
# A Moving Variety

For commercial vehicles, diversity is a standard. Scania has a nearly endless selection of vehicle types and modular vehicle configurations. And the generic electronic control unit (ECU) system has just as many variants. In a new test lab, Scania shows how this system can be validated with reliability.





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Trust is written with a capital 'T' in the transport and commercial vehicle industry because every day many people depend on reliability. High reliability and maximum uptime are not the result of chance, though. They are the result of years of experience and work towards the goal of matching performance exactly to the requirements of day-to-day driving. These requirements are quite different, with an application area ranging from smooth asphalt roads to muddy construction sites. Sometimes passengers are carried, sometimes goods. Sometimes non-road mobile machinery needs to be moved safely.

### Perfectly Matching Vehicles

Scania's goal is to provide a perfectly matching vehicle for each task. The requirements from the fields of transportation, construction site traffic (bulk cargo vehicles), municipal vehicles (garbage trucks, street sweepers, snowplows), passenger transport (buses) and special vehicles (fire engines) are extremely different. Within these different fields, there are further segments, which in turn require vehicle properties that match the demands. For example, a transport truck needs to come with optimal configurations for its special type of cargo (volume freight, reefer freight, liquids, bulk cargo, etc.), configurations that satisfy every little detail.

### High-Performance Vehicle Technology

Safe driving, smooth-running vehicle handling, and low fuel consumption – these goals appear in the specifications document for every Scania vehicle. Technically speaking, the electronic components and software play the main role, driving innovation towards these goals. Powerful brakes, electronic stability systems, camera surveillance and advanced driver assistance systems (ADAS) are typical examples of Scania's commitment to improving traffic safety, providing economic and environmental performance, and achieving maximum comfort. Modern Scania vehicles therefore carry a complex electrics/electronics (E/E) system in which a variety of ECUs work together.

### Efficient Modular System

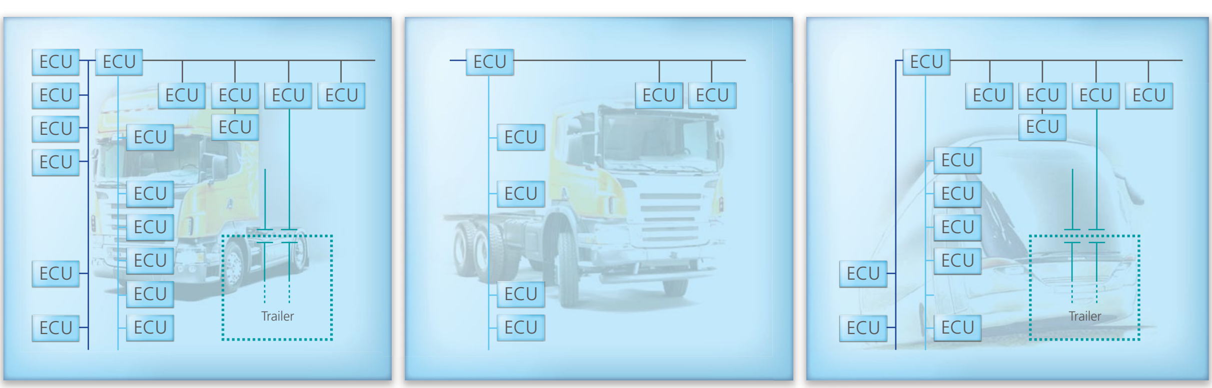
The vehicles' variety of tasks creates an even higher variety of challenges for vehicle developers. The only way to manage these development tasks and implement them economically is to use a sophisticated modular system. Depending on the requirement, a specialized and often wholly unique vehicle is put together from a pool of main components (including the cab, engine, transmission and chassis).

### Variant System for ECUs

While the mechanical components are configured differently to match the nature of the task, the E/E system, and particularly its ECUs, is generic in design. From trucks, to buses, to snowplows, all vehicles have the same E/E system, but featuring a modular approach regarding the ECUs actually needed. The vehicle-specific functions and functional characteristics of the ECUs are implemented by parameters derived from a vehicle configuration file (Scania Onboard Product Specification, SOPS). This file is like a vehicle's DNA, describing the configuration and features to the last detail. The ECU variants created according to this variant method must be validated in all the installed combinations.

> The E/E system of the vehicle fleet consists of 93 ECUs. It is validated with a simulator system from dSPACE.

*Depending on the vehicle and features, optional ECUs are installed in addition to the basic ECUs.*




*Automatically connecting the cable harnesses of different ECU variants to the simulator.*

### High Test Requirements

Efficiently and reliably validating the E/E system of the current vehicle fleet is one of Scania's most important tasks. This requires a test system that already supports developers when they are developing the functions of individual components, and that can also handle complete and, if necessary, automated E/E system tests. Ultimately, the test system must satisfy the same principles that apply to the system under test: modular design, easy variant management, and high reliability are a must. Together with dSPACE, a test concept was developed for the current E/E system. dSPACE already had experience with the simulators of the previous test system, I-Lab2 (Integration Laboratory). The new test system (I-Lab3) must cover the following scopes and requirements:

- 93 ECUs (real and with simulated restbus)
- 30 CAN/LIN buses
- 17 engines (common rail, unit injector, CNG, Euro 3, 4, 5, 6)
- 10 transmissions (manual, automatic, semiautomatic)
- Up to 5 axle-wheel configurations
- Automated ECU switching
- Automated CAN architecture reconfiguration

### Test Concept for the System Test

The validation of a complex ECU network is performed with integration tests that validate various interdependent components (ECUs) of a complex system as they interact with each other. According to the well-established hardware-in-the-loop (HIL) method for ECU tests, each ECU works with a virtual representation of its controlled system

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## Technical Details of the Simulator

- 14 wide-size 41 HU cabinets
- 9 DS1006 Processor Boards (quad-core)
- 60 I/O boards with approx. 3,400 channels
  - 1,500 digital I/O channels
  - 600 ADC channels
  - 370 DAC channels
  - 150 resistor simulation channels
  - 300 PWM inputs
  - 130 PWM outputs
  - Further special channels for:
    - Injector measurement
    - Crankshaft and camshaft sensors
    - Knock sensors
    - Lambda sensors
    - Inductive position sensors
  - 88 CAN channels
  - 66 specially developed CAN gateway modules (controlled via separate CAN)
  - 150 Failure Insertion Units (FIU), with 10 channels each


*The virtual vehicle simulator with the operator systems before it was installed in the laboratory.*

(engine, transmission, suspension, comfort and driver assistance systems). The controlled systems are also connected to each other, forming a virtual vehicle. The resulting test system is a network simulator, also called an integration HIL. To validate all Scania ECUs with this HIL method, a concept was created for a network simulator consisting of 14 dSPACE Full-Size Simulators that communicate with each other via fast fiber-optic cable connections (Gigalink). For the special challenge of replacing the ECU hardware automatically, the concept included a linear robot that can connect the cable harnesses of various ECUs to the simulator.

### Complete Test Lab

A test system of this magnitude first requires a comprehensive feasibility and cost-effectiveness check. Once the implementation of the concept was approved from the technical and the economic point of view, the different activities started in parallel to make the simulator a reality. While dSPACE set up the simulator, Scania's job was to set up an air-conditioned lab room, including an operator control center. The six workstations of the control center are where the developers implement and evaluate the tests. The only step necessary to build ECUs, including their real loads, is to enter the laboratory, which


houses the largest dSPACE Simulator delivered so far. The tests are controlled from the operator box.

### The Simulator's Special Technical Features

To handle the great variety of variants, a design concept was developed that lets the individual ECU variants of an ECU family be switched easily. This involves building the ECUs, with all of their replacements loads and real loads, compactly in drawers or on shelves. Some of the simulator cabinets contain several variants of an ECU family, which can be replugged fully automatically (such as for the engine, transmission, and brake management systems). For each ECU there is an ammeter and a Failure Insertion Unit (FIU), in addition to the usual I/O channels.

### Flexible CAN Configuration

The simulator's CAN topology was designed specifically to match the high number of variants. Since the termination of the bus is different for each vehicle configuration, the global buses form two loops through all the simulators (including the manipulation gateway). With a module developed especially for this task, each ECU can be integrated in the loop individually, and the loop can be interrupted at any time. Thus, for each configuration the

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> Truck and trailer simulations including the engine, vehicle dynamics and the traffic environment, are performed with the ASM simulation tool suite from dSPACE.

terminating ECUs can be switched as the right or left end of the topology.

### Simulation Models and Parameterization

A simulation model consisting of plant models and I/O models was developed for the entire simulator. The simulation model is distributed over 15 cores of the 9 processor boards and then calculated, with the plant models and I/O models always using separate cores. The I/O models contain the superset of all ECU signals and each channel can be activated and configured individually. dSPACE Automotive Simulation Models (ASM) are used for the plant models. These include ASM Gasoline/Diesel Engine, ASM Truck, ASM Trailer, ASM Pneumatics and ASM Traffic. The models were modified by Scania due to specific requirements for the air supply system and expanded for automatic and manual transmissions. ModelDesk is used to activate and parameterize the individual parts of the model via Variant-Based Workflow Management (VBWM) according to the particular vehicle configuration. The following vehicle characteristics can be represented:

- Engine type: diesel or gasoline
- Engine volume and number of cylinders: 5/6/8 cylinders with 9, 13, or 16 litres
- Transmission type: manual, automated, or automatic transmission, consisting of a main gearbox and sometimes a range group and split gear
- Number of axles and axle drive: from 4x2 to 8x4/4 with several steering axles
- Axle suspension: steel spring (leaf) or air spring (2-bellow, 4-bellow, lift axle)
- Brake type: ABS or EBS
- Vehicle dynamics
- Environment sensors
- Other components: turbocharger, retarder, power take-off, exhaust aftertreatment

### Test Automation and Variant Handling

Scania has a comprehensive test library for all test tasks in the development of engines, vehicle dynamics, driver assistance systems, and special functions. The Python-based tests are summarized in a single test automation (TA) framework that controls the test configuration and test processes. Variant handling is fully integrated in this framework, guaranteeing that the configurations of the simulator match the ECUs. To do this, the TA is supplied from

*Efficient variant handling is supported by the automated means of the Automotive Simulation Models (ASM) and the parameterization software ModelDesk.*

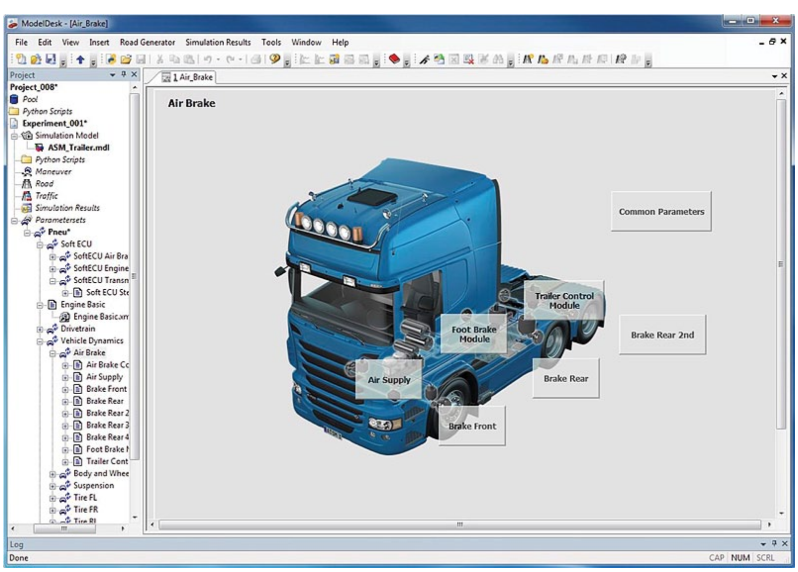

Photo credit: © Scania

the SOPS files, which also contain ECU details such as the pin assignment. The models and the simulator are automatically configured and parameterized according to the SOPS data of the ECUs to be tested.

### Test Tasks

The simulator mainly performs integration tests of all ECUs for the following tasks:

*CAN communication testing:*

- Verify that the correct CAN messages are sent, in the correct interval time, when all ECUs are connected to the CAN network

*Robustness testing:*

- Determine the effects of exceptional conditions like low voltage or bad ground connection
- CAN stress tests and the impact of abnormal bus load

*Diagnostic testing:*

- Pinpoint ECU sensor failures or defective electrical connections

*User function testing:*

- Adaptive Cruise Control
- Advanced Emergency Brake
- Climate control
- Instrument cluster warnings

Of course, the simulator is always an effective and reliable way to perform difficult in-vehicle function tests, such as testing behavior in dangerous situations. In tests like this, I-Lab3 complements the vehicle tests.

### Experience

Quality is Scania's top priority. First, the new test system was thoroughly planned and set up. Then it was tested extensively, which took nearly a year because of the high number of test cases and variants. To date, the simulator has never suffered any unplanned stops – clear proof of its reliability. In day-to-day tests, the system proved its worth in both manual testing and fully automated test runs, which usually ran at night or over the weekend. Thanks to the simulator, it is possible to test entire vehicles earlier and reach a high software maturity sooner. The simulator is a fundamental for reliably handling the combinatorial explosion of tests caused by the many different variants. Regular maintenance tasks are planned in order to keep the quality of the test system high. For day-to-day use, there are proven special processes that offer a balance of test automation, manual tests, and creating and debugging the tests and test system development. A team of eight members takes care of all maintenance aspects, and developers from different departments use the simulator to integrate and verify their ECUs.

### Conclusion and Outlook

With I-Lab3, Scania has seen the evolution of a robust test system that is valuable for integrating new functions in the whole vehicle and makes it possible to run tests that could not be performed at the necessary test depth without simulators. The test system has a flexible, modular concept that will be used in the years to come. Scania will continue developing its test laboratory to support new ECUs and further test tasks. dSPACE has already received the commission for the next configuration. ■

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## Summary

The Swedish truck manufacturer Scania is facing the task of reliably validating a generic E/E system with an enormously high number of ECU variants. To test the 93 ECUs, Scania relies on simulators and simulation models from dSPACE to perform complete vehicle simulation. The simulator is able to automatically switch the individual variants of the different ECU families. It helps developers integrate new functions that can be tested immediately in a complete virtual vehicle. The simulator is an important contribution towards reaching Scania's high standards of quality.

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