ASMs for Complete Truck Electronics Tests

- **Scania tests 33 networked ECUs with dSPACE Simulator**

- **dSPACE Automotive Simulation Models for variant handling**

- **Automated testing with virtual rebuild of buses and trucks**

Swedish heavy truck and bus manufacturer Scania has set up an integration lab to perform automated testing of networked electronic control units (ECU). The integration lab is based on hardware-in-the-loop (HIL) simulators and real-time Automotive Simulation Models (ASMs) from dSPACE. It is a virtual rebuild of a Scania bus/truck, equipped with 33 ECUs and 11 CAN networks. The lab's architecture allows a larger number of possible vehicle configurations to be tested, making it ideal for performing regression tests.

How do you verify the communication between various electronic control units (ECUs) carrying out multiple functions across multiple communication buses? The unavoidable answer, of course, is to conduct in-depth testing. A truck has significantly more variants than a passenger car due to features like dumpers, higher numbers of (driving) axles and different gear types, so efficient variant handling is a key test requirement. For heavy truck and bus
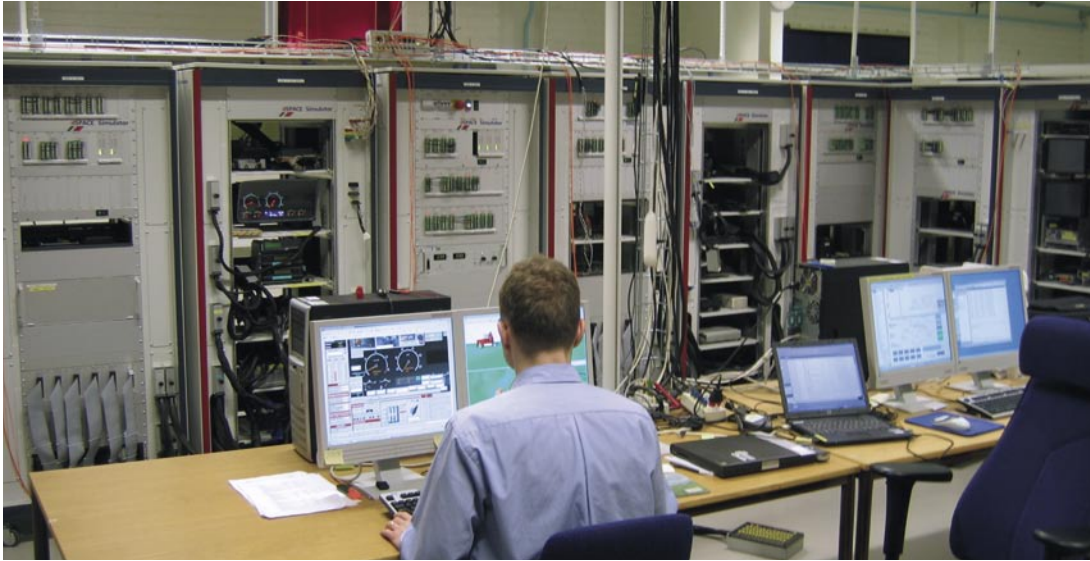
"Although it often takes longer to write a test script than to perform the same tests manually, the ability to run the same test again quickly with next to no preparation saves time for the tester when regression tests are run. This gives us the advantage of reproducibility."

Mikael Adenmark, Scania

▶ *All truck variants have to be tested in depth.*

◄ *The networked hardware-in-the-loop simulators used at Scania.*

manufacturer Scania, the sheer volume of testing that is required to evaluate such complex vehicles has made manual testing a virtual impossibility and automated testing a necessity.

Real-Time Integration Lab

To implement a more efficient and systematic means of testing networked ECUs, Scania developed a state-of-the-art, real-time integration lab, where ECUs can

> *"By using the Automotive Simulation Models from dSPACE across many simulators we can quickly and reliably parameterize our virtual trucks."*
> **Mikael Adenmark, Scania**

be integrated into a virtual truck. The ECU testing process, which was formerly done manually, is now carried out with a Python-based test framework. The system includes 33 networked ECUs for such important system functions as brake management, all-wheel drive, crash safety, engine management and climate control, and 11 CAN networks for inter-ECU communication to accommodate different engine and vehicle configurations. The volume of testing variants that Scania is able to evaluate in this new, automated environment is substantially greater, since loops can be created to run the same tests for all variants. Although it often takes longer to write a test script than to perform the same tests manually, the ability to run the same test again quickly with next to no preparation saves time for the tester when regression tests are run. Having the test variants recorded and ready for reuse

gives Scania the advantage of reproducibility. Another major benefit of Scania's integration lab is the ease with which new software versions can be uploaded, since these are often provided by external suppliers with differing release dates. As new versions can be immediately uploaded across the whole system, the integration lab makes an excellent resource for testing, in terms of both quality and quantity.

Network Simulators

The heart of the Scania integration lab includes five Full-Size hardware-in-the-loop (HIL) simulator racks from dSPACE and associated ECU racks for mounting test devices. The racks are equipped with various I/O devices. Several processor boards are connected via Gigalink cables, so that the Integration Lab is a comprehensive multiprocessor system. All the ECUs and connections are outlined in a 50-MB Simulink® model. All the tests are visualized by MotionDesk, the 3-D online animation software from dSPACE, which gives a realistic view of the moving truck's behavior. This environment has enabled Scania to bring a much wider range of vehicle variants into its testing loop, which in turn has greatly increased our understanding of how certain conditions impact connected ECUs with distributed functions.

Simulation Models

Two of the five simulator racks are dedicated to the integration testing of powertrain and mandatory truck ECUs (e.g., gear boxes, engine control units, instrument clusters, the visibility system and the coordinator system). As simulation models for

the tests, Scania uses the Diesel Engine Simulation Package and exhaust gas aftertreatment models from dSPACE's Automotive Simulation Models (ASMs). The engine model can handle different engines, e.g., a 5-cylinder 9-liter, 6-cylinder 12-liter, and 8-cylinder 16-liter. The gearboxes can be manual transmission, manual automated transmission with up to 16 gears, or different automatic transmission systems. The

> *"With automated testing on dSPACE Simulator, the possibilities increase since loops can be created to run the same tests for all variants, where applicable."*
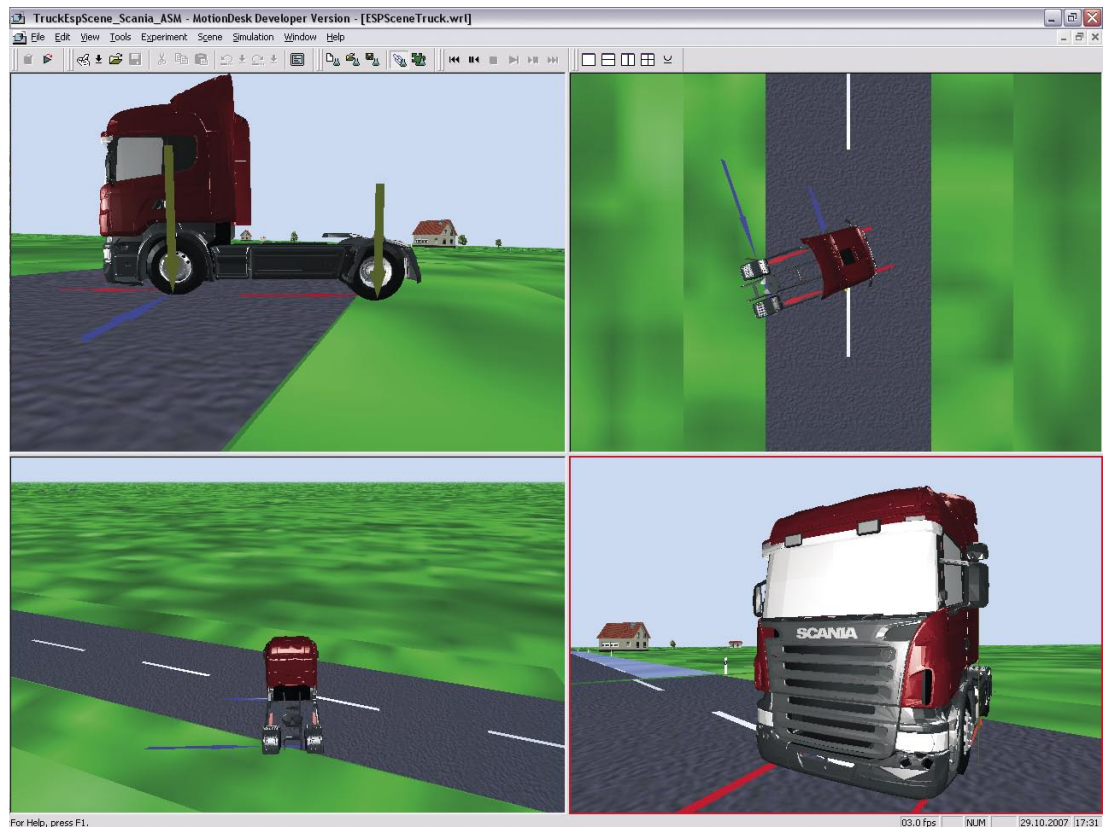>
> **Mikael Adenmark, Scania**

models make it easy to adjust parameters to the truck specifications and simulate the tested truck type in real time.

Two further simulator racks are dedicated to the testing of vehicle dynamic ECUs (e.g., brake management, air processing, suspension management, all-wheel drive, locking and alarm, bus chassis, and body work system). The ASM Diesel Engine Simula-
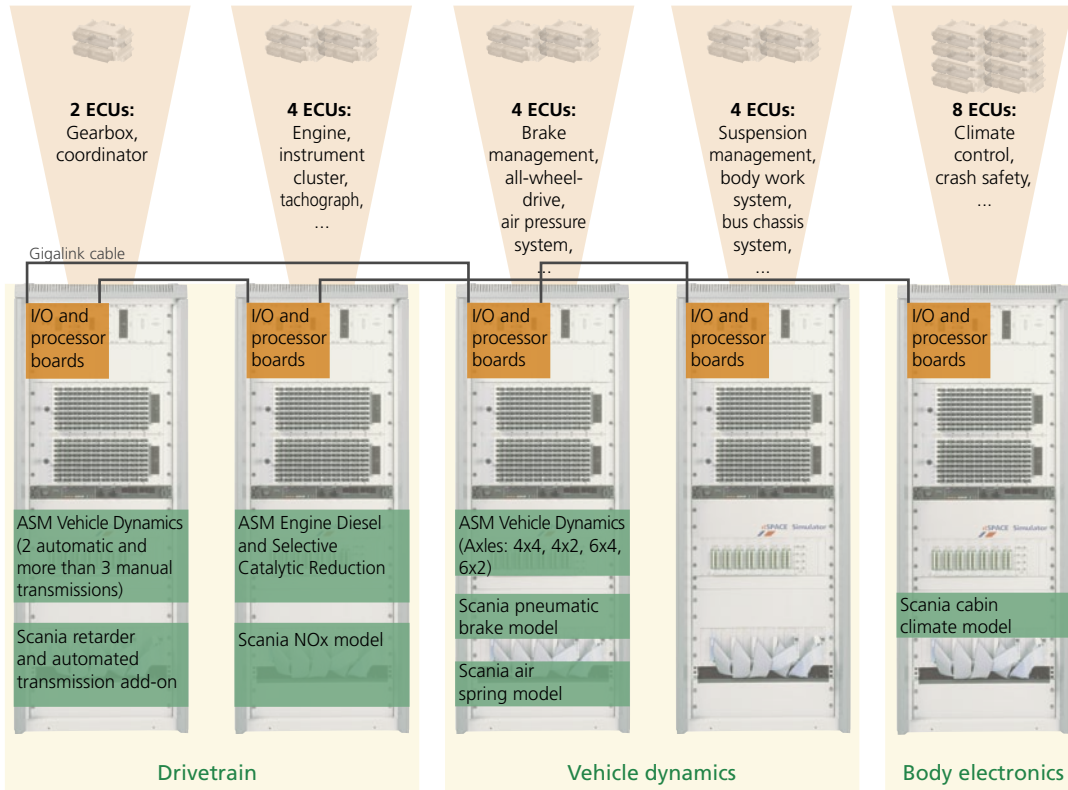
tion Package and the ASM Vehicle Dynamics Simulation Package for Trucks were used for testing all the networked truck ECUs. The vehicle model can simulate trucks or buses with two or three axles. One or two of the axles can be driven axles. The last simulator rack is dedicated to the testing of body ECUs (e.g., heater, infotainment, climate control, crash safety, audio, clock and timer systems). Simulation models developed by Scania were easily be integrated into the test system. By using ASM also for another powertrain simulator, Scania expects to efficiently exchange model parts and parameterization sets between the different systems.

CAN Bus Systems

To realize smooth communication between so many ECUs always is a challenge. Scania vehicles perform their main communication via three global J1939 CAN buses with 250 Kbps. The ECUs are connected via 11 CAN networks, for example for the drivetrain, the comfort systems, and inter-ECU communication. Each ECU can be connected to one of the doubled buses or completely disconnected.

▲ *MotionDesk screenshot showing a test drive.*

2 ECUs:	4 ECUs:	4 ECUs:	4 ECUs:	8 ECUs:
Gearbox, coordinator	Engine, instrument cluster, tachograph, ...	Brake management, all-wheel-drive, air pressure system, ...	Suspension management, body work system, bus chassis system, ...	Climate control, crash safety, ...

Gigalink cable

I/O and processor boards	I/O and processor boards	I/O and processor boards	I/O and processor boards	I/O and processor boards

ASM Vehicle Dynamics (2 automatic and more than 3 manual transmissions)	ASM Engine Diesel and Selective Catalytic Reduction	ASM Vehicle Dynamics (Axles: 4x4, 4x2, 6x4, 6x2)		
Scania retarder and automated transmission add-on	Scania NOx model	Scania pneumatic brake model		Scania cabin climate model
		Scania air spring model		

Drivetrain	Vehicle dynamics	Body electronics

▲ *Schematic of the overall ECU network.*

Scania is presently using its integration lab to perform:

- CAN communication testing to verify that the correct CAN messages are sent, in the correct interval time, when all ECUs are connected to the CAN network.
- User function testing to gauge reliability.
- Robustness testing to determine how ECUs are affected by exceptional conditions (e.g., how the communication between ECUs is affected when system voltage is reduced or when the ground connection in one or several ECUs goes bad).
- Diagnostic testing to pinpoint ECUs sensor failures or defective electrical connections.

Benefits of the Integration Lab

The integration lab demonstrates that dSPACE Simulator technology is capable of handling huge vehicle networks far more complex than those of passenger cars. Script-based testing enhances reproducibility, which will be useful for further tests, and integrating our own simulation models offers great flexibility,

The ability to conduct regression testing on multiple ECUs across distributed functions with interchanging variants has greatly simplified Scania's process for developing and testing ECUs.

Mikael Adenmark
Scania CV AB, Södertälje
Sweden

Glossary

Regression tests –
Repetition of a test part or all test sequences to ensure that new modifications do not affect formerly tested components.

J1939 CAN buses –
Vehicle bus standard, used for communication and diagnostics between vehicle components.

Integration Lab –
Combination of real existing ECUs and a virtual truck model for testing the network and communication of the ECUs.