3, 2021*

WIND RIVER LINUX

For non–real-time workloads, including mission-critical ones, Wind River provides a POSIX-compliant operating system for the deployment of reliable, secure, high-performance software. Wind River Linux is well suited to use in a modern cloud-native development practice, with robust support for VMs and popular containers technologies, including Docker and Kubernetes. Wind River Linux has achieved conformance to the latest Future Airborne Capability Environment (FACE™) Technical Standard, Edition 3.0, for the Operating System Segment (OSS) that supports the General Purpose Profile (GPP). In addition, enhanced security and cyber system hardening capabilities are available for aerospace and defense use cases with Wind River Star Lab Titanium Security Suite.

WIND RIVER HELIX VIRTUALIZATION PLATFORM

As a real-time embedded Type 1 hypervisor based on VxWorks, Wind River Helix™ Virtualization Platform is an ideal substrate for running virtualized, mixed-criticality, mixed-OS workloads on shared hardware. The environment enables side-by-side operation of real-time and non–real-time workloads on a range of hardware architectures, including Intel® and Arm®-based processor platforms. Helix Platform also supports combinations of containers and VMs, including mixed, nested combinations of both for maximum flexibility. Additionally, Helix Platform has simultaneous support for airborne platforms such as ARINC 653 APEX API, POSIX, and FACE.

WIND RIVER SIMICS

During development, teams can rely on Wind River Simics® to accurately simulate the interaction of software with real-world hardware systems, without need for the actual equipment. During testing and certification, Simics automates test cases, reducing time, staff, and cost requirements. Development teams can also adopt new approaches such as digital twins and security penetration testing as they experiment, debug, and collaborate on solutions.

CONCLUSION

Even as intelligent edge technologies redefine current aviation systems, they also set the stage for emerging future use cases, from reimagined airspace monitoring and control to autonomous vertical lift urban air mobility vehicles.

In the future, the intelligent edge will be the site of dramatic innovations, moving passengers, cargo, and data to their destinations. Wind River builds tools with the security, reliability, and cost-efficiency needed to enable that spirit of fearless invention. For more about how Wind River powers the next generation of aviation, visit windriver.com/solutions/aerospace-and-defense.