

Full Vehicle Integration Testing via Cloud-based Electronics Digital Twins at Volvo Cars

“We have a long history of working with Silver for embedded ECUs, although it’s only level 1, it has the benefit of being fast and stable with a good capability of adding Functional Mock-up Units. Silver supports Linux and command line execution, something that is essential for our software factory.”

– Johannes Foufas, Technical Manager, Software Factory, Volvo Cars

V O L V O

Challenges

Late integration of Electronic Control Units (ECUs) has been shown to be a contributor to delays in the start of production (SOP)¹ and has also resulted in some OEMs launching platforms that were not fully complete. This creates downstream pressure on validation, release schedules, and overall product readiness.

A key architectural change is that, instead of suppliers delivering single-purpose ECUs, the original equipment manufacturer (OEM) now owns and controls the application software stack that spans a reduced overall number of ECUs. This consolidation shifts responsibility and integration complexity toward the OEM while aiming to streamline hardware.

Modern software-defined vehicle (SDV) platforms introduce distributed functionality across the entire network. As a result, piecemeal validation is no longer feasible; even the most basic functions require the entire ECU network to be present and interoperable to validate end-to-end behavior.

Within this context, Volvo Cars faces the particular challenge of validating its own in-house middleware, the ‘Core System Platform’ (CSP), in addition to the broader integration tasks. Ensuring this middleware operates reliably across all components adds another critical layer to the validation effort.

Electronic Simulation Architecture

The Scalable Product Architecture 3 (SPA3) vehicle platform comprises a High-Performance Core Computer that connects to several zonal ECUs². These zonal ECUs, in turn, interface with the Mechatronic Rim, creating a layered network that balances centralized compute with localized control.

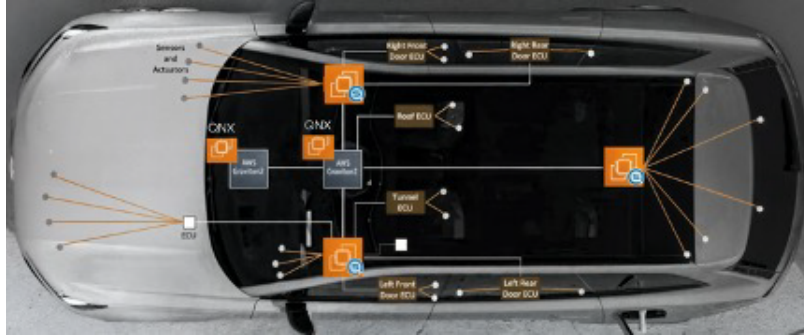


Figure1: SPA3 is a zonal architecture with two core computers, three zonal controllers, and multiple ECUs

To enable early integration testing, the team seeks an electronics twin of this architecture that can be simulated on Amazon Web Services (AWS)³. This cloud-based approach supports scalable experimentation and continuous validation without depending on physical prototypes.

The High-Performance Core Computer runs the QNX Operating System (QNX OS). For simulation, QNX OS has been modeled as a virtual machine running on AWS Graviton⁴, corresponding to a level-4a virtual ECU. This setup mirrors the target environment closely while leveraging cloud compute efficiency.

The zonal ECUs are modeled as level-3 virtual ECUs in Synopsys Silver^{TM5}, running an AUTOSAR Classic Operating System. Together, this combination provides accurate behavioral fidelity for ECUs within the electronic architecture.

Communication to the Mechatronic Rim is simulated using mocks provided by RemoteLabs' RemoteTopology⁶. These restbus simulations are used as stand-ins for real hardware, allowing end-to-end communication flows to be exercised in the digital twin.

Synopsys and Partner Solution

By virtualizing QNX OS on ARM architecture CPUs⁷ with Silver virtual ECUs and RemoteTopology restbus simulation, the team achieves a fully coupled, closed-loop simulation of the entire vehicle network. Taken together, these components constitute an 'electronics digital twin'⁸ that allows comprehensive validation of software and network behavior before physical integration.

“As vehicle software complexity accelerates, OEMs need to start development earlier to stay ahead. By virtualizing the QNX OS together with Synopsys Silver virtual ECUs in the cloud, we provide a digital twin that mirrors production hardware with exceptional fidelity. This collaboration empowers automakers like Volvo to validate software stacks long before hardware arrives, reducing integration risk and speeding time-to-market, ensuring that what works in simulation, will work on the road.”

– Sheridan Ethier, VP, Engineering Middleware, QNX

“What this setup demonstrates is that system-level validation doesn’t have to wait for hardware. By combining virtual ECUs, target binaries, and realistic restbus simulation, teams can validate end-to-end vehicle behavior early, when changes are still inexpensive to make.”

– Aleksandar Filipov, CTO RemotiveLabs

Key Benefits of Synopsys and Partner Solution

The simulated environment can be embedded into Continuous Integration (CI) pipelines for regression testing, enabling a meaningful shift-left of development that reduces cost, shortens timelines, and minimizes external dependencies⁹. This early verification capability catches integration issues sooner and accelerates iteration cycles.

A high-value use case is ensuring that, for every code commit, the simulated car reaches a drivable state. If a commit breaks drivable functionality, the system automatically rejects it via a gating check¹⁰. This policy preserves system integrity and prevents regressions from propagating downstream weeks later.

CSP middleware binaries recompiled for the QNX cloud environment can be deployed into the simulation¹¹. The file structure of the QNX OS has to undergo minor adaptation to allow access for the testing framework. Close parity between target and simulated environments increases confidence that validated behavior will carry over to real hardware.

The Silver virtual ECU simulation includes a simulated AUTOSAR Operating System together with the complete production AUTOSAR Basic Software and Volvo Cars’ application stack. In practice, this means the simulation behaves like the real system across the zonal ECUs, validating not just at the Run-Time Environment (RTE) layer but through the full software stack.

Each ECU is modeled as a separate container (featuring either Silver or a RemotiveLabs ECU mock inside) running on top of a single AWS Elastic Compute Cloud (EC2) instance based on Ubuntu Linux¹². This node runs parallel to a QNX OS AMI instance through Amazon EC2 containing the CSP middleware. Coupled together, this simulation environment enables validation of Ethernet communication between the Core Computer and the zonal ECUs at real-time speeds, matching the in-car network one-to-one. Likewise, communication between the zonal ECUs and the Mechatronic Rim can be validated using CAN and LIN protocols supported by RemotiveTopology, ensuring protocol-level fidelity throughout the network.

Challenges and Results

The environment is now used in production as a formal gating mechanism for software development. Work continues to harden the setup for routine CI enforcement.

Two areas of improvement remain: a lack of encrypted communications between the Core Computer and the zonal ECU simulation, and modelling of VLAN communication within AWS Virtual Private Cloud (VPC). Workarounds to both issues are in progress to reduce the simulation-to-real (‘sim-to-real’) gap¹³, thereby improving confidence that validated behavior will translate to on-road operation.

“By combining AWS Services such as Amazon EKS and Amazon EC2 Graviton processors with Synopsys Silver virtual ECUs in a digital twin testing environment, OEMs can now perform complex vehicle integration testing at scale, accelerating development and validation cycles while reducing dependency on physical prototypes. This approach exemplifies how cloud-native architectures and advanced virtual ECU solutions are enabling the future of software-defined vehicles.”

– Mohammed Hashem, Senior Industry Solutions Architect, Amazon Web Services

A comparable simulation environment for SPA2 demonstrated commit rejection rates of 30%, clearly proving the value of early integration gates. Without such a guard, these defects might only surface in hardware-in-the-loop (HiL) rigs, box cars, or—worst case—in road testing. Using the same real-time OS, such as QNX OS, from cloud simulation, virtualization to real-time testing with HiL and into production deployment enables a seamless transition - from digital twin to real-world implementation.

The zonal ECUs modeled in Silver correlate well with hardware targets, as evidenced by their ability to pass the test suite intended for a HiL rig. This correlation underscores the accuracy of the virtualized approach and its suitability for pre-hardware validation.

Following introduction into CI, Volvo Cars is pursuing further improvements in target binary compatibility, time synchronization, GPU acceleration, and sensor simulation to keep pace with 'one-track software' development and to prepare for future platform introductions. These enhancements aim to maintain realism and performance as software scope expands.

“Combining the High-Performance Core Computer SIL with level-3 virtual ECUs in Synopsys Silver SIL for our Zone Controllers has proven to be highly beneficial. This scalable test environment lets us create new projects where we move applications around the board with shorter lead time, something we would lack hardware test resources to do in a controlled manner.”

– Van Trieu The, Product Manager Zonal Execution Environment, Volvo Cars

Authored by: Marin Stanev and Markus Selensky, Synopsys

References

- [1] [Managing and minimizing new auto model launch delays: PwC](#)
- [2] [Investors.volvocars.com/en/news-and-events/strategy-update-2025](https://investors.volvocars.com/en/news-and-events/strategy-update-2025)
- [3] [Volvo Cars Streamlines In-Vehicle Software Testing with AWS Graviton on Amazon EKS—AWS for Industries](#)
- [4] [Accelerate embedded software development using QNX® Neutrino® OS on Amazon EC2 Graviton—AWS for Industries](#)
- [5] [Accelerating Development of Software Defined Vehicles with Virtual ECUs](#)
- [6] [Integrate with CI pipeline](#)
- [7] [ARM Processor—Performance Processor—AWS EC2 Graviton—AWS](#)
- [8] [Software-Defined Vehicles: Synopsys & Arm Collaboration—Synopsys](#)
- [9] [What is Triple Shift Left?—Shift Left Testing Explained—Synopsys](#)
- [10] [Zuul CI at Volvo Cars—Volvo Cars Engineering](#)
- [11] [Extracting ISA Parity from Cloud to Edge: Why This Matters to the Ecosystem—Arm Newsroom](#)
- [12] [Ubuntu on AWS | Ubuntu](#)
- [13] [Bridging the Sim-to-Real Gap for Industrial Robotic Assembly Applications Using NVIDIA Isaac Lab—NVIDIA Technical Blog](#)