

Volvo Vehicle Electronics System Validation

WHITE PAPER

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Business Summary

Volvo Car Corporation has a strong reputation for solidity, reliability, and safety. With the increasing size and complexity of electronics in its vehicles, the company understands that product revisions during a program are more expensive than ever before, and that miscommunication of even a single requirement can have disastrous consequences. Today's embedded software demands earlier testing and more thorough test coverage. In order to protect its brand, Volvo began embedded software virtual testing for electronics components years ago. The company is now taking verification and validation (V&V) to the next level through a strategy of concurrent development and testing.

Technical Summary

Volvo's Central Electronic Module (CEM), a complex and highly interconnected ECU, controls interior and exterior body electronics, monitors and controls safety features, and provides convenience functions. Volvo found model-based engineering to be an efficient way to develop algorithms and features for the CEM and other electronics in the vehicle. They also found software-in-loop (SiL) testing is an excellent way to perform early/advanced feature testing of software before actual electronics are available. Volvo was challenged by the unavailability of commercial integrated test solutions. The company wanted a single tool to support model-in-loop (MiL) validation of algorithm simulations, SiL verification of hand-written features, and hardware-in-loop (HiL) testing of the CEM electronics. Volvo wanted the tool to use portable test cases that could be reused across the MiL/SiL/HiL environments, and across different vendor's HiL equipment. The tool needed to be scalable from component level testing, all the way through complete system testing.

Solution – Mx-Suite™ Offers a Comprehensive Scalable Testing Framework

Volvo chose Mx-Suite embedded software test environment to meet the need for test automation resulting from increased software content within key automotive function areas. These areas include primarily body control, infotainment, hybrid technology, and advanced driver assistance systems. Mx-Suite provides the ability for Volvo to test the entire CEM software in a software representation of the electronics control unit (virtual ECU). In addition, Mx-Suite test cases can be used throughout the development process, whether model-based algorithms design, embedded software functional testing, or HiL testing. The same black-box test cases are used with simulation models, virtual ECUs, components on the bench, and vehicle testing lab equipment. Mx-Suite test cases and simulation models can be provided to development teams or suppliers as comprehensive executable specifications.

User Application

Volvo's CEM is a complex and feature-rich ECU that controls the majority of body, chassis, safety, and convenience features in the vehicle. It communicates with other sensors and components using a combination of hard-wired signals and CAN/LIN communications in order to control body, safety, and convenience features. These features require complex and highly interdependent software functions capable of monitoring and controlling more than 1200 signals. Because of conflict between electrical components and between features, developing a robust CEM is both challenging and time consuming.

Each feature or function algorithm is developed using simulation models or hand-coded software. The features are validated in a simulated ECU environment through MiL testing as simulation models or as SiL testing as a virtual microcontroller at the component level, then as multiple virtual controllers at the system level. Software is then integrated into the CEM and HiL tests are performed at increasing levels of integration, starting with regression tests of components, and ending with the vehicle electronics system.



Issue Resolution – Test Framework Connectivity

The new generation CEM software is developed according to the AUTOSAR standard and most of the software application layer is developed internally at Volvo using a model based approach. A number of commercial and customer tools are used to develop and test the CEM software in a prototype vehicle rig called a “Box Car”. The test environment must support:

- Unit testing and automated integration testing of the application layer software components.
- MIL testing using a PC workstation and Simulink®.
- Software testing in a HiL environment (dSPACE® Simulator).
- CAN/LIN simulation and other functions for testing in a vehicle network.

The tool environment must also connect to both custom and commercial tools for diagnostics, software download, and CAN testing. There are two key requirements of the test environment:

1. To provide the ability to create automatic, equipment-independent test cases for MiL, SiL, and HiL tests.
2. To reduce the number of HiL equipment needed and domain knowledge required to execute HiL tests.

Customer Approach – MiL/SiL/HiL Testing

Before committing to any single test tool, Volvo chose to evaluate a number of industry leading tools that provided automation and the ability to test in MiL, SiL, and HiL environments. Tools from Danlaw, dSPACE, MathWorks, National Instruments, and Vector were chosen as potential solutions.

The set of data that are available for the creation of test cases and the evaluation of the tools come from different environments, including model simulations and MATLAB® data, bench measurements, CAN logs, in-vehicle data acquisitions, and HiL simulation equipment. Several other custom data sources are also used, including hand-generated data.

While not specifically part of the tool evaluation, it is important to Volvo that other capabilities also be supported. Co-simulation with multiple model support for LIN and MOST networks connectivity with debuggers and scripting environments, integration with software quality analysis tools, and support for requirements management and configuration management are also desirable.

During the requirements analysis and design phase, Volvo designers use Mx-Suite to import test cases, CAN data, and discrete bench data as signal sources in order to drive the simulation models. Mx-Suite recognizes the MathWorks® signal database and builds its own software test harness. The automatic harnessing feature and intuitive behavior pass-fail thresholds allow Volvo to create experiments more quickly than with other tools. Additional tests are easily handcrafted using Mx-Suite’s graphical interface, which define test signals and test messages to inject into simulation models in order to verify behaviors of each feature of the CEM. Volvo reports that Mx-Suite is easier to use than other tools to create test cases for Simulink® models. It is easy to learn and very useful for engineers with limited or no knowledge of programming. Volvo notes that delivering a comprehensive specification package to a supplier that includes test cases is the most effective form to communicate executable specifications.

Volvo software engineers can either reuse existing test cases from the design group, or they can import data from bench test equipment logs and field data to create additional test points for new experiments. Harnessing the CEM software to a virtual ECU for testing is straightforward. In the case where CEM features are implemented in handcrafted software, the regression testing capability of Mx-Suite is especially useful because it alerts the engineers when they “check-in” code that breaks other software feature behaviors. Mx-Suite’s integration with Bullseye Coverage also provides code execution coverage reports for the executed tests and helps to establish ISO 26262 compliance.



Many of today's testing teams struggle with maximizing the utilization of expensive HiL equipment. Volvo is no exception. By performing earlier testing in a virtual vehicle, and performing higher levels of test coverage, HiL testing is more efficient. Higher throughput is obtained through the HiL testers and fewer HiL testers are needed to complete testing. In addition, Mx-Suite's portable test cases allow any unused HiL capacity to be loaned to developers, who can use their MiL/SiL tests to test their components on the HiL. Mx-Suite's regression testing feature allows quick turnaround.

One of the highest payoffs that Volvo has achieved is the consolidation of their test benches. Most of the HiL tools come with software that has their unique way to represent and execute tests, so there is little potential reuse or portability from one HiL set-up to another. Mx-Suite provides the benefit of being able to reuse test cases throughout the life-cycle, i.e., model-based test cases from the design phase, test cases from the software design verification testing efforts, and test cases from CAN tools or other HiL tools. Test cases can be imported into Mx-Suite and converted into the portable format. Mx-Suite is "HiL-agnostic" and can connect with any third-party test tools and vehicle networks, so it is possible to reduce the number of different third-party tools used in the organization's test framework. Volvo considers this to be one of the most important aspects of their model-based development strategy. They have a standard way to measure quality of the embedded control software. By having portable, reusable test cases, they create efficiency in their own organizations as well as the suppliers' organizations.

Volvo noted that a unique feature of Mx-Suite is its licensing mechanism, whereby licenses can be shared across the enterprise, and are not locked to any specific feature. Each feature is managed by a license server that determines the "cost" of the feature, versus the "central reserve". As long as the "reserve" is positive, the license server permits the feature to run and debits the reserve by the cost. When the feature completes execution, the server credits the cost back to the reserve. The benefit is to allow any user to run any available feature (including newly released features) without having to purchase additional licenses.

Benefits

With Mx-Suite, Volvo is able to create an enterprise-wide testing strategy and consolidate testing resources. Storing test data and test scenarios in a universally understood format allows test cases and scenarios to be leveraged across the whole development cycle. Mx-Suite supports automatic regression-testing and reporting of test results. It allows developers to focus on feature implementation, and promotes concurrent testing during development, regardless of the tools used to model, develop, or unit test the implementation.

According to Volvo, Mx-Suite brings the following benefits to the company:

- Reusable Test Cases: it is possible to use the same test cases both for MiL and HiL testing which reduces test case implementation time
- Full life cycle support: the tool allows connectivity to virtually any system under test (MiL/SiL/HiL)
- HiL connectivity: the tool supports commercial, generic, or custom HiL hardware
- Ease of use: the graphical GUI is easier to learn and use most other tools, and geared toward engineers with limited or no knowledge of programming
- Leveraging historical experiments: measurement data is easy to use as test cases. Complex test cases can easily be generated from comma-separated-variables in data files
- Dynamic feature licensing strategy: new tool features can be tried out without having to contact Danlaw first.
- Creating new tests: well-structured user interface enables quick generation of test cases and scenarios
- Extensibility: it is possible to integrate Mx-Suite™ with other Volvo internal Windows applications (e.g., for software diagnostics, software download, software build, etc.)
- Support and training: excellent software support from Danlaw

Using Mx-Suite embedded software test environment, Volvo engineers are pleased with the reductions of the time and effort required to provide comprehensive testing. Mx-Suite provides executive summaries, requirements-traceability, code-coverage and detailed test cases to prove that software is fully tested. Mx-Suite provides the test cases that are often missing with traditional executable requirements specifications.



About Volvo

Volvo Car Corporation is a global car producer, with the head office in Gothenburg. The company has around 20,600 employees spread in factories in Sweden, Belgium, Malaysia, and China. It has produced the world's safest cars since 1927.

About Danlaw

Danlaw is a leading global supplier of technology and services to the automotive and aerospace industries for safer, smarter, and more secure systems. Thirty years ago, we designed software for the first 8-bit Electronic Engine Control module, and today, we continue to develop forward-looking technologies. We focus our efforts on R&D to stay ahead of rapidly changing industry needs in an increasingly connected world. Danlaw is known for ground-breaking tech, efficient development, and adaptive solutions for dynamic environments.

Danlaw's engineering professionals provide embedded electronics solutions to OEMs and Tier-1 suppliers. Our team specializes in embedded systems development and testing for Embedded Control Units, vehicle network communications, infotainment, and telematics. With engineering centers in the USA, Europe, India, and China, Danlaw is one of the largest suppliers of connected products, tools, and services in the world.