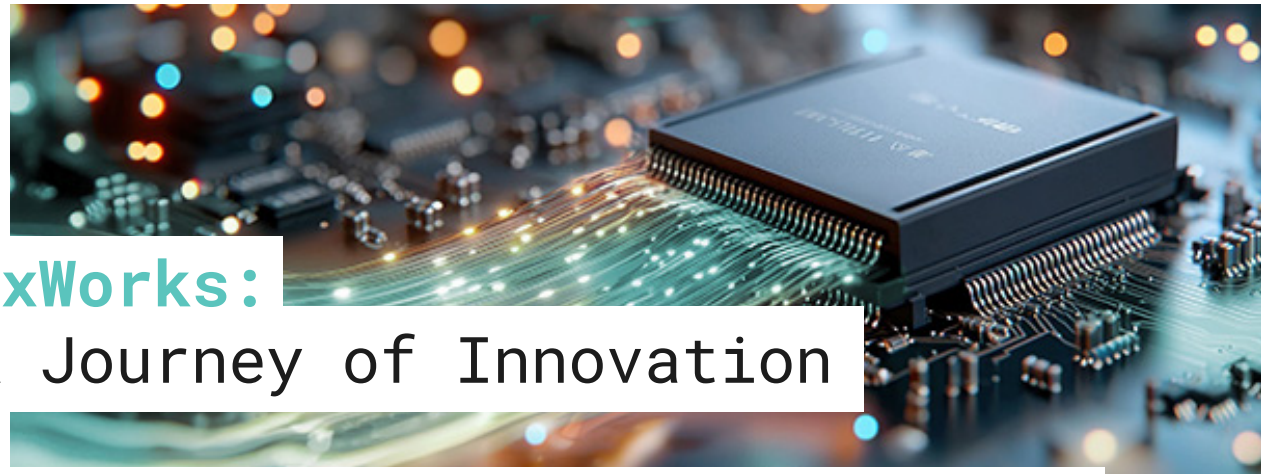

VxWorks: A Journey of Innovation

VxWorks continues to evolve to meet the demands of the intelligent edge. In this article, we explore those innovations that keep VxWorks at the forefront of the embedded systems software industry.

Whether it be controlling a life support machine, flying people around the world, assisting a driver in a car, defending the skies, performing precise surgery, exploring space, or controlling next-generation manufacturing, complex and highly performant real-time embedded systems are vital. These systems rely not only on advanced processors but on well-designed software, certified to the highest safety levels. The foundation upon which this software is built and runs, the real-time operating system (RTOS), represents one of the most important and innovative areas in the computing world.

Embedded systems software is undergoing rapid change. Complex workloads rely on advances in processor silicon and architecture, and edge-to-cloud connectivity has become commonplace. Software engineering teams also demand more from their operating systems and the tools that facilitate cost-effective development.

VxWorks® from Wind River® has earned its top-notch reputation by addressing these challenges with commitment and leadership at the intelligent edge.

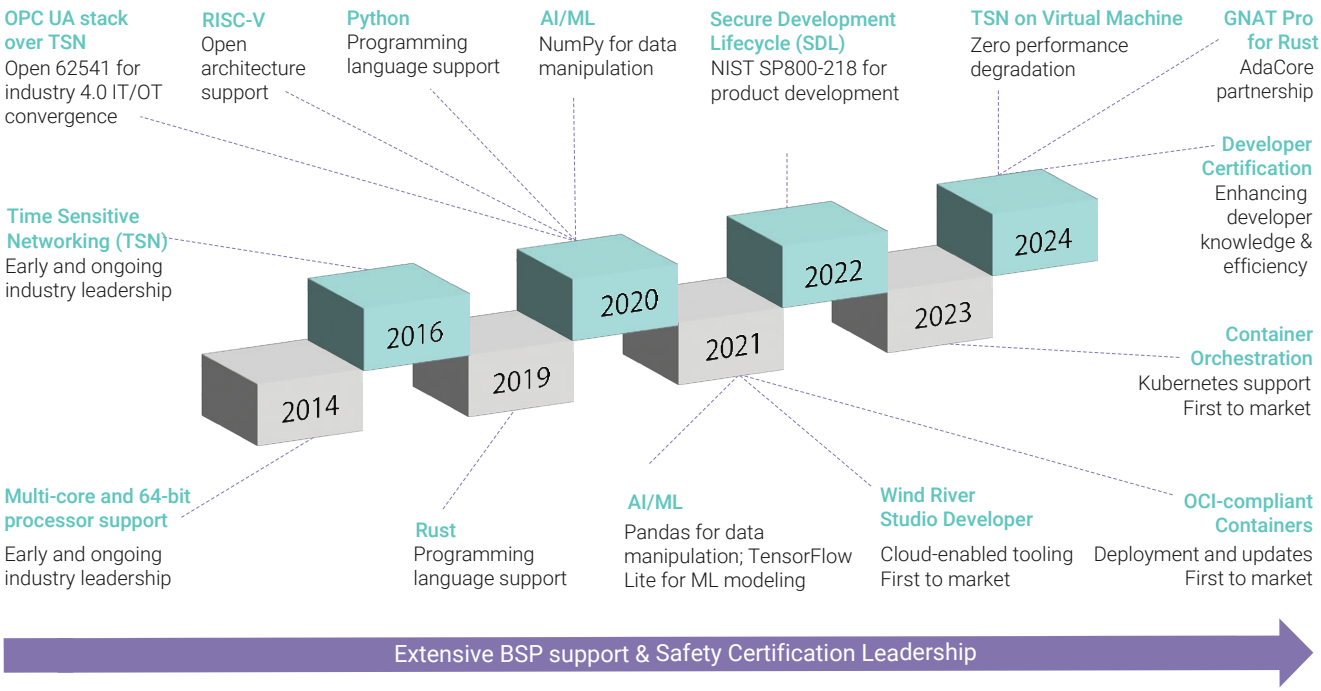

Figure 1. VxWorks innovation and leadership

FUELING HIGH PERFORMANCE

Every embedded systems project needs to deliver impressive results on time, within budget, and with innovative features that help its users. VxWorks contributes to that effort.

Bringing Artificial Intelligence and Machine Learning to the Edge

AI and machine learning (ML) workloads once were exclusively in the domain of the cloud. Today, AI and ML computations are made at the network's edge, which reduces the data traffic sent to the cloud for processing.

Milestone: VxWorks enables the rapid implementation of AI/ML via library extensions. These included NumPy in 2020 and Pandas in 2021 to improve data manipulation. Also in 2021, we introduced TensorFlow Lite for easier implementation of ML models.

These enhancements equip development teams to capitalize on dynamic edge-to-cloud processing. For instance, using these features can help deployment of image recognition in aerospace and defense applications. It can process sensor data within a vehicle for predictive maintenance. And it can speed up medical diagnostics.

Supporting Time-Sensitive Networking

Modular design is a popular approach to cost-effective systems development. System modules or components connect via Ethernet, with the goal of interoperability across vendors' equipment.

However, traditional Ethernet connectivity cannot guarantee timely delivery of high-priority system data. To address this issue, the IEEE industry standards organization (IEEE 802.1) is augmenting traditional Ethernet definitions to encompass Time-Sensitive Networking (TSN). Among other enhancements, the TSN Working Group addresses time synchronization, scheduling, and traffic shaping.

Milestone: VxWorks introduced TSN support in 2016. Since then, we have added support for Arm® and Intel® hardware architectures. This lets embedded systems engineers minimize network latency and jitter, providing bounded end-to-end delay and guaranteeing data delivery time over Ethernet.

Open Platform Communication Unified Architecture (OPC UA) is a cross-platform, open source, IEC62541 standard for data exchange from sensors to cloud applications developed by the OPC Foundation. It provides a modern, secure, and reliable way to facilitate HMI/SCADA and general-purpose industrial automation activities, as well as integration with business intelligence, analytics, and cloud platforms for Industry 4.0. Wind River is an active contributor to the open62541 community.

Milestone: The open62541 (OPCUA stack) over TSN was added to VxWorks in 2020.

High-performance processors increasingly carry on-board TSN capabilities. Each VxWorks release enhances TSN processor support to keep up with evolving TSN standards and to improve high-performance system design flexibility. Systems consolidation projects often place requirements on these processors to run multiple system functions on multiple OSes, within virtual machines via a hypervisor.

Milestone: March 2024 saw formal validation testing of VxWorks supporting TSN features as a guest operating system on Wind River Helix™ Virtualization Platform, our safety-certified hypervisor. This proved that there was no degradation of performance when VxWorks is used for TSN applications in a virtual machine (VM).

In support of TSN, we participate in PlugFest workshops, industry forums, and collaborative activities with embedded systems vendors across industries.

Learn more: Following close collaboration with aerospace and defense and automotive systems vendors, we published a white paper, "Hitting the Moving Target with TSN," which describes how development teams can move forward with TSN implementation in their designs.

Modular design has become commonplace in aerospace and defense systems, where it is crucial to source equipment from different vendors and to upgrade or replace modules efficiently. Automotive vehicle systems architectures are also adopting TSN to support the adoption of on-board, high-priority, safety-critical sensor data.

ENABLING MORE COST-EFFECTIVE FUNCTIONAL SAFETY CERTIFICATION

Functional safety certification is expensive, risk-heavy, time-consuming — and absolutely necessary. VxWorks certification evidence enables development teams to achieve cost-effective certification of designs so engineers can focus on the code they build, not the tools they use.

This is a key advantage with today's embedded systems, which commonly include multi-core processors. Multi-core processors present several design and safety certification challenges because of the ways in which deterministic timing is affected when hosted applications run in parallel on them. These so-called interference channels always involve some kind of shared resource. Good RTOS designs provide a versatile toolbox with many different approaches that help to mitigate such interference, so system designers can choose the most appropriate and lowest-impact strategies for their design.

Learn more: Our definitive white paper "Mitigation of Interference in Multi-core Processors," a collaboration with Rapita Systems, covers these challenges in technical detail, addresses how to mitigate the issues, and provides methods to achieve functional safety certification.

VxWorks with off-the-shelf certification evidence provides design and integration documentation to help system integrators analyze how their applications can and should use shared resources and exercise interference channels.

Milestone: Wind River has completed more than 600 functional safety certification projects, spanning aerospace and defense (DO-178C DAL A, EUROCAE ED-12C, ARINC 653), industrial automation (IEC 61508 SIL 3), medical (IEC 62304 Class C), and automotive (ISO 26262 ASIL D).

SCALING TO MULTI-CORE

The ability to scale systems to use multiple processor cores while maintaining single nanosecond latency is essential for supporting modern high-performance real-time embedded system functions.

Milestone: VxWorks has supported multi-core processors and 64-bit architectures since 2014, all the while ensuring a flat operating system overhead, irrespective of the number of cores.

EASING ARCHITECTURE ADOPTION

New processors bring new architectures, and Wind River makes it easier to adopt those architectures. Together with about a hundred partners, Wind River offers an extensive range of board support packages (BSPs) for the embedded software industry. BSPs are software components that provide an interface between an operating system and the hardware of a specific computer board. BSPs assist developers with board bring-up and design, so they spend less time searching for compatible components and more time developing revenue-generating products.

Milestone: In July 2020, RISC-V support was introduced on VxWorks, giving development teams the option to use this open processor architecture, thus avoiding the need to pay royalties charged by other major processor architecture vendors.

Architectures include (but are not limited to) Arm/ARM64, RISC-V, x86/x86-64, and PPC/PPC64. Because of our close relationships with silicon vendors and hardware manufacturers, Wind River can offer ready-to-use products that support the latest processors so developers can choose the best development platforms for their specific architecture.

Need a custom BSP? Wind River Professional Services can tailor a BSP to your device's specific needs. Any board, any architecture — we can help.

MAKING DEVELOPERS MORE EFFICIENT

Modern Programming Languages

Teams developing next-generation embedded systems are always under pressure to deliver mission-critical systems under tight timeframes. Having the right programming language and tooling support within an RTOS is thus crucial.

The Python programming language enables rapid application development and scripting to connect existing software components, encouraging modularity and code reuse.

Milestone: VxWorks support for the Python programming language was introduced in 2020.

Rust is a programming language with strong emphasis on code safety, including areas such as safe concurrency, vulnerability prevention, and memory management, all allowing for the building of dependable, efficient software. Its syntax is readily understood by C or C++ developers.

Milestone: VxWorks support for the Rust programming language was introduced in November 2019. And in 2024, we enhanced our Rust support via our partnership with AdaCore, with GNAT Pro for Rust for VxWorks 7.

Cloud Enablement

To accelerate time-to-market, developers require IT-like tooling and methodologies that enable a shift-left approach — with software testing earlier in the lifecycle, as well as integration with existing development and deployment processes.

VxWorks remains the only RTOS that supports a DevSecOps approach to mission-critical systems development, incorporating cloud-based development, testing, integration, deployment, and updates.

Milestone: Wind River Studio Developer, first announced in January 2021, supports the creation and provisioning of VxWorks-based systems.

DEPLOYING AND UPDATING EFFICIENTLY WITH CONTAINERS AND ORCHESTRATION

Secure, efficient software deployment and updates are table stakes for the intelligent edge. VxWorks supports OCI containers and Kubernetes orchestration.

Milestone: In 2021, VxWorks became the first RTOS to support OCI-compliant container technology. In 2023, we added container orchestration with Kubernetes, which helps development teams eliminate manual errors, standardizes tools, and accelerates the rate of product iterations.

UNDERPINNING PROJECTS WITH PROVEN RTOS SECURITY

Product security is an obvious need, particularly given the importance of RTOS-based implementations, and efficient developers ensure that security is an integral part of the development and deployment process.

Milestone: Since 2022, Wind River has supported a secure development lifecycle (SDL) across our products, enforced by policy and implemented with processes and procedures, as defined by the NIST SP 800-218 Secure Software Development Framework (SSDF) standard. VxWorks also is backed by Wind River Security Center for Common Vulnerabilities and Exposures (CVE) tracking and mitigation.

GOING FORWARD

The VxWorks journey of innovation is set to continue, as we keep pace with the demands of new advanced processors, supporting the high-performance needs of TSN and AI/ML, providing ongoing safety certification and high security, and enabling development teams to be more efficient.

As you navigate the rapid evolution in embedded systems software, you can rely on VxWorks and Wind River proven expertise to help you succeed.

WHEN IT MATTERS, IT RUNS ON VXWORKS

WNDRVR

Wind River is a global leader of software for the intelligent edge. Its technology has been powering the safest, most secure devices since 1981 and is in billions of products. Wind River is accelerating the digital transformation of mission-critical intelligent systems that demand the highest levels of security, safety, and reliability.