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dSPACE MAGAZINE

1/2014

Manitowoc – Kitchen under Control

Moog – Test Flights in the Lab

Continental – Drive Electric, Park Smart


MicroAutoBox
dSPACE

This issue brings you more wonderful examples of all the different fields our technologies are being used in. After all, dSPACE does so much more than just automotives. For example, our involvement in aerospace goes back a long way. You can learn more about that in the article from Moog, a dSPACE customer for almost 20 years.
It was quite some time ago that we reported on a complete avionics simulator for a business jet; the plane is now going into production. We have just shipped a hardware-in-the-loop simulator for a mission-critical subsystem in a military transporter that has to be certified before the airplane can be commissioned. And recently, we joined a research project that is being planned to improve aircraft system design. But those are all "expectable" applications.

Personally, I love it when there's something "exotic". In this issue, it's hardware-in-the-loop simulation for the food service industry. And why not. When the systems under test are complex, when real parts are not available soon enough for tests, when a high degree of test automation is required: what you need is hardware-in-the-loop. Models change, bus protocols can contain special features, but a signal – be it analog, digital or PWM – is hardly any different from signals in other application fields.

There is one area, however, that requires special technology and above all the right know-how: increasing electrification. Ever since our company was founded, we have been actively involved in electric drives and motion control, but today's requirements are particularly tough. This is why, over the years, we have repeatedly invested in both rapid control prototyping and simulation. And it has paid off. We have a constantly growing number of projects in this area. Valeo's application on page 22 is yet another example.
And medical engineering is always good for a surprise. We've had a pacemaker, cochlear implants, respiratory ventilators, adaptive blood pumps, and more. And now a skull-cutting tool. Well, it's all just signal processing, algorithms and mechatronics. Mechatronics is what we're all about, and after all, one of our first customers more than 20 years ago was Hilti, a world-famous manufacturer of heavy-duty concrete drills.

I wish you a very happy 2014, and hope that you will never need any of the above medical devices.

Dr. Herbert Hanselmann
President

Embedded Success dSPACE

IMPRINT

dSPACE MAGAZINE is published periodically by:

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Print: Media-Print Group GmbH, Paderborn

Contents

PEFC
PEFC/04-31-0810
PEFC certified
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Simulation à la carte

Model-based development boosts efficiency in the food service industry

You're sitting in your favorite restaurant and looking forward to your meal. Will it live up to your expectations? The answer depends on numerous factors, not least on the equipment that stores, prepares and dispenses your food. Manitowoc, a leading supplier of food service equipment, has decided to use model-based development and hardware-in-the-loop (HIL) testing to ensure the high quality of its products.

Tough Demands on Food Service Technology

Manufacturers of food service equipment face many challenges, some of the greatest being short development cycles, quick prototyping to show proof of concept to the customer, and aggressive delivery and reliability targets. Fast, consistent food preparation, perfected cooking processes and standardized, patented recipes require modern control software and sophisticated process control, including the precise execution of time-triggered events and states. For example, there are specific frying instructions for each

Typical application fields for Manitowoc products: cook, chill, prep/serve, ice.

Example of a touch panel for operating an oven from Merrychef, a Manitowoc brand.

kind of meat, defining the timing and temperatures for different phases of the frying process and also for hot holding if required.
As in any other sector, some of the most important requirements in the food service industry are precision, energy efficiency and fail-safe functioning.

High-Tech Product Portfolio

Manitowoc is a leading manufacturer and vendor of professional food service equipment. The company's product range includes primary cooking equipment, refrigeration & ice machines, serving equipment and beverage dispensers. Manitowoc works incessantly to enhance its high-tech product portfolio with the help of electronic controls and extensive control software. For the systems to succeed in the kitchen, handling them has to be easy and problem-free.

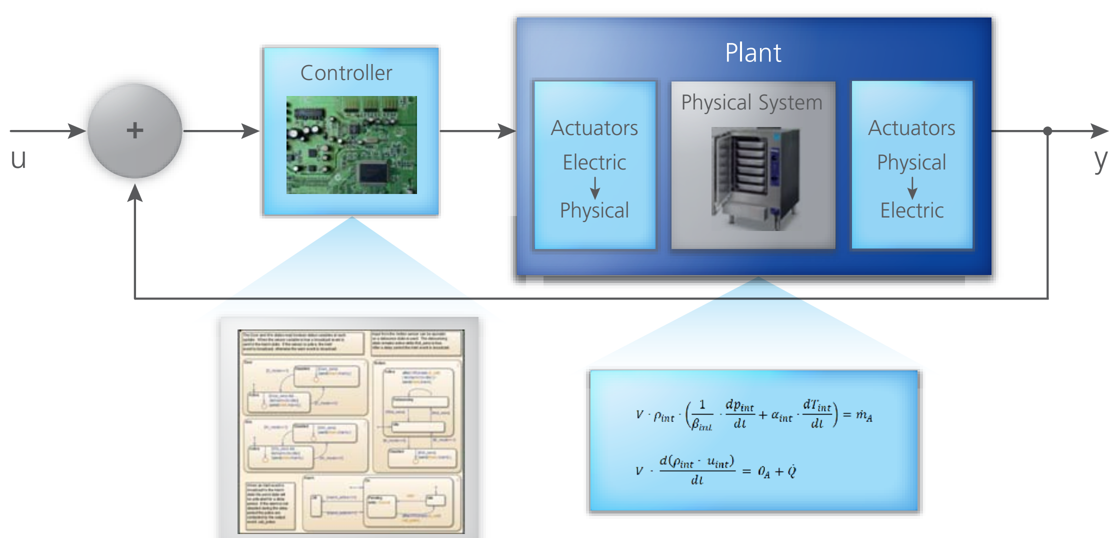
A Broad Range of Electrical Components

A variety of sensors and interfaces with touch panels, AC relays and coil drivers, motors and switches are just a few of the electrical devices in food service equipment. They all communicate more or less directly with sophisticated embedded electronic controls. The result is a complex electrical/electronic (E/E) system whose functionality has to be validated.

The Challenge of Software Quality

Food service equipment particularly requires software for the electronic control units and user inter-

The principle of hardware-in-the-loop (HIL) simulation: The equipment is represented by mathematical models. Actuators and sensors are also virtualized.



Beverage dispenser, Frymaster Cobra Fryer and Convotherm Oven-P4: These products are tested on the dSPACE Simulator.

faces that regulate their internal processes, for example, in heating elements and valves. And if there are any problems or errors in the user interface, there is a risk they will impact negatively on food preparation, giving restaurant guests an unpleasant culinary experience.
A high-quality user interface module is therefore essential. Maintaining consistently high software quality across such a wide product portfolio is a major challenge for Manitowoc. This is where development approaches used in other industries such as the automobile and commercial vehicle sector can help, as the food service sector is confronted with similar tasks.
Suitable methods and processes are crucial, together with a tool chain that ensures efficient software development.

Model-Based Development Methods

As food service equipment grows ever more complex, the manual methods used up to now no longer suffice to develop and validate its functionality. So Manitowoc took the bold step of becoming the first manufacturer in the food service equipment industry to adopt model-based testing. The aim is to redefine how products are developed in order to achieve a significant competitive advantage.
With this objective in mind, Manitowoc contacted dSPACE, who partnered us in introducing model-based development. The following requirements were defined:

- Develop generic models for Manitowoc's broad product portfolio
- Reuse the test system across all the strategic controller platforms
- Develop generic test cases and harmonize our tool chain across all of our operating companies
- Simulate the physical behavior of loads and test with the controllers which are still under development
- Develop stress test cases to simulate the failures found in field tests and validate the diagnostic codes

Why HIL Simulation?

When Manitowoc's engineers compared the company's requirements with dSPACE's products and services, it became clear that hardware-in-the-loop (HIL) systems from dSPACE can play a major role in fulfilling the quality standards. For the first time ever, HIL simulation enabled the developers to virtualize the real environment such as the heating elements. This means important electronics tests can be performed

"To switch to using model-based development, we needed a hardware test platform that supports future extensions. dSPACE's reconfigurable and extensible platforms were perfect for integrating all our requirements."

Pedro Zayas, Senior Engineer,
responsible for Hardware-in-the-Loop Tests and
Rapid Control Prototyping at Manitowoc Foodservice

"Testing food service equipment requires systems like the dSPACE Simulator with its enormous flexibility in handling different types of signals and communication protocols."

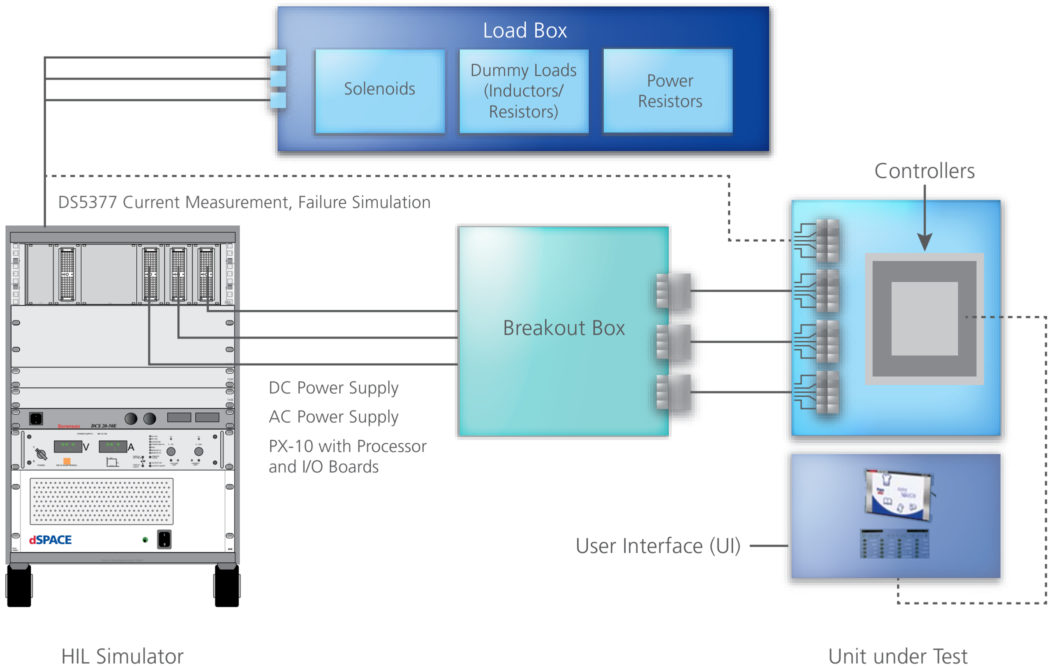
Jake Blake, System Engineer, responsible for Hardware-in-the-Loop Tests and Automation at Manitowoc Foodservice

much earlier in the software development process, even before the actual heating element is available to developers. It is anticipated that this will lead to a lower failure rate in everyday use, higher product reliability, and greater customer satisfaction. It was therefore decided to use a dSPACE Simulator. In terms of development methods, it provides the ideal conditions for a strictly model-based approach to all development issues. The system was first used in development projects for ovens, fryers and a drink dispenser.

Concept of the HIL Test System

Manitowoc needed a flexible HIL system for hardware tests which meets the I/O and load requirements of the entire product range – from ovens, grills, fryers, and smoothie machines to drink dispensers and refrigeration systems. The different I/O and interface boards in dSPACE's versatile product portfolio provided excellent solutions for the resulting mix of I/O and interface boards.
For Manitowoc it was important to continue using an internally developed test automation platform (TAP) as the central entity for auto-

Test bench concept: HIL simulator (left), break-out box (center) and the unit under test (UUT) with its user interface (right). The substitute loads for performance tests are housed externally in a load enclosure.



mated product testing. dSPACE offered a simulator API that provided a generic architecture for this, allowing developers to integrate the HIL simulator seamlessly into the TAP. Manitowoc's global company structure means that test developers all over the world work together, and now they can access the generic dSPACE test bench architecture to test different products. The entire test system is housed in a movable rack. The controllers under test are connected via a break-out box. Substitute loads are available for integrating power stages into the tests if required.

The Simulator Goes Live

The HIL simulator was put into operation in Manitowoc's development labs and completely integrated into the existing test automation platform. The system appeared very mature and has convenient handling options. The simulator definitely meets the requirements to run systematic tests, analyze targeted errors, and use regression testing to verify whether the errors were successfully remedied.
In the meantime, practical experience has been gained in three development projects and the approach can be compared with previous test methods.
The results exceeded expectations: Testing time was reduced by 80%, yet engineers achieved several times the test coverage – even though they are far from using the simulator's full potential.
Tools such as the Stimulus Editor and the Failure Insertion Unit (FIU) already brought numerous improvements.

How Testing Benefits

When creating and executing tests, testers have the following decisive advantages over the previous approach:

- Time savings: Test execution takes only a fraction of the time it needed previously, helping to meet the requirement for short product development cycles.
- Time-synchronous testing: Time-critical tests are easy to implement and monitor.
- Easy regression testing: Repeated test runs and software updates can be performed quickly and at lower cost.

These advantages put developers in the happy position of being able to perform more comprehensive and more targeted testing.
And because this can even be done in a fraction of the time, there is new potential for extending the scope of tests and expanding the test architecture and processes.

"With this ground-breaking technology, our reliability tests have the same quality standard as the automotive and aerospace industries. Model-based development is opening up a new era for the food service industry. It would not have been possible to introduce model-based design tools and short development cycles without a committed partner like dSPACE."

Vikram Verma, Manitowoc



From left to right: System Engineer Jake Blake uses dSPACE ControlDesk to configure the Convotherm HIL test bench.
Pedro Zayas and Vikram Verma check the signals on the Convotherm HIL test bench.
Monitoring the signals for oven control with ControlDesk.
Jake Blake, Pedro Zayas, Vikram Verma, Paul Touchette. (from left to right)

"The dSPACE tool chain enabled us to implement our strategic visions for electronic control systems by using model-based development and hardware-in-the-loop simulation."

Paul Touchette, Director of Engineering, Manitowoc Foodservices, Center of Advanced Electronic Control

Results and Conclusion

Consolidated results and experience from the three completed development projects performed with model-based development and HIL testing are now available. Moreover, the equipment has passed the acid test of real-world use in professional kitchens. The results can be summed up as follows:

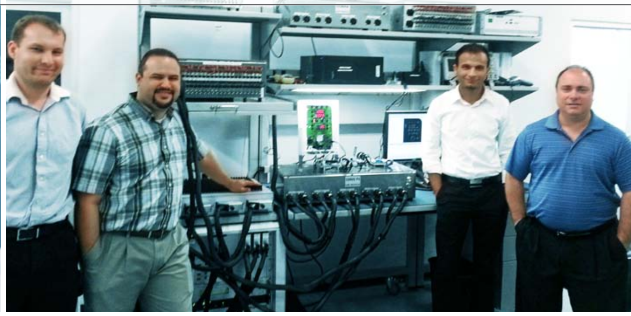
Greater competitive advantage and higher reliability:
By using the HIL system, Manitowoc was able to test the electronic control units much faster than we had been with any manual test, and even improved test coverage. This cut the time to market and further reduced the failure rate in the kitchen.

Cost savings:
Instead of writing product-specific tests, test teams now employ dSPACE hardware to create adaptive platforms that can be used across as many different Manitowoc products as possible.
The quick, efficient tests halved the cost of testing. The HIL systems also greatly reduce guarantee costs,

The Manitowoc Group

Manitowoc was founded in the lakeshore community of Manitowoc (Lake Michigan), Wisconsin, as a shipbuilding and ship-repair company. Since that time, the company has grown and diversified, entering the lattice-boom crane business in the mid-1920s and branching into commercial refrigeration equipment in the late 1940s.
Today, the company is comprised of two segments – cranes and food service equipment. Manitowoc is one of the world's largest manufacturers of commercial food service equipment, with a portfolio covering cooking, refrigerating, prepping, ice making, dispensing, holding, merchandising, and warewashing. Its products have been awarded numerous prizes for quality and energy efficiency. These are some of its brands:
Cleveland Range, Convotherm, Dean, Delfield, Frymaster, Garland Commercial Ranges, Lincoln Impingers, Merco, Merrychef, Moorwood Vulcan, Delfield, Harford, Kolpak, Kysor Panel Systems, Manitowoc Ice, Manitowoc Beverage Systems, McCall.

Manitowoc
BUILD SOMETHING REAL



because far fewer faults occur in daily use.

Pioneering role:
Manitowoc is playing a pioneering role in using HIL systems to develop food service equipment. The systems can be extended, and functions can be added by integrating the hardware components of other vendors. This opens up completely new possibilities.

Synergy effects:
At the lowest development level, automated regression testing can be used not only for food service equipment, but also in Manitowoc's other business field, the development of cranes. This is the perfect scenario for achieving synergies in Manitowoc's research and development processes. ■

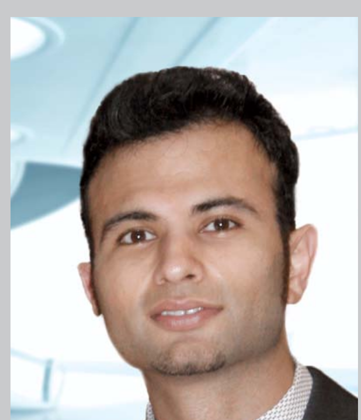
Vikram Verma, Manitowoc

Video:
Manitowoc products in action in Munich's famous Hofbräuhaus.
http://www.youtube.com/watch?v=4JtQvPhS9jQ&sns=em

Summary

Manufacturers of food service equipment are increasingly using embedded control electronics and multi-option graphical user interfaces, and developing extensive software for them. The US-based global company Manitowoc is using model-based development and hardware-in-the-loop (HIL) simulation to make development and testing more efficient. Manitowoc worked with dSPACE to create a completely model-based development approach to developing food service equipment. New processes and tool chains are boosting both efficiency and software quality. Testing has particularly benefited, from early testing (frontloading) and increased test depth providing significant improvements compared with the previous manual methods. Manitowoc is using the dSPACE Simulator to reduce time to market and improve the reliability of the food service equipment.

Vikram Verma
Vikram Verma is Engineering Manager and Lead Architect for HIL Testing, Rapid Control Prototyping and Model-Based Design at Manitowoc Foodservice, in New Port Richey, FL, USA.



Electronics Take Off

Real-time testing of modern actuation systems at Moog

Modern aviation actuation applications are trending towards electric actuation technologies as an alternative to hydraulic systems. These advances have introduced complex electronics and embedded software into an industry that has been historically mechanical in nature. This change is prompting developers of these systems to seek more effective testing strategies to ensure high reliability, performance and safety in operation. Real-time testing has played a key role in the development of complex, modern actuation systems.

Moog is using dSPACE real-time testing solutions in a wide range of applications, from control electronics for traditional hydraulic actuators to real-time simulators for qualifying safety-critical flight software in redundant electric actuation systems.

Moog has been a key supplier to the aerospace industry for the last 60 years and has grown from being a high-technology component manufacturer to a leading supplier of integrated flight control actuation systems. Moog's reliable flight control systems and specialized control products can be found across the aircraft marketplace throughout the world.

Moog Aircraft Group's offerings are wide-ranging, from integrated flight control systems, such as primary and secondary flight controls, high lift, and maneuvering leading edge systems, to critical control applications such as engine control, active vibration control, weapon bays, navigation and guidance. Moog supplies products as integrated system solutions and as individual components. Moog's development capabilities include critical control products such as flight control computers and software, cockpit controls, control electronics and power drives, actuators, sensors and related components. Supporting and keeping pace with an evolving wide range of products that are critical to aircraft operation requires a modern, advanced development environment that can support demanding design and testing needs.

Evolution of Aircraft Flight Control Actuation

Flight control actuation systems are critical to enabling the flight of modern high-performance aircraft. Right from the start of the first human flight, these systems have always received specific attention. Early aircraft included mechanically linked direct pilot control, where pilot control effort moved the control surfaces. Gradually, as aircraft evolved and control surface loads increased, hydraulic power was added to assist the pilot inputs. In these systems, hydraulics linked to pilot inputs augment the control of flight surfaces. Over time, systems evolved to full hydraulic actuation to move flight surfaces. These actuation systems position the control surfaces in response to mechanical inputs from the pilot controls.

A major leap from the mechanical-hydraulic systems was the introduction of fly-by-wire actuation systems. In these systems, pilot controls pro-

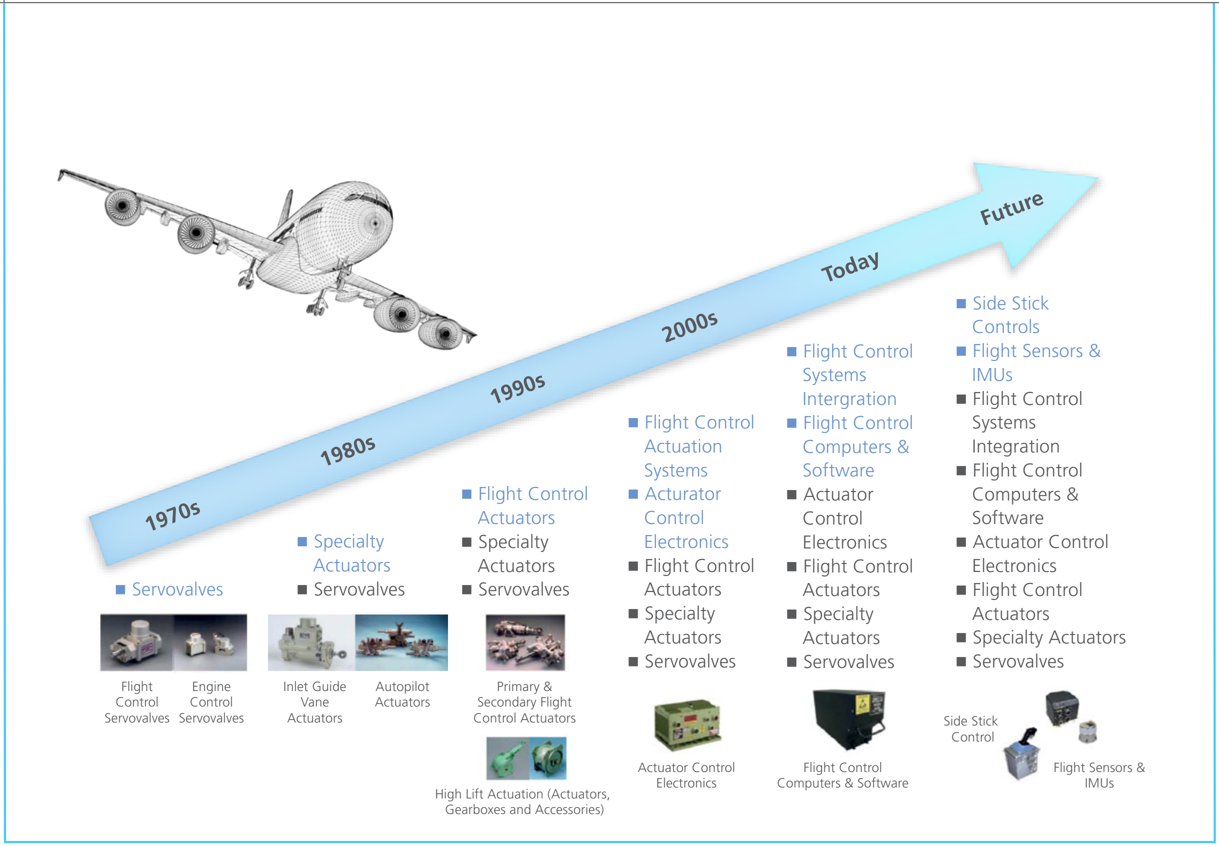


Figure 1: Moog evolution from component supplier to integrated systems supplier.

vide inputs not directly to the flight controls, but rather to the flight control computer, which then controls hydraulic actuators with electrical signals. This was a major transition, and this type of actuation can be found in many modern aircraft currently in operation.

Further progress with actuation systems is the transition to power-by-wire technology. Power-by-wire systems are controlled and powered electrically. Pilot controls provide inputs to the flight control computer, which controls the electrically powered actuator. The command signals to the actuation systems are sent directly as electrical signals or as communication messages over a communication bus such as ARINC 429, MIL-STD-1553, IEEE 1394b, etc. Actuator controllers position the actuator in response to the commands from the flight control computer.

In addition to the above product evolution, two critical changes at the technical and business level have also had a big impact on actuation systems. The first is the aerospace industry's move toward procurement of integrated actuation systems, including controllers and actuators, from a single supplier. This results in the transfer of integration responsibilities to the supplier. As a result, suppliers have had to transform themselves from component suppliers to major systems suppliers with high-level system engineering expertise.

> "Moog is using dSPACE systems in a wide range of applications, from control electronics for traditional hydraulic actuators to real-time simulators for qualifying safety-critical flight software."
>
> *David Cook, Moog*

The second is the move towards modular distributed systems, wherein the actuator controllers are mounted directly on the actuators. This move has resulted in more electronics and software content in products that have historically been all mechanical. These changes, in addition to advances in actuator technology, have resulted in products such as electromechanical actuators (EMAs), electrohydrostatic actuators (EHAs), electric backup hydraulic actuators (EBHAs), and hydraulic actuators with integral control electronics. The use of electric-powered actuators located in unpressurized aircraft bays has also required actuator suppliers to develop expertise in high-altitude, high-power electronic control systems. These trends have increased system and component complexity tremendously and imposed the need for sophisticated development processes and testing capabilities.

Development Process for Modern Actuation Systems

As described previously, the evolution from actuation devices to entire systems poses additional challenges to the development process. In particular, there are challenges in the areas of requirements management, systems analysis and design, system integration, and system verification and validation. A summary of some of the challenges associated with actuation system development are described below.

As system complexity increases, good requirements management and traceability become even more important. In this process, it is important to break down the high-level requirements into specifics for particular components and to allocate requirements to development teams appropriately. Proper requirement allocation and flowdown are essential to ensure that the system components provide all the necessary functionality to meet the requirements of the integrated system.

Requirement traceability is also a key tool in ensuring that all system and component requirements are properly verified.

System complexity also makes system-level analysis and design more challenging. Effective system design is required to ensure that the components of the system operate in a safe manner. This often requires system monitors to detect faults, built-in tests (BITs) to determine system health, and logic to manage the operation of redundant system elements. In the design and analysis process, discipline must be maintained to ensure the focus remains on optimizing the system versus optimizing the various system components.

As system complexity increases, additional effort is required to ensure that the components function properly when integrated at the system level. System-level integration involves defining and testing how the system components will be integrated into the overall actuation system and how the actuation system will integrate with various other aircraft systems. The hardware and software components must interact to perform the necessary system functions while ensuring system safety. System integration involves managing system interactions throughout the design process and culminates with integrating the actual system in a lab environment. Although system integration is required to get the system to an operational state, test activities must also be performed to ensure that the system does not have any unwanted or unsafe behavior.

When system problems are found, they must be analyzed, tracked, and resolved to ensure that the system operates in a safe manner and that system requirements can be satisfied.

Once a system is assembled and integrated, verification activities must be performed to ensure that the system meets its specified requirements. For some projects, certification activities are required to support FAA or EASA type certification of the aircraft. Certification typically involves adherence to DO-178 for software and DO-254 for complex electronic hardware. All aircraft actuation system projects require extensive testing to verify system performance and safety in the intended operational environment.

As system complexity increases, the required testing also becomes more complex. Component-centered testing is not sufficient for verifying system requirements. Complex lab facilities are necessary to provide system stimulus and to measure system responses in order to verify the system behavior. The entire verification and certification process requires rigorous documentation to ensure that the right system is tested in the right way, and to the right requirements.

Actuators with remote electronics

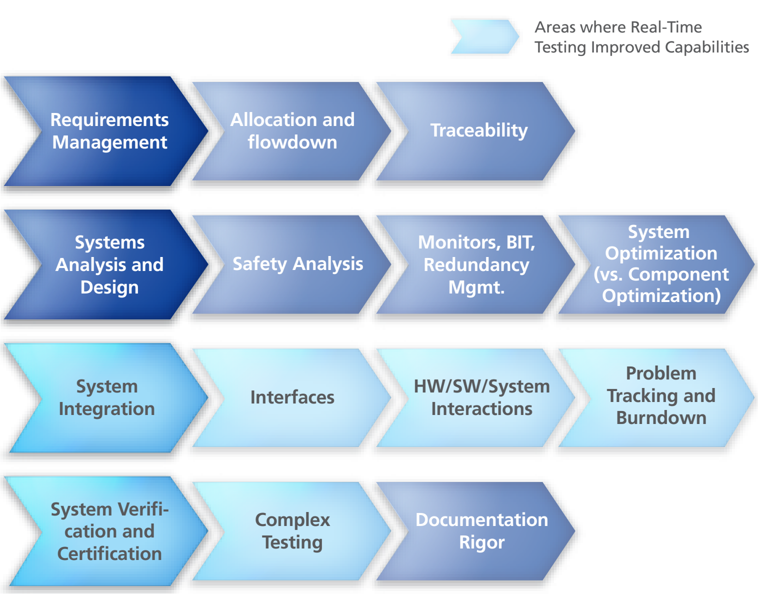
Rotary primary EMA

Linear primary EMAs

EHAs and EBHAs

Figure 3: Aircraft actuation systems.

Figure 2: Process challenges in actuation system development.



> "Moog has utilized dSPACE real-time test systems since 1991 for developments for commercial aircraft, business jets, unmanned aerial vehicles, and more."
>
> *David Cook, Moog*

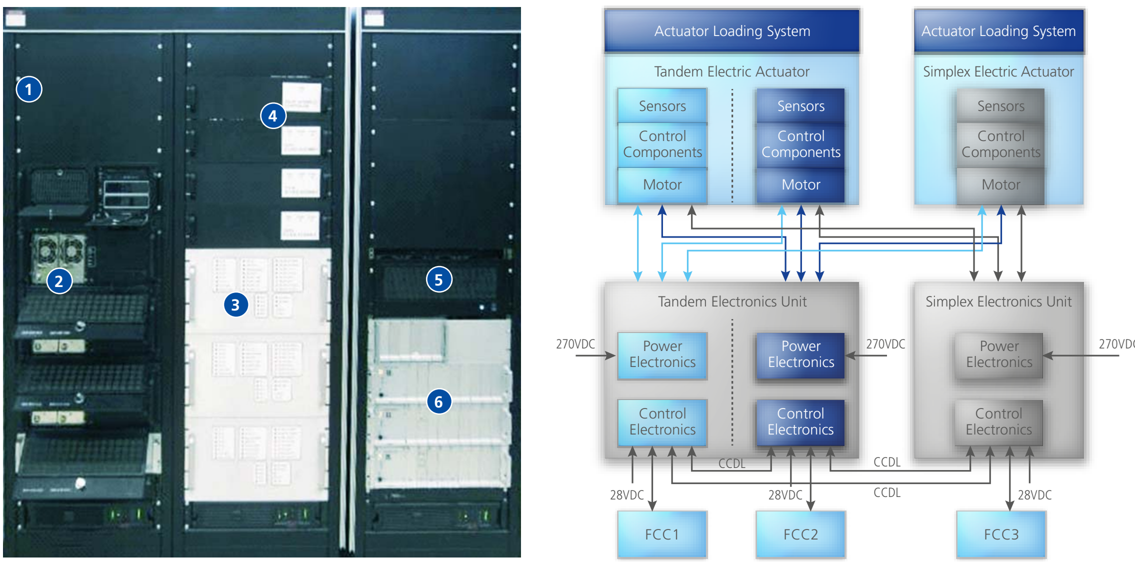
Role of Real-Time Testing / Benefits

Of the mentioned challenge areas, system integration and system verification have the potential to benefit from the use of automated real-time test systems. Because of this, Moog uses these systems in a variety of roles throughout the development process. Some examples of applications with real-time systems are shown in the table below. Model-based real-time simulation systems have helped increase the flexibility of Moog's test systems. Moog utilizes real-time test systems to emulate controllers when testing actuators, to emulate actuators when testing control software, and to test integrated systems by emulating the system inputs and measuring the system responses. Additionally, the automated testing capabilities enable complex test sequences to be executed in a repeatable and deterministic fashion. This makes it possible to quickly run regression tests for system modifications and variants. The automation and deterministic real-time systems also enable the creation of difficult test conditions in lab environments. In particular, this allows more complete and thorough failure mode and effects testing (FMET). For example, the simulation of actuator failure conditions allow the testing of actuator-related fault detection algorithms without costly test hardware. These features improve the overall testing capability and result in significant cost savings. Moog has utilized the benefits of the real-time test systems offered by dSPACE since 1991. First applications of the dSPACE test systems were for actuator products for a large commercial aircraft. Since then, Moog has utilized dSPACE real-time systems on a variety of projects and in a variety of roles. Moog currently has 20-30 test systems that are still being used for new applications. dSPACE real-time test systems have been used for aircraft programs, including V-22, F-117, B-2, X-35, F-35, A400M, KC-46, 787, A350 and various other UAV, biz jet, and commercial aircraft programs.

Testing Role	Application	Example
Actuator Controller Emulation	■ Actuator acceptance testing ■ Actuator qualification testing	■ Emulation of FCC actuator control laws for actuator acceptance and qualification testing.
Test System Control	■ Various forms of testing	■ Control of dynamic loading system for actuator or system testing
Controller Prototyping	■ Component development testing ■ Actuator development testing	■ Providing control loops for valve testing. ■ Control prototyping for actuator R&D.
Actuator Simulation	■ Component development testing ■ Software and system integration and verification testing	■ Actuator simulation for component level testing (EHA pumps) ■ Simulation of mechanical and electrical elements for system or software testing
External System Simulation	■ System and software integration and verification testing	■ Simulation of flight control computer for integration and verification testing

Figure 4: Real-time testing role and benefits.

Figure 5: Aircraft with Moog actuation systems tested with dSPACE.



1. Bays for Control Electronics
2. Computers with Real-Time Hardware
3. Break-out Boxes (Pull-Out Bays)
4. Failure Insertion Units
5. Real-Time Computer for Control of Test Lab
6. I/O Signal Conditioning

Figure 6: Left: System software workstation for electric actuation system.
Right: Use of the workstation for testing a triple redundant, electric-powered actuation system.

Application Examples:

The following are three examples of applications where Moog has employed dSPACE-based real-time test systems in the development of complex actuation systems.

1. System Software Workstation for Electric Actuation System

The first test system (figure 6) is used for testing a triple redundant, electric-powered actuation system. The test system provides testing capabilities for software verification, as well as for testing the integrated system. It serves as a hardware-in-the-loop platform for software testing, and provides measurement, control, and data acquisition for integrated system testing. For software testing, the system provides real-time simulation of power electronics and actuators of the triplex system.

The test system contains seven DS1005 processor boards in a multiprocessor configuration installed across five rack-mounted chassis. The hardware also includes three IEEE 1394 buses with fault injection capability, and three proprietary CCDL buses. High-performance motor models are executed at a rate that exceeds 30 kHz to provide real-time feedback to the motor control software. There are just over 780 I/O channels in this system.

The simulator functionality is used for software testing and for system testing with difficult-to-implement faults. Automation allows running these tests in batch mode, unattended or with remote monitoring. By simulating the plant, it is possible to conduct software testing in a representative closed-loop environment. The high fidelity simulation in this test station also reduces the time required in the system lab for problem resolution. Utilizing an automated software test environment has reduced software verification time from two weeks to two days per system configuration.

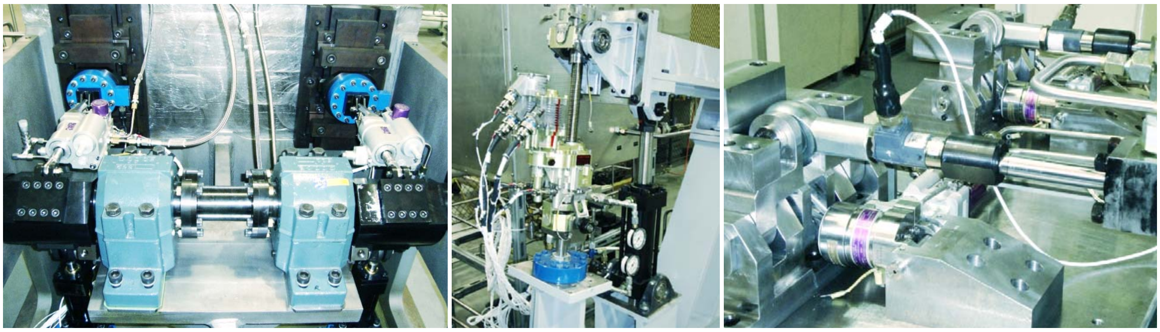


Figure 7: Actuator test rigs for testing commercial flight control systems (left: rudder actuator test rig; middle: HSTA test rig; right: spoiler actuator test rig).

2. System Software Workstation for Commercial Flight Control System

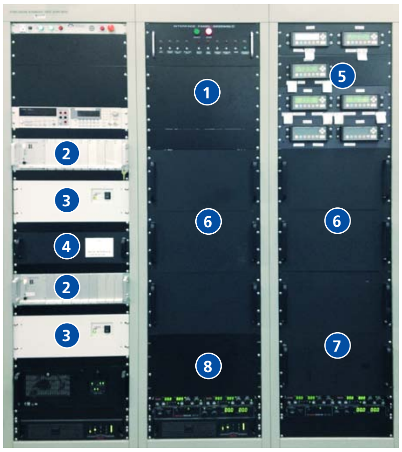
The second example (figures 7-9) is a test system for a flight control system used on a commercial aircraft. Similar to the previous application, this test system also provides a single platform for testing the integrated system and for software verification. It provides capabilities to test with real components, simulate individual components, or simulate the entire system. This system also includes the ability to use real pilot controls or to simulate control inputs for repeatable testing. The test lab includes a variety of actuation hardware and associated actuator test rigs. Various actuator rigs are connected to the test system. The test system provides control and monitoring of actuator test rigs. Examples of the test hardware and test rigs are shown below.

The flight control system in this application also includes controls for the high-lift surfaces on the aircraft. The high-lift test rig, as shown below, includes hardware for one wing. The other wing is simulated with a load motor and real-time control. By doing this, it is possible to reduce the required lab space for test equipment. This setup allows complex failure scenarios to be tested that are difficult to achieve with real hardware.

This system is comprised of two PX20 chassis, with seven DS1005 processors in multiprocessor configuration, 16 Tx/Rx channels of ARINC 429, relays to switch between simulated or real hardware, and almost 400 I/O channels.

The system provides fault injection capability and the ability to use various test rigs in the test environment individually or as a system. Automated testing allows for formal verification of software and system requirements. This representative closed-loop environment provides an effective development and certification platform for the integrated system and the embedded software.

Figure 8: Left: Pilot control station with representative controls and related flight control hardware.
Right: High lift test rig for commercial flight control systems.



1 Motor Control for High Lift Sim
2 Simulator I/O Conditioning
3 dSPACE PX20 Expansion Boxes
4 Relay Controller
5 Load Control for Test Rigs
6 FIU/Switch Relays
7 Simulator Loads
8 ARINC Interconnect

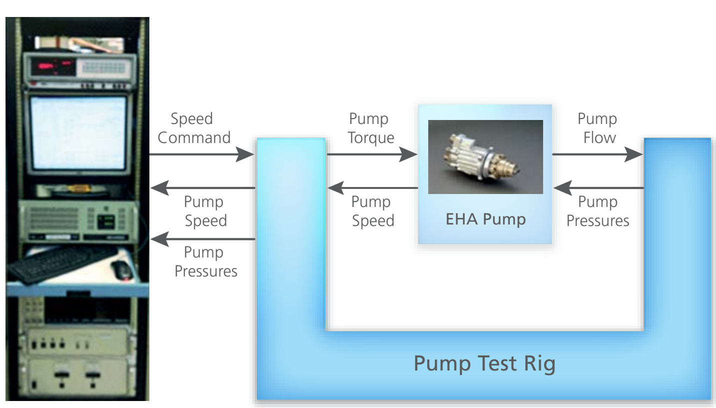
Figure 9: Test system hardware for commercial flight control systems.

3. Virtual Electro-Hydraulic Actuator (EHA) for Pump Testing

This system (figure 10) provided a unique test capability for use in the development of pumps for flight control EHAs. Intermittent duty, reversing motion and loads, and high accelerations are some of the unique demands that flight control EHAs impose on hydraulic pumps. Derivation of pump duty cycles from actuator level duty cycles can have significant uncertainty. Therefore, for risk mitigation testing of a new EHA pump, a virtual EHA was modeled and realized in a test system for pump life testing. The system provided a test environment that was representative of what the pump would see during operation in the actuator. Use of a real-time test system with virtual EHA removed many of the uncertainties associated with pump characteristics over life and provided accurate and meaningful test results. ■

David Cook,
Moog Aircraft Group

Figure 10: Test environment for electrohydrostatic pumps.



Summary

Modern actuation system complexity has increased tremendously with the integration of electronics and software with actuation devices. The move to electric-powered actuators has made motor control technology essential to the development of modern actuation systems. These advances pose additional challenges to those developing modern flight control actuation systems. Real-time test systems, based on dSPACE technology, have provided unique test capabilities that have enabled Moog to meet the demanding test requirements associated with the development of modern complex actuation and flight control systems.

David Cook
David Cook is System Engineering Manager at Moog Inc. in East Aurora, New York, USA.

Highly Dynamic Testing

Real-time modeling of a permanent magnet electrical machine for ECU functional validation applications

As part of a hybrid vehicle project, VALEO's Functional Validation Laboratory in Créteil, France, developed a HIL bench to emulate a permanent magnet electrical machine. Given the very fast dynamics of the system, and the need to work on refined electrical models, VALEO decided to use a new FPGA-based modeling technology.

Hybrid Technology at VALEO

VALEO Power Electrical System is a section of the PowerTrain Systems Business Group of Valeo. It has been very successful in providing innovative hybrid technologies which have been adopted by OEMs. When developing hybrid and mild hybrid products, VALEO faces the major challenge of designing, developing, and validating the control software for the machines they manufacture.

Designing and Evaluating Control Software

The software is implemented on electronic control units (ECUs), which need to be tested after the programming phase. The control strategies and the related software are tested in several steps. Depending on the stage in the development cycle, HIL (hardware-in-the-loop) tests are performed either by the ECU connected to the model of the permanent magnet electrical machine (PMEM) or by the ECU connected to the real PMEM. The advantage of using simulation is that control algorithms can be evaluated in any states or scenarios, including ones that are very difficult to replicate in the real world (destructive tests, tests outside the working range, robustness analyses, etc.), not to mention the cost saved by avoiding real-world tests.

Functional Validation of Hybrid Drives

For many years now, VALEO Power Electrical System, including ourselves in the Functional Validation group, have used HIL benches to evaluate or validate products with regard to the production code on the ECUs.

Figure 1: One of the electric motors that were simulated with the XSG Electric Component Library.

> "The openness and flexibility of the dSPACE E-drives solutions were ideal for the punctual completion of our mild hybrid project."
>
> *Stéphane Fourmy, VALEO Power Electrical System*

With the growing trend towards more hybrid technology in vehicles, we are running an increasing number of new projects. These involve machines with more and more power, and requiring even more complex control algorithms and strategies that need to be developed and validated. To meet market requirements, not only does the complexity of the systems increase; time-to-production also remains inflexible or is even shortened, necessitating constant improvements in development processes. The challenge faced by our Functional Validation Laboratory in VALEO Power Electrical System is to give R&D teams a validation and evaluation solution whatever the complexity of the new technology.

Mild Hybrid Development Project

The control strategies on a new PMEM needed to be developed and validated for a project in the mild hybrid range. VALEO also had the responsibility of providing the production code for the ECU controlling the electrical machine, the inverter and the resolver. Because of the power involved, the new type of machine, and changes to the sensors used, the project involved substantial modeling efforts. To test the code on the ECU, VALEO used hardware-in-the-loop simulation as usual.

FPGA for Quick Response Times

The fast dynamics of the system required a change in real-time HIL technology. A survey of available solutions showed that field-programmable gate arrays (FPGAs) would provide very fast response times. It also revealed that major progress had been made on facilitating FPGA programming for modeling and simulation purposes. Solutions enabling fast and easy programming were considered the key to success. We then compared avail-

Figure 2: Configuration of a hybrid demo vehicle of VALEO.

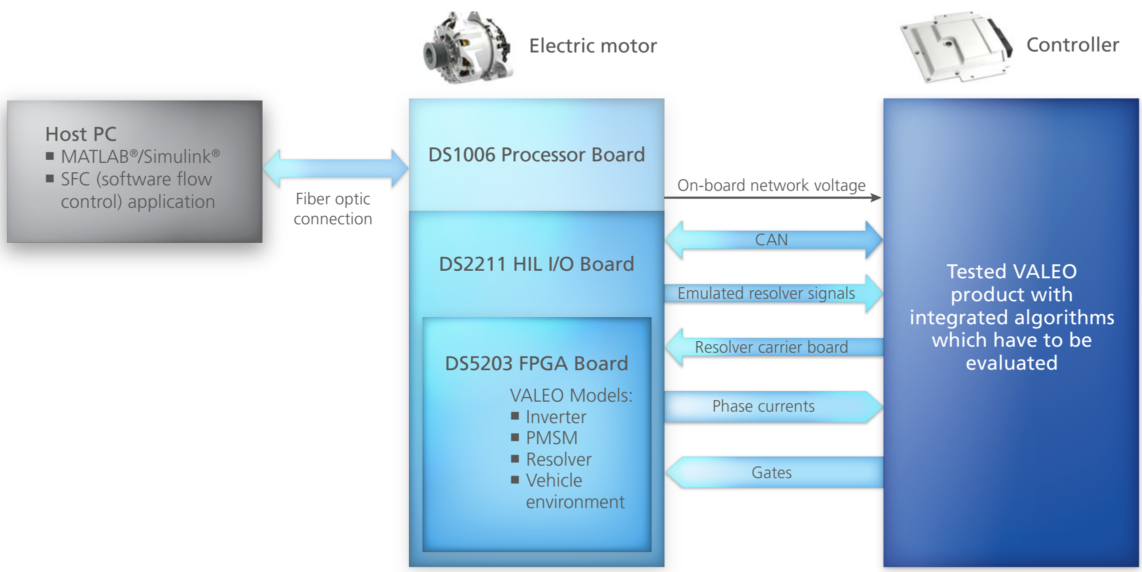


Figure 3: Structure and signals of the HIL system for emulating permanent magnetic electric machines.

able product offers. Our criteria were based on technical performance, as well as cost and development time for the bench.

HIL System for E-Drives

Because VALEO had been familiar with dSPACE tools for several years, and development time was tight, the optimal solution was a DS5203 FPGA Board from dSPACE. The overall HIL test bench includes a DS1006 Processor Board, a DS2211 HIL I/O Board, and a DS5203 installed in a PX10 Expansion Box. An external break-out box (BoB) is used to connect to the ECU in order to test its production software.

The Model of the Electrical Machine

The model of the electrical system was developed with the XSG Electric Component Library from the dSPACE Automotive Simulation Models (ASM) product family. This library builds on the XSG programming block diagram library from Xilinx® and allows Xilinx FPGAs to be programmed graphically from Simulink®. In a first step, our developers familiarized themselves with the ASM XSG Electric Component Library and one of its models – a permanent magnet synchronous machine. After hands-on training with the new ASM XSG electric component models and the FPGA board at dSPACE in Paderborn, the Functional Validation Laboratory tailored a model to VALEO's needs. Because the ASM XSG electric models are available as open XSG blocks under Simulink, it was easy to modify them with regard to current requirements or to add new blocks (for example, by varying parameters as functions of temperature and current, and introducing harmonics or deteriorations). This flexibility enabled us to adapt the model and the bench to actual project needs. The same flexibility will enable us to meet the new mechatronics validation requirements of upcoming hybrid projects for either VALEO or OEMs.

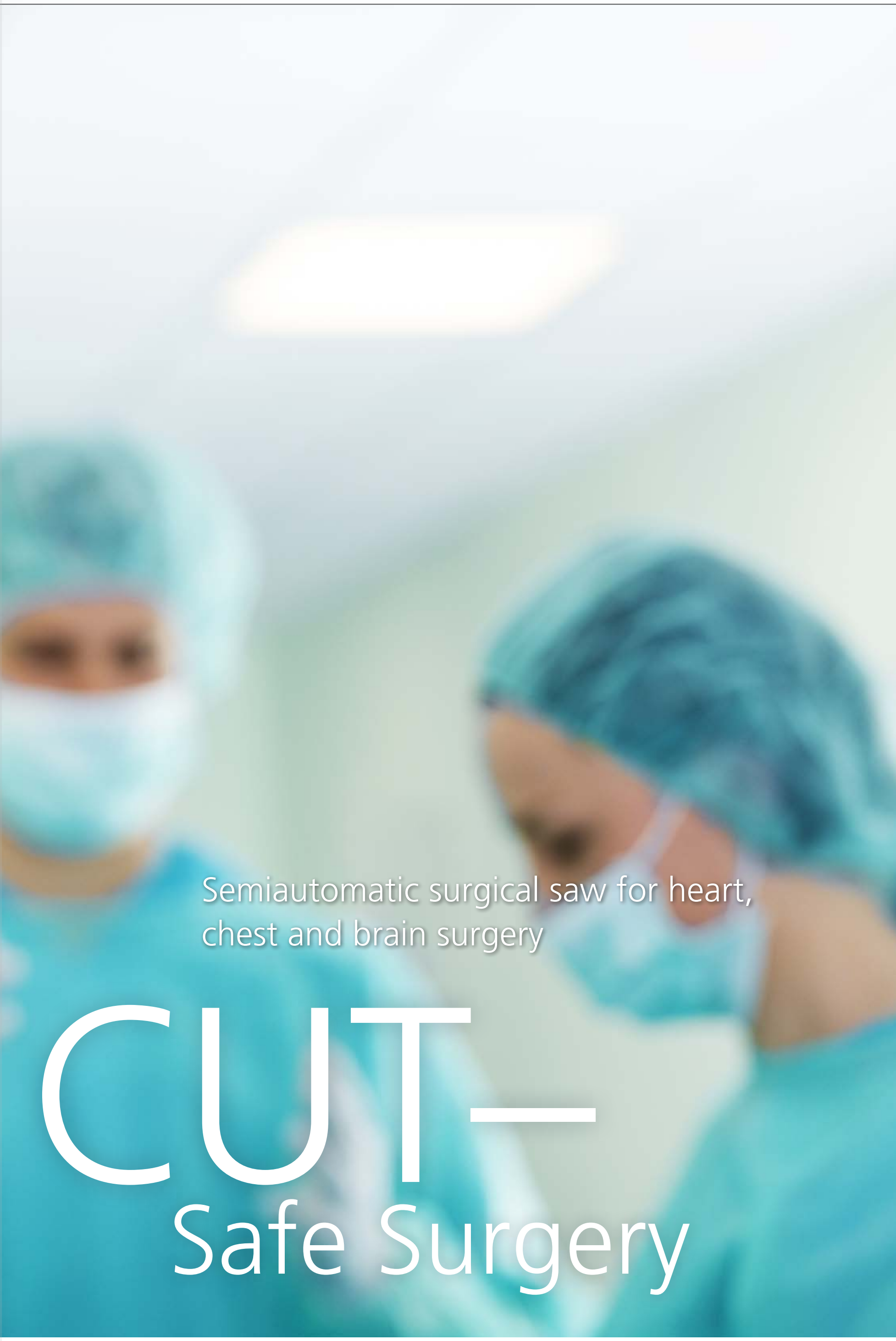
Use Scenarios for the E-Drives Test Bench

The first hybrid project with the new bench was successfully completed. The bench is already booked for a further project. Our group is currently preparing to reconfigure and adapt it to the new electrical system. We will benefit from the experience already acquired to develop a more complex model of a synchronous machine, such as a mixed-excited, double-star coupled electric machine. Thanks to the modularity of MATLAB, Simulink and the dSPACE tools, the team responsible for test bench adaptation can easily test the blocks and get results fast. That is the strength of such products. ■

Stéphane Fourmy,
VALEO Power Electrical System

Stéphane Fourmy
Stéphane Fourmy is Head of the Functional Validation Laboratory at VALEO Power Electrical System, Créteil, France.

Currently under development is a semiautomatic, handheld surgical saw for cutting bone tissue safely in neuro- and cardio-thoracic surgery. The surgeon and the "intelligent instrument" work together synergetically. While the surgeon guides the instrument on the bone surface and performs high-level process control, the incision depth is adjusted completely automatically with the help of computer tomography (CT), ultrasound, or optical sensors, and dSPACE real-time hardware.



Semiautomatic surgical saw for heart, chest and brain surgery

CUT – Safe Surgery

Figure 1: The new, semiautomatic smartCUT surgical saw (left: the symmetric rotation instrument for skull incisions, right: the thoracic surgery instrument, which is optimized for linear cuts).

Avoiding Trauma to Soft Tissue

Even today and under optimum conditions, many surgical interventions pose major challenges, e.g., in cases of vital soft tissues directly adhering to the bone structures which are to be cut during brain and cardio-thoracic surgery. Solely close collaboration between well-experienced surgeons allows such interventions to be performed safely and with the best possible result for the patient. Nonetheless, both applications still involve a comparatively high risk of complications. Thus, any improvement to the surgical instruments could help to greatly enhance patient safety. This is why the smartCUT semiautomatic saw is being developed at the Chair of Medical Engineering at RWTH Aachen University, with the aim of avoiding trauma to soft tissue structures during resternotomies and craniotomies. The new instrument relies on synergetic interaction with the surgeon. Haptic and visual feedback enable him or her to monitor the procedure directly. The precision and reliability of a machine combined with the high cognitive skills of a human being – such as the ability to respond to unexpected events – produce an ideal synergetic interaction.

Smart Control of Incision Depth

For optimal soft tissue preservation, the instrument's smart incision depth control combines sensor-based control with a sawing method that is specially adapted to avoid damaging soft tissue. Soft tissue protection is provided by the saw blade's circular oscillations. Unlike the rigid bone structure, the soft tissue is able to oscillate with the blade, and thus prevents trauma to a certain extent. Such a technique is necessary in order to be able to cut through the bone and to compensate for the tiny errors in determining incision depth that result from capturing spatial positions and other sensor data, and from medical imaging. Three different variants were developed and tested for the sensor-based incision depth control:

> "Thanks to the flexibility of the dSPACE real-time system, the system was quick to adapt to different sensor and imaging modalities. With relatively little effort, it can also be transferred to systems with different kinematics and degrees of freedom."

Alexander Korff, RWTH Aachen

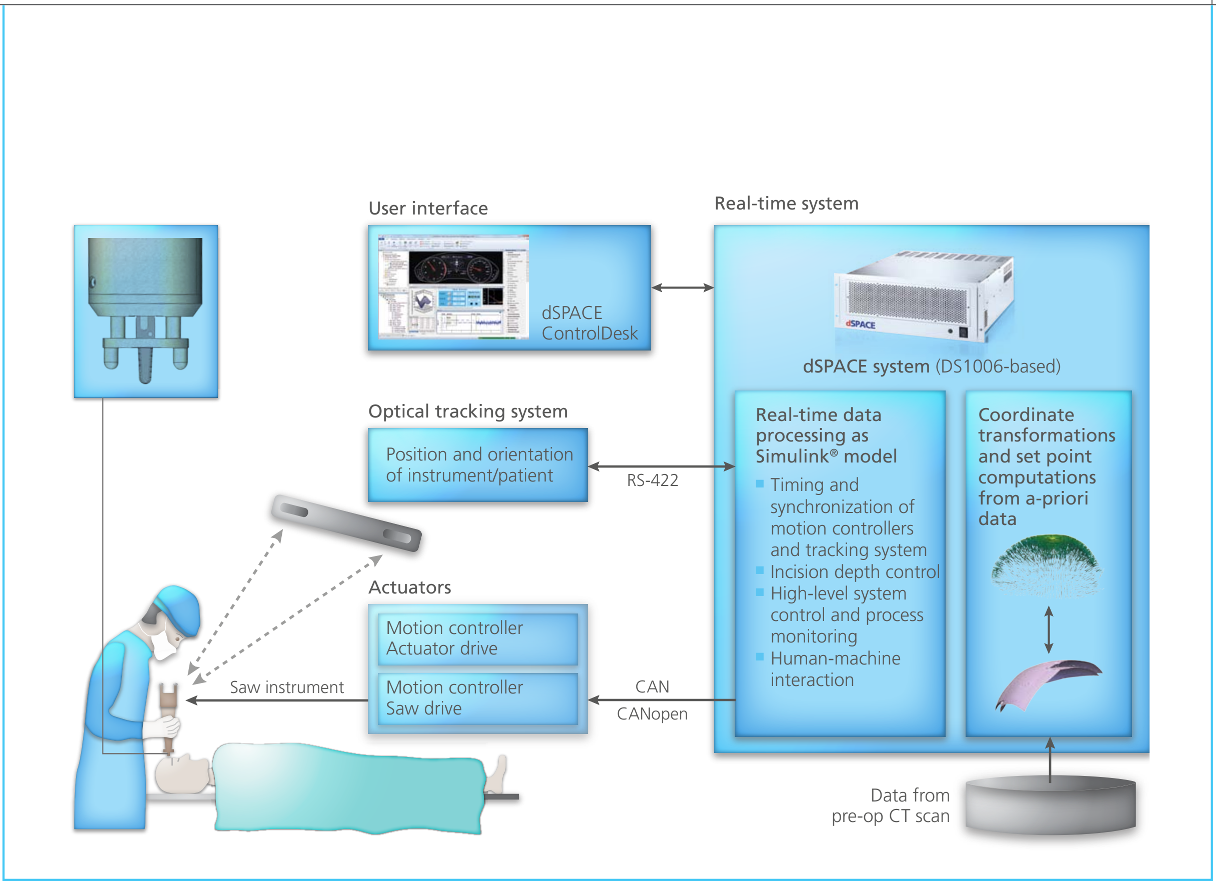


Figure 2: Using computer tomography (CT) data to open the skull with smartCUT.

- *CT-based:* Three-dimensional multi-layered images from a preoperative computer tomography (CT) scan are processed and then used with a dSPACE real-time system and an optical tracking system (that determines the instrument's position relative to the patient) to perform real-time incision depth control. The essential process steps, such as optical instrument tracking combined with CT imaging, are routinely used in neurosurgery nowadays.
- *Ultrasound:* While the CT-based method requires data to be collected before the intervention, with ultrasound, data is captured via an ultrasound probe during the operation. The method has been optimized for the linear sectioning of bone required for resternotomies. As with the CT-based method, a dSPACE real-time system is used for incision depth control, but in contrast to the CT approach, position data capture is implemented with a linear encoder.
- *Optical sensor:* An optical fiber is integrated into the saw blade and combined with a color sensor to determine whether the tip of the saw is in contact with bone or with soft tissue. Unlike the other two methods, this one can continuously and directly identify the position of the saw blade tip relative to the dividing surface between bone and soft tissue. The dSPACE real-time system ensures the precise distinction between bone and soft tissue and enables control of the incision depth.

smartCUT places great emphasis on human-machine synergy. The surgeon has control of the overall process and can freely select the medically most appropriate incision path, and also draw on his or her experience to specify individual parameters such as the cutting speed. The technical system performs the parts of

smartCUT in Brief

smartCUT is a semiautomatic surgical saw for cardio-thoracic and cranial surgery.

- Safe sectioning of bone structures (skull, thorax) while avoiding trauma to adjacent soft tissue
- Soft tissue partly protected by special saw kinematics (micro oscillations)
- Intelligent, sensor-based incision depth control: CT, ultrasound and optical
- dSPACE real-time system for sensor data capture and evaluation, safety, implementing human-machine interaction and controlling the overall system

Interview

The Neurosurgical Clinic at the University Clinic of the Ruhr-Universität Bochum carried out practical tests with smartCUT in a pilot project. The surgeon, Prof. Dr. Kirsten Schmieder, describes her impressions.

Prof. Dr. Schmieder, when you work on an artificial skull, how does a semiautomatic surgical saw handle as compared with conventional methods?
We're in a good position to compare, because we also used the conventional method on an artificial skull. Our experience shows that the prototype currently available is very usable as regards handling.

What advantages does the instrument have for the surgeon?
There are two advantages in using the smartCUT instrument. The first: We believe that accidental opening of the dura will occur less often during trepanation. The second: It produces a narrower cut, which reduces the risk of inadequate bone formation and closure after the skull flap is reattached. This affects the overall cosmetic result, an aspect that is quite rightfully receiving increasing attention.

How do you assess its potential for use on real patients?
It is our belief that the final product will have a good chance of replacing, or at least supplementing, the established technology. So we would be very happy to help bring the current prototype up to market maturity.

Thank you for talking to us!

Prof. Dr. Kirsten Schmieder, Director of the Neurosurgical Clinic at the University Clinic of the Ruhr-Universität Bochum, Germany.

the sawing process that cannot adequately be controlled manually, such as safely controlling and monitoring the incision depth. This makes tough demands on the real-time system and the control algorithms, especially with regard to the data that has to be available and processed online (such as parts of the CT data).

Model-Based Development of smartCUT

The real-time system used by smartCUT is a dSPACE system installed in an Expansion Box and equipped with a quad-core DS1006 Processor Board and various I/O boards (DS3001, DS4003, DS4201-S, DS4302). The software is the ControlDesk® experiment software and Real-Time Interface (RTI), plus the RTI CAN MultiMessage Blockset and the CANopen Master Solution for the CAN bus connection to the hardware. The real-time system is responsible for overall control, which includes incision depth control, data capture and processing, and implementing human-machine interaction. Model-based development with dSPACE tools proved to be an advantage in several ways:

- It provides an integrated data processing workflow. First image and signal processing (data preprocessing) is used in MATLAB®/Simulink®, after which the control of the system is created in Simulink and tested offline. The dSPACE RTI blocks are integrated, the preprocessed data is then integrated directly into the model, and tests are performed with the dSPACE real-time system. ControlDesk and MATLAB/Simulink are used for capturing and evaluating the measurement data.

- Even with large data volumes (from CT and ultrasound scans), the image and signal processing functionality is easy to integrate into the model for use with the dSPACE real-time hardware.
- The solution is available as a transparent, overall model with a uniform tool environment which can easily be operated and evolved to a higher level by students and staff at RWTH Aachen University.
- With this model-based approach and the modular dSPACE system, the modules developed for smartCUT are easy to adapt to other mechatronic systems used in surgery and medicine.

Results of the Pilot Project

This first practical experience with the instrument clearly demonstrated the different characteristics and advantages of the three methods.

- *CT-based:*
  In practice, the separation between measuring the structure (by the pre-op CT scan) and actually making the incision leads to a long chain of errors. The limited precision of optical tracking and the complexity of the overall system are particularly challenging. However, the errors that occur can be offset by the intrinsic soft tissue protection (circular oscillation of the saw blade). This method might especially be used in neurosurgery, where the necessary systems (such as optical tracking) and methods (such as registering the image data with the patient coordinate system) are already established procedures in neuronavigation.
- *Ultrasound:*
  This method is especially suitable for cardio-thoracic surgery, because unlike the CT-based method, it requires neither optical tracking nor CT data. Interoperative data acquisition using an ultrasound probe means that a simple linear encoder can be used to directly relate the spatial positions and measurement data to one another.
- *Optical sensor:*
  This method proved its suitability for both medical applications. Because measurement data is captured during the incision, no additional imaging is required during or before the operation. This approach is therefore very similar to the standard workflow for the two interventions. ■

By kind permission of the Chair of Medical Engineering, RWTH Aachen University

Conclusion and Outlook

Comprehensive laboratory tests were performed on artificial bone to demonstrate the feasibility of the smartCUT instruments with the three different methods. In the near future, research will focus on further optimizing the control strategy, and on better integration of the sensors into the saw blade. The dSPACE real-time system will surely continue to play a decisive part in development and control optimization.

This work was partly funded by the Federal Ministry of Education and Research (01EZ0841 - STS), the Ministry of Economics, Research and Technology of the State of North-Rhine Westphalia, and the European Regional Development Fund (280155601 - smartCUT).

Alexander Korff
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Dr. Klaus Radermacher
Univ. Prof. Dr.-Ing. Klaus Radermacher is head of the Chair of Medical Engineering at RWTH Aachen University, Germany.

A city car for soft, CO_2-less mobility. Left: Integration of a joystick into the center console (draft prototype, under construction). Right: Installation of the MicroAutoBox in the trunk, with a 12V supply inverter.

Electric Parking

Non-intrusive, fast integration of an x-by-wire control system

A semi-automatic x-by-wire park assistance system has been designed by Continental Automotive France and integrated in the TH!NK City electrical demo car as part of the European-funded project POLLUX. With the help of the rapid control prototyping system MicroAutoBox, the steering controls were implemented quickly and reliably.

X-by-Wire Park Assistance for Electric City Cars

The park assistance concept is based on a handy joystick-driven actuator that simultaneously controls the steering, gears and traction engine during parking maneuvers semi-automatically. Successive front and rear turns are automatically programmed so that the driver does not need to actuate the pedal, gear selector and steering wheel several times during parking maneuvers. The XY position of the joystick defines a 'vector' control to program and adjust the steering directions, speeds and amplitudes of the vehicle movements with high accuracy during parking maneuvers. This is facilitated by the fast, secure and accurate controllability of the electric motor and transmission found in such electric vehicles.

Quick Function Implementation

In order to avoid intrusive modifications on the car's existing powertrain control unit (PCU), a MicroAutoBox® (first generation) was used to implement this new functionality. The comprehensive set of available I/O allows the multiple connections required by the system to connect logic, analog and CAN data signals with the pedal, gear selector, additional torque actuator on the steering wheel, PCU controller, dashboard and joystick actuator. Function design is performed with the MATLAB®/Simulink®/Stateflow® tool chain, which provides appreciable flexibility for tests and validation and a close connection with the controller in the dSPACE MicroAutoBox.

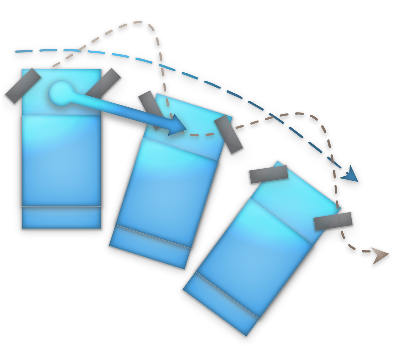
The Integration Challenge

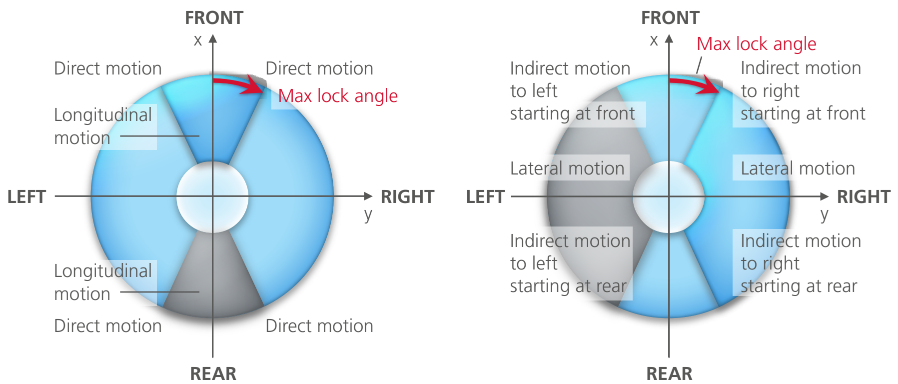
The challenge and constraint for the initial demonstration of this x-by-wire park assistance system on an existing electric car was to integrate the complete functionality on the existing powertrain control unit (PCU) without any modifications. This PCU was already designed, when the electric vehicle Th!nk City was put on the market in the late 2000's on behalf of the Ford Group. At the time, it was not expected that the software would be modified later on. Furthermore, the steering system was not purely electric, which prevented external control of the wheels. Since then, an additional torque stepper has been integrated at the base of the steering wheel axle to allow automatic steering control. All these constraints made it evident that it was necessary to use a fast prototyping device. Continental Automotive decided to use dSPACE MicroAutoBox, one of the most useful and available devices for prototyping demo cars, for x-by-wire applications. After this project, Continental Automotive will also use MicroAutoBox for developing serial electric vehicle controllers (EVC) in our product portfolio.

Function of X-by-Wire Steering

The solution involves a (semi-)automatic maneuver control (including HW devices and SW functions) for the driver. The goal is to help the driver in low-speed maneuvers that

Figure 1: Example of a side maneuver to the right: The vehicle automatically moves in "indirect" motion mode when the position of the joystick is kept to the right.





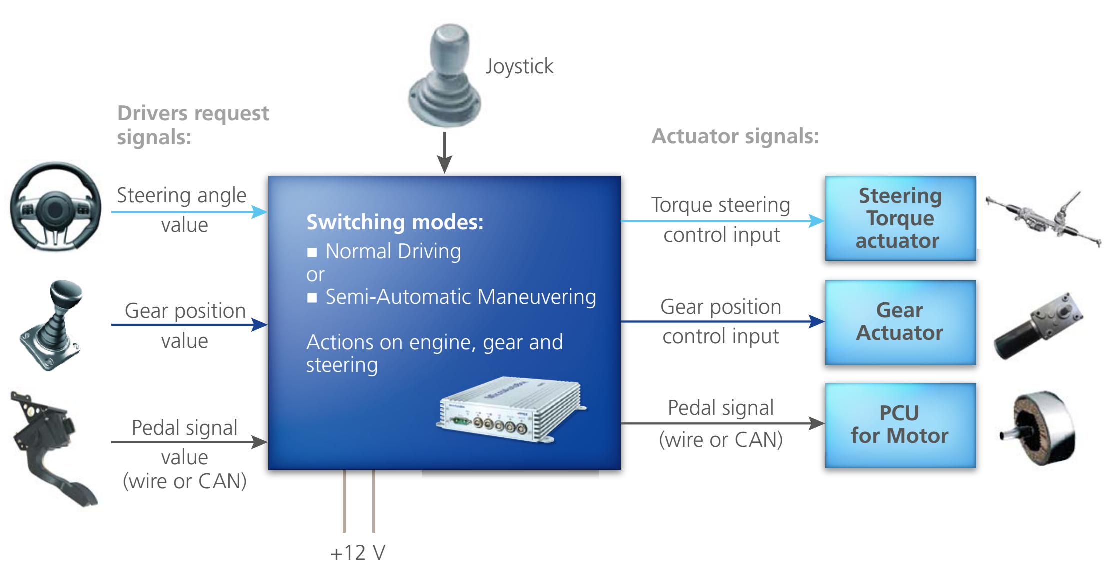
Joystick Control:
- "Direct motion" is active when the joystick is pushed to the front or rear direction
- "Indirect motion" (fig. 1) is active when the joystick is pushed to the lateral right or left side

Figure 2: Operating concept of the joystick control.

> "The implementation of the electric steering controls went quickly and fluently thanks to dSPACE MicroAutoBox's versatile interfaces."
>
> *Dr. Mariano Sans, Continental Automotive*

require both traction and steering controls by avoiding the necessity to activate the accelerator and brake pedals, the gear and the steering wheel with the repeated, and annoying, 'push-&-pull' or 'front-&-rear' steps that are typical for parallel parking maneuvers. This solution is based on a joystick or a trackball (or any other equivalent 2-or 3-axis hand actuator), fixed on a central dashboard in the car. The driver uses this device intuitively to indicate the desired vector direction, which is then converted into a traction torque set-point and a steering angle set-point. In this semi-automatic mode, no action on the pedals, the gear or the steering wheel is necessary anymore. Manual gear shifting is possible by pressing the appropriate buttons on the joystick, but the preferred method is to have the gear shifts controlled automatically.
The semi-automatic movement control calculates a trajectory of the steering wheels (normally on the front axle) in order to follow this dis-

Figure 3: Connections to the vehicle controller are cut to insert the x-by-wire control system



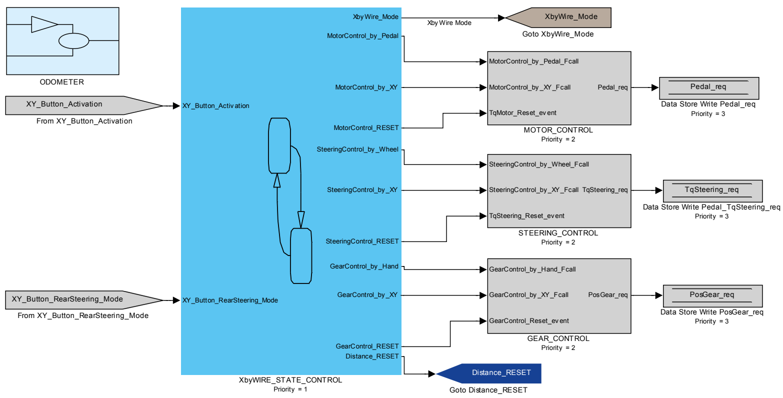


Figure 4: The main model chart, delivering control signals to the 3 actuator chains: re-calculated pedal, gear and steering signals.

placement vector with automatically programmed steering maneuvers and forward and backward movements. No external sensors are used to detect obstacles and the available distance; the driver maintains control of the vehicle's movement and can brake at any moment. In each case, the vehicle traction is stopped as soon as the joystick is released to its central (neutral) position.

System Function Architecture

The selected configuration is to plug the MicroAutoBox as an intermediate interface between the sensors (pedals, gear selector, steering position, and joystick) and the actuators (stepper and PCU). This cuts down all direct connections of the original architecture and provides re-constructed signals to the PCU, making it run as in a normal configuration.

The connection wiring harness includes all kinds of signals:

Inputs:

- analog signals from the accelerator pedal (3 redundant signals, for safety correlation)
- logical signal from the brake pedal (on/off)
- logical signals from the gearbox selector (with truth-table combination)
- digital signals from the steering motor (state, position, speed,…)
- CAN data from the vehicle system (vehicle speed, key-on, etc.)
- analog and pulse signals from the joystick (X, Y, Z, and push buttons)

Outputs:

- analog signals of the re-calculated pedal position to the PCU
- logical signals of the re-calculated gearbox selection to the PCU
- digital signals for the control of the steering motor actuator to its power drive (mainly stepper pulses)
- logical feedback information from the x-by-wire status to the PC or dashboard (with vocal messages)

The MicroAutoBox interface offers a large number of such connections for all this equipment.

Model Based Design

The functions include analytic calculations, closed-loop controls and time sequential coordination.
All of this is developed with MATLAB/Simulink/Stateflow in a user-friendly way, using all the programming capabilities of this tool, able to be autocoded on the MicroAutoBox with just light effort.

Dr. Mariano Sans, Continental Automotive

Dr. Mariano Sans
Dr. Mariano Sans is Senior Expert for Automation and Energy Management at Continental Automotive in Toulouse, France.

Summary

Continental Automotive integrated an innovative x-by-wire steering assistance system in the electric test vehicle TH!NK. The prototyping system MicroAutoBox was used to evaluate the control signals, control the actuators and calculate the steering functions.
It was possible to integrate MicroAutoBox nearly seamlessly into the vehicle infrastructure, so the x-by-wire steering system was implemented quickly.
The development tool chain is planned to be used to develop the serial electric vehicle controllers (EVC).

Ontinental

POLLUX

Project partners and co-authors:
ZEM Zero Emissions Mobility Company (Oslo – Norway), AKKA Technologies (Toulouse – France), SINTEF Energy Research Institute (Oslo – Norway)

Active noise reduction in the home

Sound Asleep

Researchers at the Helmut Schmidt University/University of the German Federal Armed Forces in Hamburg are working on systems for actively canceling out sound – for example, to reduce the levels of traffic noise in residential buildings. This requires a computation-intensive adaptive algorithm, which they implemented on a dSPACE DS1006 Processor Board.

Noise Pollution

Exposure to the noise all around us, especially in towns, is stressful and can cause illness. Homes can be soundproofed, but even the best insulating materials are useless if a window is even only slightly opened for ventilation. Moreover, the insulation becomes less efficient as the sound frequency decreases (i.e., low tones or increasing wavelength). A bass sound wave of 100 Hz (such as the deep growl of a truck's diesel engine) has a wavelength of just under 3.5 m. Sound waves like these go straight through commonly used insulating layers a few centimeters in thickness.

It is for these scenarios that the Helmut Schmidt University/University of the German Federal Armed Forces in Hamburg, funded by the German Federal Foundation for the Environment (DBU), developed an active noise reduction system that works even at low frequencies and with a window open.

Eliminating Noise with Anti-Noise

Active sound reduction is based on the principle of destructive interference, in which two opposite-phase waves cancel each other out (figure 2).

The canceling sound wave is computed from measurements made by two microphones: one that measures the noise signal near its source, and another that measures the signal resulting from the superposition of sound waves and canceling sound waves. However, total elimination of all noise is scarcely possible because sound propagates in all directions, and the measurements taken at the source of the noise are themselves affected by the canceling wave. Moreover, the noise also reflects off the walls, creating a complex sound field. Finally, noise usually consists of a broad range of frequencies for which no precise canceling signal can be generated (or only very locally at best).

Active Noise Reduction in the Home

The experiment setup (figure 3) for the noise-cancellation system developed at the Helmut Schmidt University consists of two rooms: a low-reflection outer room where the sound waves and canceling sound waves are generated, and an inner room whose acoustic properties are typical of a room in a residential building. This connects to the outer room via a standard, off-the-shelf

Figure 1: Noise-cancellation speakers reduce the noise before it reaches the window (third project phase).

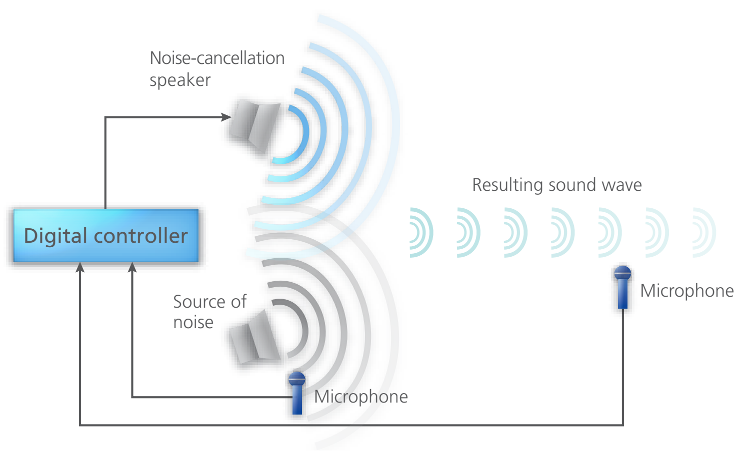


Figure 2: The principle of active noise reduction: The original sound wave (grey) and the canceling sound wave (blue) are superimposed and (almost) eliminate each other (cyan).

window and has to be protected against too-high noise levels.
The signals of the error microphone (the “error” is the residual noise, which ideally needs to be reduced to zero) are passed via a dSPACE DS2004 High-Speed A/D Board to the DS1006 Processor Board, which computes the output signals with an adaptive, digital control algorithm (the filtered-x least-mean-square or FxLMS algorithm). The output signals are output via a DS2102 D/A Board, then passed through a low-pass filter, amplified, and finally passed to the noise-cancellation speakers. In some experiments, there is also a reference microphone that measures the noise directly at the source.

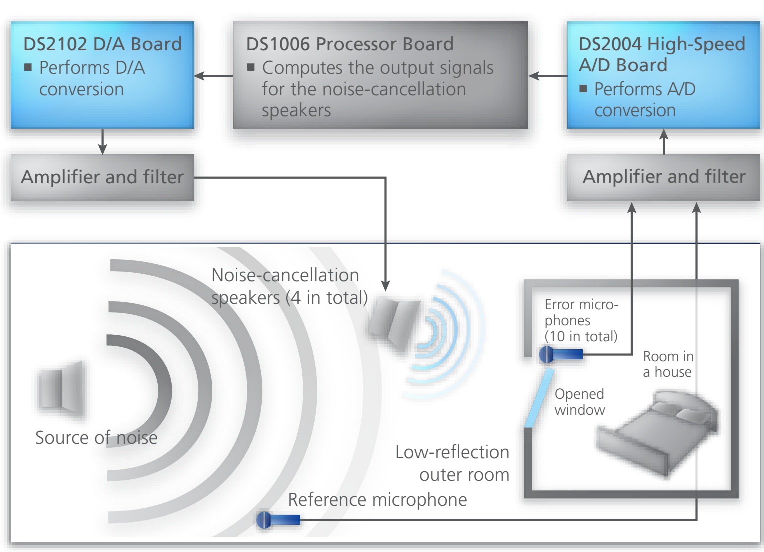
Details of Signal Processing

The requirements for signal processing speed are very high because the canceling sound wave has to be generated by the time the noise reaches the noise-cancellation speaker. In the short time that the noise takes to travel to the speaker (approx. 0.6 milliseconds for 20 centimeters), the input and output signals have to pass through the amplifier and the analog anti-aliasing filter, and the FxLMS algorithm has to calculate the output signals. In multichannel systems, the algorithm consists of a digital, adaptive finite impulse response (FIR) filter for each noise-cancellation speaker and additional FIR filters that represent the acoustic path between each noise-cancellation speaker and each error microphone (secondary paths).
Thus, the setup described here, with 4 noise-cancellation speakers and 10 microphones, has 4 FIR filters for the control and 40 FIR filters for the secondary acoustic paths. Each FIR filter corresponds to one convolution operation. As the number of filter coefficients increases, so does the number of multiplications. The filters need a certain number of coefficients to deliver good control results, however, because they represent pulse responses that are physically present. The higher the sampling rate, the more filter coefficients are required, and the less time is available to compute them.

Enlarging the Zone of Silence

In the first project phase*), active noise reduction was performed by means of two error microphones in a pillow and two speakers at the head of the bed (figure 4). The noise reduction was about 18 dB, but it was spatially very restricted. In the second project phase, the zone of silence was enlarged by using additional speakers and microphones and optimizing their positions. This setup is not very practical in real life, however, so the aim of the third

Figure 3: Schematic of the experiment setup for the canceling sound wave experiment.



*) Funded by the German Federal Foundation for the Environment (DBU) in several projects between 2006 and today.

> "With the high processing power of the DS1006 Processor Board, it was no problem to increase the sampling rate of the noise-cancellation system from 2 kHz to 8 kHz. Full utilization of multitasking will provide further reserves for improving the control."

Sergej Jukkert, University of the German Federal Armed Forces in Hamburg

project phase was to muffle the noise directly at the window (figure 1). This "active sound blocker" works with a reference microphone that measures the noise at the source, and also uses speakers and microphones directly on the window frame. This greatly reduced the noise (by 16 dB) in a mean frequency range of 80 Hz to 480 Hz, as measured at twenty measurement points distributed throughout the room.

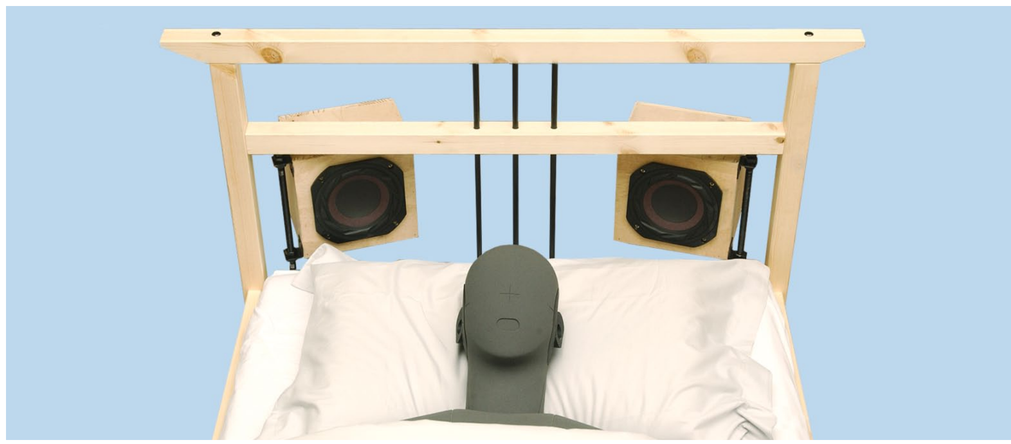


Figure 4: Noise-cancellation system directly at the head of the bed (first project phase).

From Lab to Home

In collaboration with Adaptronics International GmbH, work is currently being performed on other practical aspects. The aim is to remove the reference microphone as well as to integrate the speakers and microphones in the window frame. In this new control concept, a reference signal is generated from the error signal internally. Because this delays the generated signal as compared with the noise signal, high execution speed is even more important. The speed was already increased from 2 kHz to 8 kHz with the same number of channels, though there is not yet a sufficient number of filter coefficients. The current focus is therefore on distributing the control algorithm across all four cores of the DS1006 board. Controller concepts that calculate model parts in the frequency range are also being investigated. This will make it possible to increase the number of filter coefficients and further improve control quality. ■

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Sergej Jukkert
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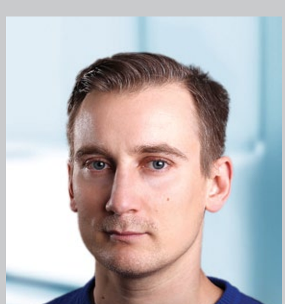
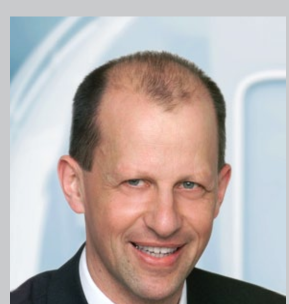


Dr. Delf Sachau
Univ.-Prof. Dr.-Ing. Delf Sachau is head of the Professorship for Mechatronics at the Helmut Schmidt University/University of the Federal Armed Forces Hamburg, Germany.



Peak Performance

Racing to the top with standard car parts: the MiEV Evolution II

Electric vehicles are no “snail-paced” eco-mobiles, as Mitsubishi proved at the tough Pikes Peak mountain race in the USA. Based on standard parts from the i-MiEV, the MiEV Evolution II is a bundle of electric energy that excels on the race track. Its electronics command center is a MicroAutoBox II from dSPACE.

Figures 1-4: From top to down: Fine-tuning the controllers on the MicroAutoBox; The Pikes Peak racing team; Drivers Greg Tracy (left) and Hiroshi Masuoka (right) with their trophies for 2nd and 3rd place; The MiEV Evolution II on the track

The Pikes Peak International Hill Climb

Mitsubishi's entry in this year's legendary Pikes Peak International Hill Climb in the USA was MiEV Evolution II, the special race version of their electric road car i-MiEV. Cars have been racing up this 4,300-meter-high mountain in Colorado since 1916, covering a difference in altitude of more than 1,500 meters along its winding road. Climate is also a challenge: as the cars and their drivers speed to the top, they face constantly changing air pressure, atmospheric conditions and temperatures.

Experienced Race Drivers

Mitsubishi's two racing prototypes were driven by Hiroshi Masuoka (Japan) and Greg Tracy (USA). Masuoka is a true motor racing great, having taken part in the Dakar Rally no fewer than 21 times and winning it in two consecutive years, 2002 and 2003. Greg Tracy has an equally impressive track record with six wins in the Pikes Peak motorbike class.

Production Vehicle

Like its predecessor the i-MiEV Evolution in 2012, the Mitsubishi MiEV Evolution II has numerous production vehicle parts installed, combined with specially developed high-powered electric motors and batteries. Its body is made of carbon fiber and has been specially adapted to racing requirements – it is extremely light and has excellent aerodynamics.

Drive and Performance

Four electric motors drive the MiEV Evolution II – two at the front and two at the back, with a total power of 400 kW (544 HP). Based on the experience gained in last year's race, this year the developers integrated the Super All-Wheel Control (S-AWC) vehicle dynamics system with curve and stability control. This regulates the driving and braking forces on each wheel separately to transmit the forces to the track safely and ensure maximum dynamics. High driving power with reduced air resistance was ensured by slicks – approved for use for the first time in 2013 – and by aerodynamic adjustments to the body.

Central Control

To implement the new control algorithms in the vehicle quickly, Mitsubishi used dSPACE's prototyping system MicroAutoBox II, which acts as the central control unit.

> "The MicroAutoBox II is a compact and highly reliable unit in a challenging on-vehicle environment. We were able to use it worry-free for the Pikes Peak vehicle that had to run up from an altitude of 2800 m to 4300 m within about 10 minutes."

Tetsuya Furuichi, Assistant Manager, EV System Advanced Research, EV Component Research Department, Development Engineering Office, MITSUBISHI MOTORS CORPORATION

The MicroAutoBox II is mounted in the vehicle as an ECU which coordinates and controls the four electric motors and brake systems in the MiEV Evolution II. It estimates motor running and drive battery conditions using information collected from a variety of sensors and ECUs, thus optimizing control of the four electric motors and brake systems and enabling safe and stable high-speed running conditions for the MiEV Evolution II. The production ECU from the i-MiEV performs battery management.

Impressive Results

The concept of the MiEV Evolution II is definitely a winner: The two cars took the 2nd and 3rd places in the Electric class at the 2013 Pikes Peak – an achievement that speaks for itself. This powerful race car has potential for further development and provides valuable knowledge that benefits the development of electric road vehicles. A win-win situation for electromobility.

Video: Presentation of the race track. http://www.youtube.com/watch?v=ub6l2CTu6co

Technical Data for MiEV Evolution II

Full length	4,870 mm
Full width	1,900 mm
Full height	1,390 mm
Wheel base	2,700 mm
Drive system	4WD (Fr: LSD, Rr: right/left independently driven)
Motor/Inverter (From Meidensha)	Hardware and control software were upgraded based on those for i-MiEV
Maximum output / torque	400kW/800 Nm (100kW/200 Nm x 4)
Battery (From LEJ)	Advanced prototype 50kWh
Chassis	Dedicated tube frame
Cowl (From Toray)	Carbon fiber (CFRP)
Suspension type	Front and rear double wishbone
Steering assist device	Column assist EPS (For Outlander)
Tire size (from Dunlop)	260/660R18

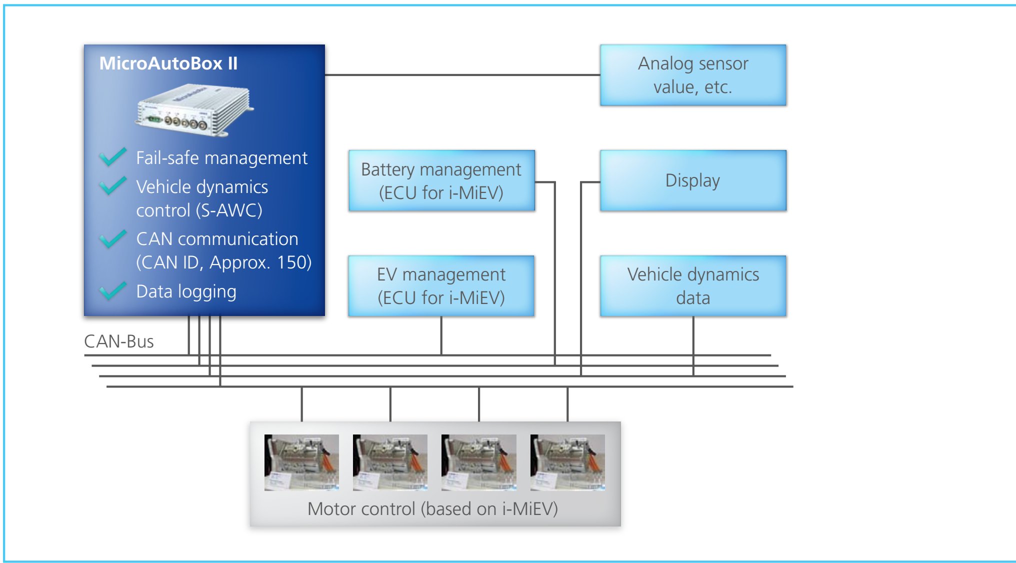
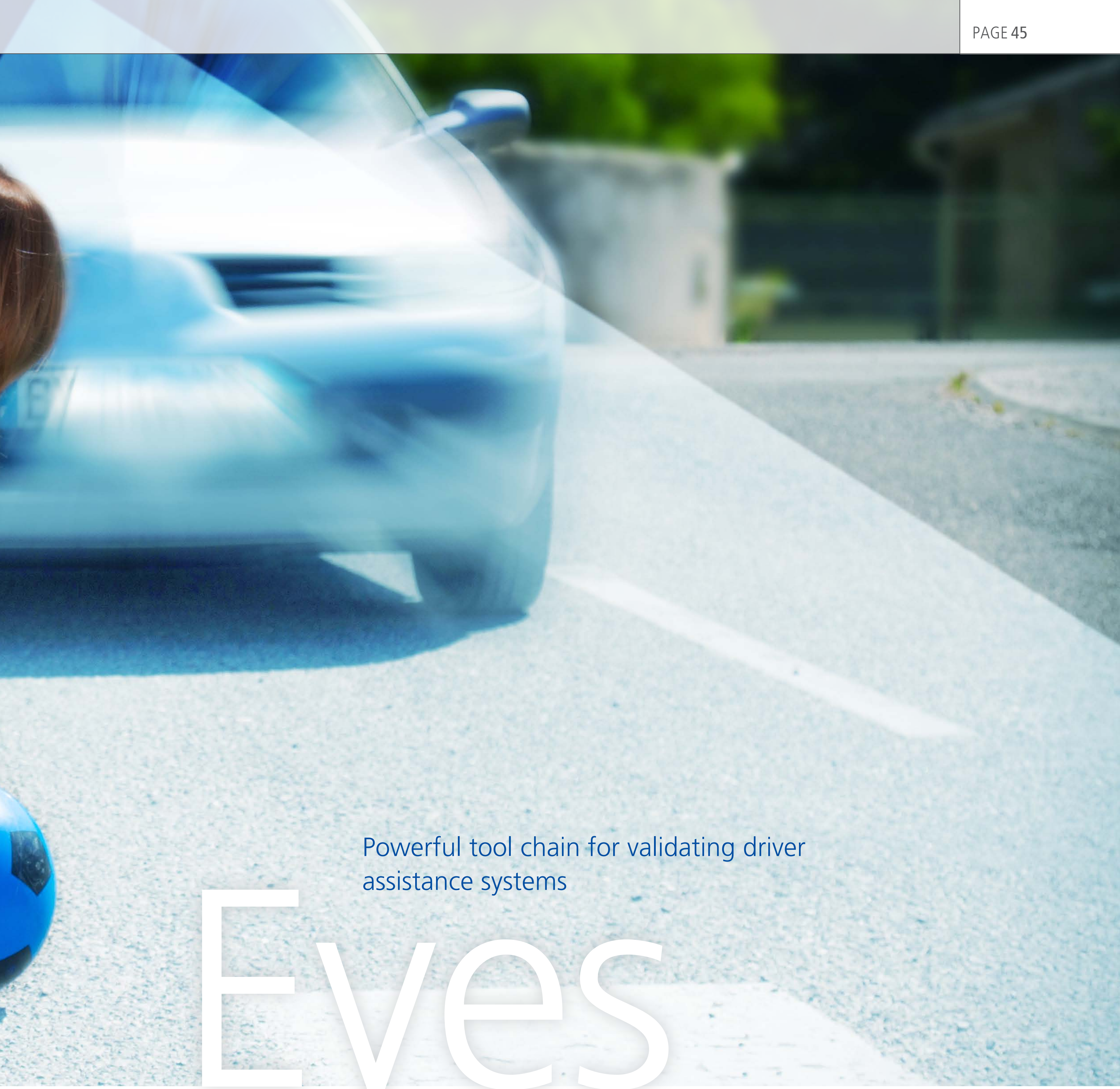


Figure 5: Schematic View of the control system based on the MicroAutoBox II.

"By using the dSPACE prototyping system, we were able to develop the Vehicle Dynamics Integrated Control System for MiEV Evolution II in a short period of time."

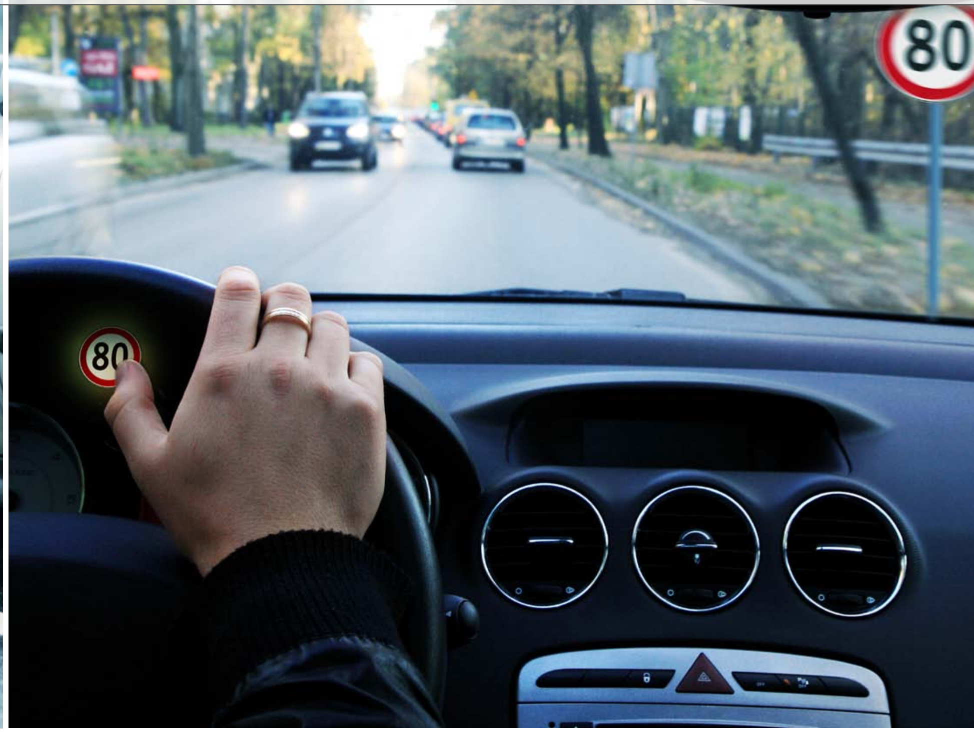
Akira Hashizaka, EV/Powertrain System Design, EV/Powertrain System Engineering Department, Development Engineering Office, MITSUBISHI MOTORS CORPORATION

Well-coordinated tools for simulation, testing and visualization are indispensable in validating modern driver assistance systems. Developers need a quick, easy way to model the properties of the vehicle under test, as well as road networks, traffic and electronic control units (ECUs), and to visualize driving maneuvers realistically. Together, the Automotive Simulation Models (ASM), ModelDesk and MotionDesk from dSPACE form a perfectly coordinated tool chain for this task.



Eyes on the Road

Powerful tool chain for validating driver assistance systems



Requirements Get Tougher

Increasingly tough safety and comfort requirements are enormous challenges for the automotive industry. One way in which OEMs are responding is by implementing a growing number of modern driver assistance systems. These help boost road safety and make motorists' routine tasks easier. In the future, automobile manufacturers will increasingly introduce active safety functions in different vehicle classes due to mandatory regulations at European level and stricter Euro NCAP criteria. Camera- and radar-based assistance systems that constantly monitor a vehicle's environment are one of the focuses of ongoing development work in this area. These systems support the driver during driving maneuvers, output warnings in dangerous situations, or themselves react autonomously in a fraction of a second. Typical examples of such systems include emergency brake, lane keeping and intersection assistants, as well as adaptive cruise control – to name but a few.

Euro NCAP

Now car makers are facing a new challenge: that of stricter criteria used by the European New Car Assessment Programme, or Euro NCAP for short. Launched by European transport ministries, motoring organizations and insurance associations, the program uses crash tests and other means to evaluate the safety of new vehicle models according to a five-star system. The safety assessment covers four areas: adult protection, child protection, pedestrian protection and safety assist. There are currently plans to give much more weight to active safety systems for accident avoidance before awarding a vehicle the maximum of five stars. From 2014 onwards, ratings will include an assessment of lane keeping assistants and autonomous emergency braking with low-speed (AEB City) and higher-speed (AEB Inter-Urban) systems. Autonomous emergency braking with pedestrian detection (AEB Pedestrian) will follow in 2016.

The Challenges in Detail

In the future, car manufacturers have the possibility to introduce driver assistance systems in various vehicle classes, based on standardized software and scalable, modular concepts. Most new and innovative functions come about when existing systems are more intensively networked and given additional components. Such systems actively intervene in engine control, steering, braking, and so on. This means that to validate the systems' functions by simulation, real-time-capable models representing a vehicle's overall behavior are needed. The ability to mimic different vehicle classes and variants with sufficiently flexible simulation models is essential in this context.

One particular challenge with these driver assistance systems is to merge the data from different sensors (such as radar and camera sensors) and use it to make reliable decisions in a fraction of a second.

The interactions between the environment sensors and the ECU software have to be tested under realistic conditions in the laboratory. It is vital to visualize the vehicle's environment realistically in real time and with low latencies so that the objects detected by the individual environment sensors or the corresponding sensor models are precisely time-correlated – especially when camera-based driver assistance systems are validated by camera-in-the-loop simulation. This

makes it possible to validate the behavior of the driver assistance functions and the networked ECUs effectively. To keep the amount of work involved in test implementation at a reasonable level, there must be a quick and easy way to create test scenarios with a road network, traffic, traffic infrastructure and roadside structures. The tool chain used should provide suitable solutions for a large number of different driver assistance applications. The high innovation rate in this field also means that customer-specific components such as dedicated sensor models need to be integrated.

The Solution: Tailor-Made Tool Chain for Validating Driver Assistance Applications

dSPACE offers a comprehensive tool chain that is tailor-made for all these challenges. There is no need to integrate tools from other vendors (for example, to visualize the vehicle environment), which usually produces additional latencies in communication with the simulation platform.

Simulation Models

The dSPACE Automotive Simulation Models (ASM) are a wide range of open models, created in MATLAB®/Simulink®, for simulating vehicles (engine, drivetrain, vehicle dynamics, electric components) and their environment (road, traffic, traffic infrastructure, roadside buildings). They are tailor-made for PC offline simulation as well as for hardware-in-the-loop (HIL) simulation in real time. The ASMs include models for passenger and commercial vehicles that adapt flexibly to specific vehicle variants.

Interaction between ASMs, ModelDesk and MotionDesk

This example shows how ModelDesk helps construct a road intersection and a test scenario for an emergency brake assistant based on a real aerial photograph. Two environment sensors (for the radar sensor and the monocamera) are configured in the vehicle model as examples. Different perspectives in MotionDesk make the test scenario plausible. To stimulate the monocamera for the camera-in-the-loop laboratory test, the exact same angle of view is generated as that of the image processing ECU installed in the real vehicle. MotionDesk is able to generate stable frame rates (for example, 60 Hz) for this.

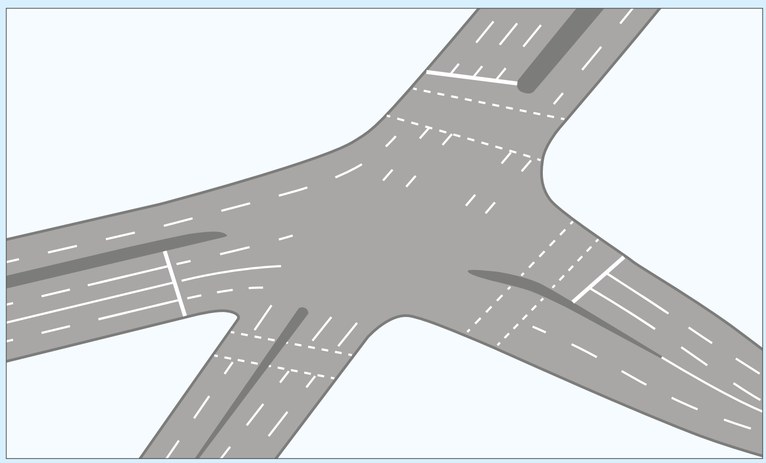


Figure 1: Graphic of a complex intersection that the test scenario is based on.

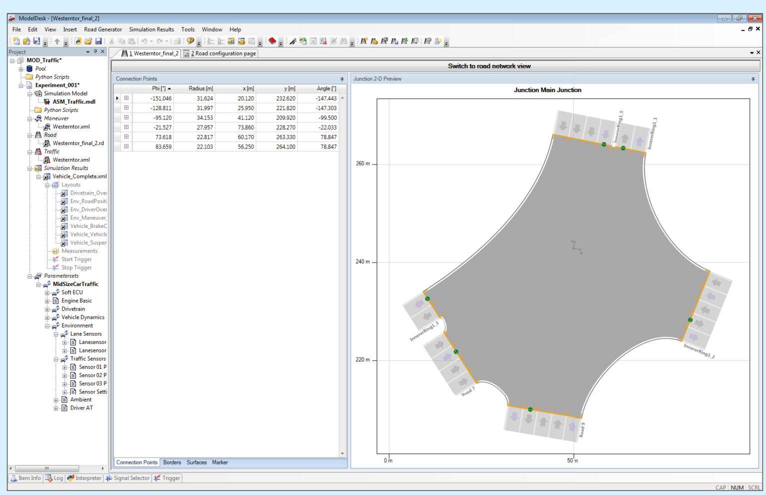


Figure 2: Modeling the intersection in ModelDesk. A road network can be created manually or automatically with one of the available road converters, such as the one from Nokia/Here for ADAS RP, OpenDRIVE files or measurement files with GPS data from real test drives.

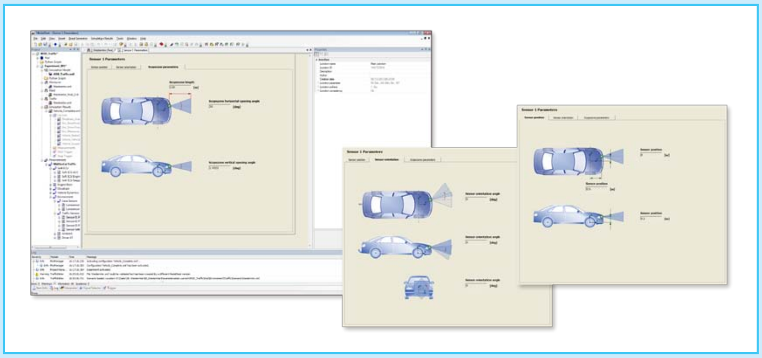


Figure 3: Modeling the sensor system for the EGO vehicle in ModelDesk.

Figure 4: The intersection from different viewpoints in MotionDesk. The view cones of the monocamera and the radar sensor are visualized in orange and blue respectively.

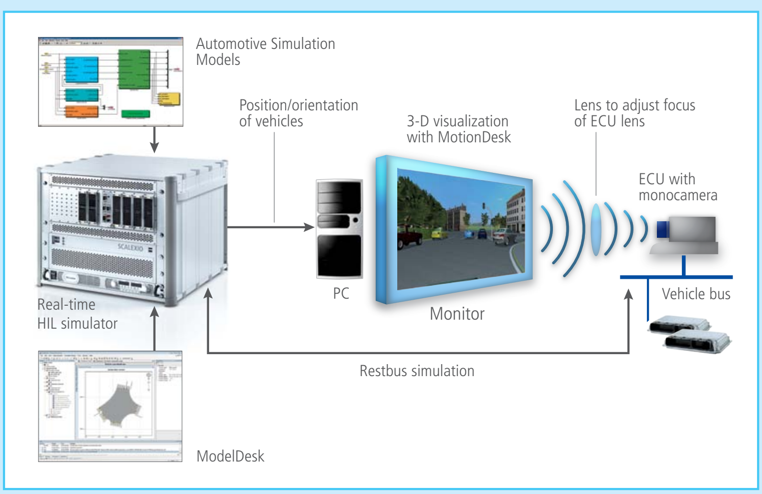


Figure 5: Schematic of a HIL simulator for testing camera- and radar-based driver assistance systems. The lens of the front camera in a real vehicle usually focuses on distant objects, so an additional lens is used to adjust its focal length for the laboratory test, in a similar way to using reading glasses.

Commercial Vehicles in Focus

The ASMs for truck simulation are being used particularly intensively in the commercial vehicle sector, where emergency braking and lane keeping assistants have been mandatory for new vehicle models since the end of 2013. They can be flexibly adapted for automated testing, i.e., without repeating code generation, by modifying features such as the number of axles, the tires (single or double) and the trailer/semitrailer configuration. If a driving maneuver has to be tested, there is also a driver model that provides longitudinal and lateral control of the vehicle. The models are configured and parameterized conveniently in the graphical tool ModelDesk (product profile page 50).

Visualization

MotionDesk visualizes driving maneuvers in 3-D. After defining scenarios in ModelDesk, users can fine-tune them in MotionDesk, for example, by dragging environment objects such as traffic signs, houses and other roadside features from a library. MotionDesk then visualizes the test scenarios in a realistic 3-D animation in real time for tasks such as stimulating the image-processing ECUs in camera-in-the-loop tests of driver assistance systems. These and other applications can be validated with the tool chain currently available:

- Lane keeping assistant
- Emergency brake assistant
- Traffic jam assistant
- ACC, ACC Stop & Go
- Blind spot detection
- Parking assistant
- Traffic sign recognition
- AEB City and Inter-Urban
- Intersection assistant

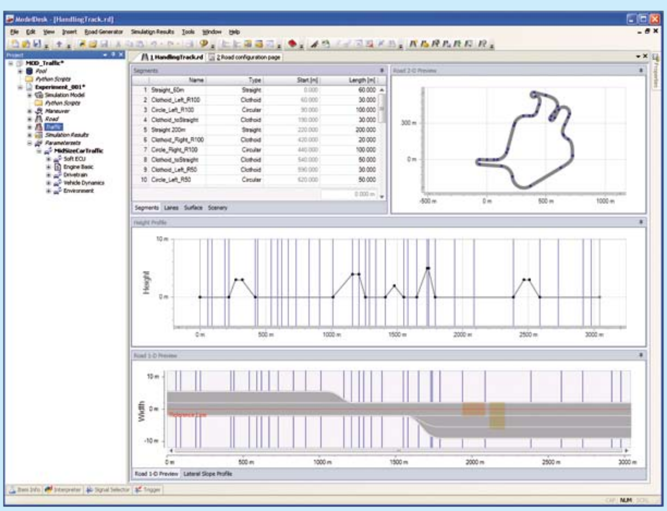
More applications will be addressed by dedicated extensions to the tools in the dSPACE Releases scheduled for 2014. These are some of the applications that are planned:

- Narrow passage or road works assistant
- Systems with pedestrian detection (such as AEB Pedestrian)
- Car2x applications

Integrating Unavailable ECUs

Modern driver assistance systems often interact with several ECUs simultaneously (engine, brakes, steering, etc.), and the software for these ECUs is frequently not available in the early stages of development. Despite this, the necessary tests can be developed and checked for plausibility very early on by suitably simulating the reactions of the missing ECUs. The ASMs from dSPACE pro-

Profile of ASM/ModelDesk



When modern driver assistance systems are developed, the ability to simulate a vehicle's reactions to other road users and the traffic infrastructure is essential. There has to be a quick, simple way to equip the vehicle with various environment sensors and to build the traffic environment with other vehicles, traffic signs, and roadside structures. The traffic environment model and the vehicle dynamics simulation from the ASMs work together to let developers define the behaviors of several independent road users, equip the test vehicle with sensors for object recognition, and run virtual test drives to validate a driver assistance function.

A wide range of scenarios are supported: fast-flowing, oncoming and crossing traffic; stop & go; driving into a traffic jam, and so on. An environment sensor model is used to test whether there are vehicles or pedestrians within a defined zone. This sensor model can simulate radar, camera, ultrasound and other sensors. Application-specific models for lane detection and so on are also available. Because the ASMs are open Simulink models, user-specific model parts can be integrated whenever required. ModelDesk is the graphical tool for intuitive parameterization and parameter set management for the Automotive Simulation Models (ASM). It can parameterize an entire virtual vehicle, or just single components like the drivetrain or chassis. The parameters of the user-specific model parts can also be managed in ModelDesk. Users can define road networks and individual roads, including lanes and driving maneuvers. Roads can even be created automatically, for example, by importing real measurement data or map data. ModelDesk also supports the OpenDRIVE standard for describing road networks and can automatically generate roadside structures for visualization in MotionDesk. Traffic scenarios can be defined with great flexibility in the Traffic Editor.

The dSPACE tool chain gives very effective support for frontloading tests in the development process for modern driver assistance systems.

vide soft ECUs for this – behavior models for ECUs that do not yet exist. And if the ECU software already exists (at least partially), even if only as object code, dSPACE's offline simulation platform VEOS® can be used to construct a virtual ECU based on the software components available. VEOS is then used to perform realistic automated tests and test drives on a PC. ■

Profile of MotionDesk

With a proven track record going back more than 10 years, dSPACE's visualization tool MotionDesk animates vehicle behaviors in defined environments for vehicle dynamics and driver assistance scenarios. Driving maneuvers are visualized in a virtual 3-D world so that the behavior of simulated systems can be seen and understood. MotionDesk reads the necessary data from a dSPACE Simulator, the validation platform dSPACE VEOS®, or MATLAB®/Simulink®, and animates movable objects (the vehicle, wheels, steering wheel, etc.) in real time. Visualization gives developers and test engineers a clear understanding of how the simulated objects actually behave. For example, the multitrack mode can overlay several simulations optically to make one single animation. This method is ideal for reference comparisons in which different vehicle dynamics strategies are compared.

The latest MotionDesk version has been completely revised and extended with numerous useful functions for developing modern advanced driver assistance systems (ADAS). MotionDesk can simulate changing weather conditions (such as rain and snow) and adds realistic shadows.

Even complex scenes can be output at a constant refresh rate, such as 60 images per second. The extensive 3-D object library includes traffic signs, houses, realistic environment objects and country-specific features. Scenes can be created simply by selecting objects from the library and positioning them.

The properties of the objects can be edited however required – for example, by changing their size, position or rotation.

With all these features, self-explanatory, realistic environments can be defined very quickly.

Classic hardware-in-the-loop (HIL) simulation uses the real electronic control units (ECUs) to test whether their software functions correctly. Now virtual validation and virtual ECUs are providing new potential for more efficient, high-quality HIL simulation tests.

Virtual Validation in Preparation for HIL Simulation

Virtual validation describes the overall method of using PC-based simulation for validating, verifying and testing ECU software. A PC-based simulation platform is one way in which virtual validation benefits HIL simulation. It is used to create and validate test scenarios in advance, and also to configure the simulation model. Virtual ECUs (V-ECUs) for executing initial test scenarios are another. No connection to a real, physical system is needed: Open-loop and closed-loop tests of ECU software and plant models run on a PC to detect errors and enhance the quality of the ECU software before the actual HIL simulation is performed. Creating and preparing tests in advance in this way ensures that HIL simulator time is used more efficiently[1)].

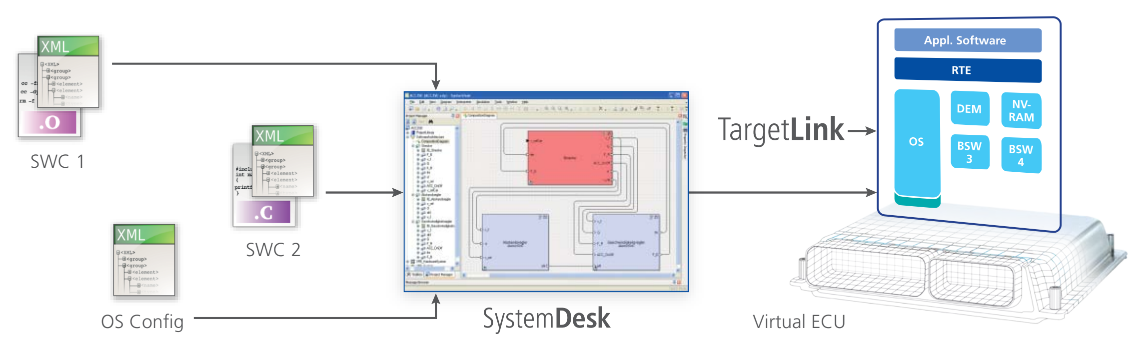
Configuring and Creating Virtual ECUs

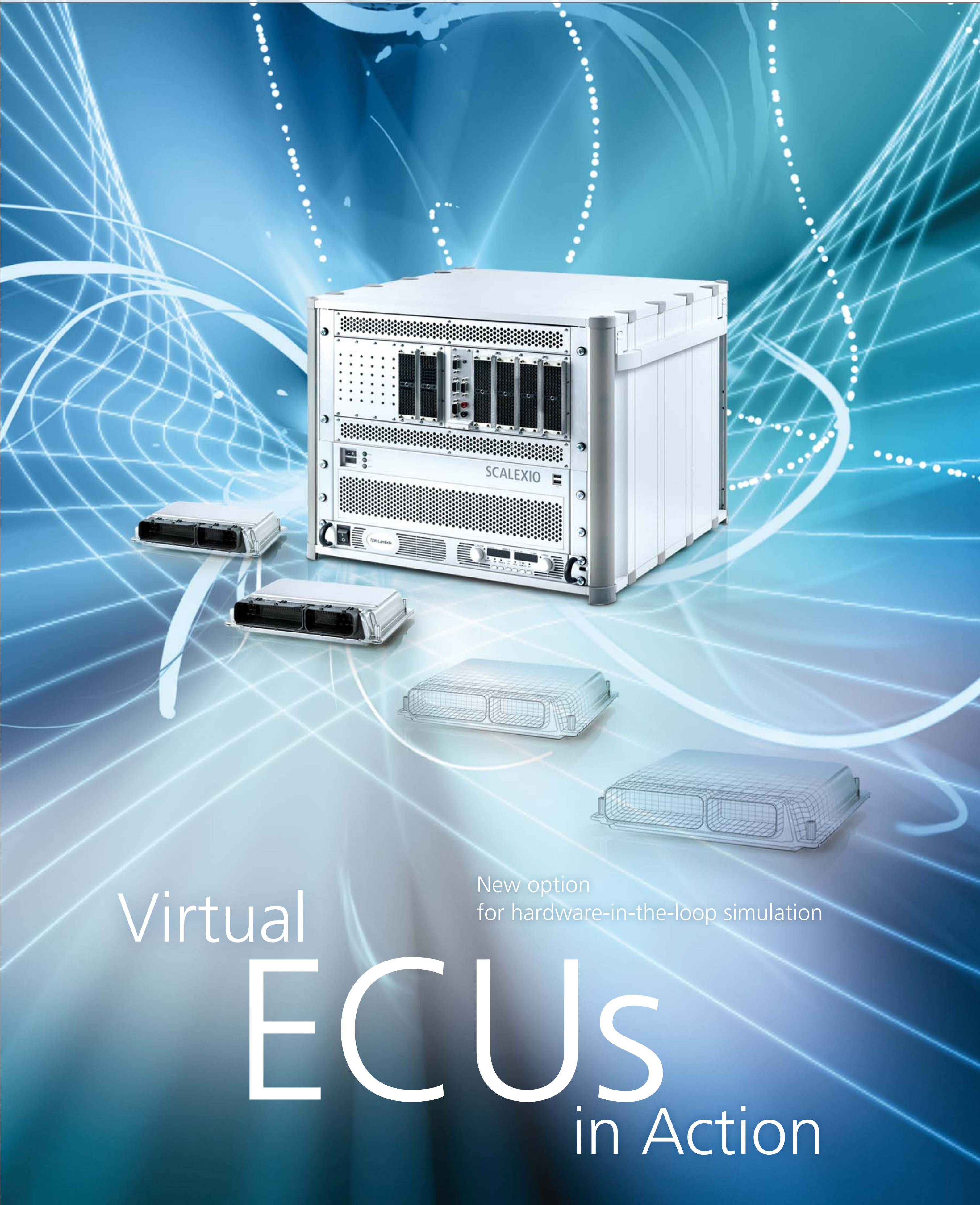
V-ECUs provide the same functions and software components as the final ECUs. They can be set up in several different ways:

- With individual AUTOSAR ECU functions
- With several or all AUTOSAR application software components
- With the entire integrated and configured application software, the run-time environment (RTE), the operating system and the hardware-independent basic software

dSPACE SystemDesk is used to generate V-ECUs straight from a software architecture according to AUTOSAR (see "All-Round Integra-

Figure 1: SystemDesk and TargetLink can be used to generate virtual ECUs with varying configurations.





New option
for hardware-in-the-loop simulation

Virtual ECUs in Action

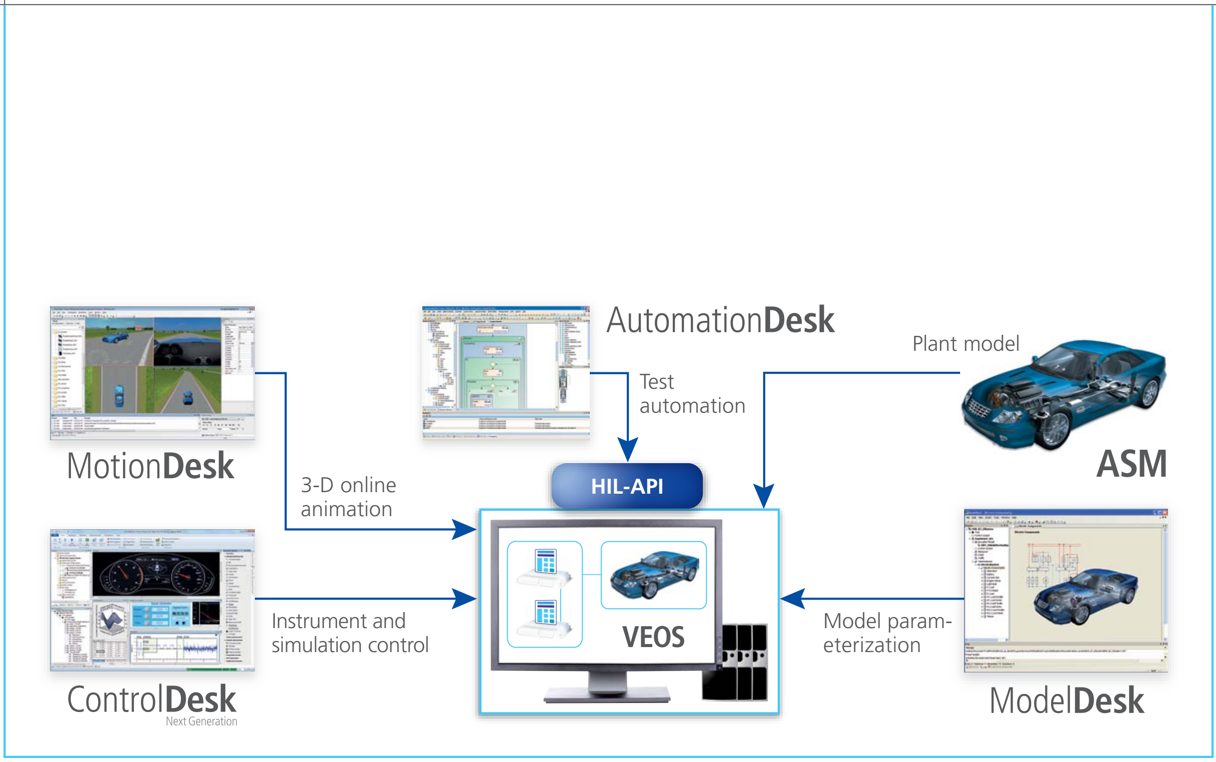


Figure 2: With VEOS, test scenarios can be designed, prepared and tested without a HIL simulator.

tion”, page 56). They can also be generated from a function model in Simulink® or TargetLink® (figure 1). Once generated, the V-ECUs can be used for PC-based simulation on dSPACE VEOS® or for HIL simulation on SCALEXIO®.

V-ECUs in HIL Simulation

In a HIL scenario, if there is no real ECU hardware available for a particular part of the ECU network, a V-ECU can be used as a substitute. The V-ECU is created from AUTOSAR software components that represent the ECU. The V-ECU can be directly integrated into the HIL simulation together with other plant models, so no additional work is required to produce a software behavior model. Reusing existing ECU code in this way saves users development and validation effort.

Several SCALEXIO plant models and V-ECUs can be executed on a SCALEXIO system simultaneously. The configuration is produced in ConfigurationDesk® by connecting the interfaces of the V-ECUs with the plant model. The models and the configuration are stored separately so that the configuration settings are preserved if a model is modified.

Dynamic Restbus Simulation with V-ECUs

V-ECUs can be used for high-quality CAN restbus simulation. If the object under test is a real ECU in a closed-loop test, the classic method in restbus simulation is to create ECU behavior models that form part of the plant model. For static restbus simulation, no behavior models are necessary, but dynamic restbus simulation

dSPACE VEOS

The VEOS simulation platform is used in the early stages of development to simulate individual software components, ECUs and ECU networks on a PC. The interfaces are open, so additional tools can be used: ControlDesk® for instrumentation and control, MotionDesk for visualization, AutomationDesk® for automating the simulation sequence, third-party products, and so on. Users can therefore continue working in their familiar tool environment and reuse all their existing data, models, layouts and configurations.
The V-ECUs, models, layouts and simulation scenarios that are created and used for VEOS can be reused in HIL simulation. This reduces the work involved in preparing for HIL tests (figure 3).

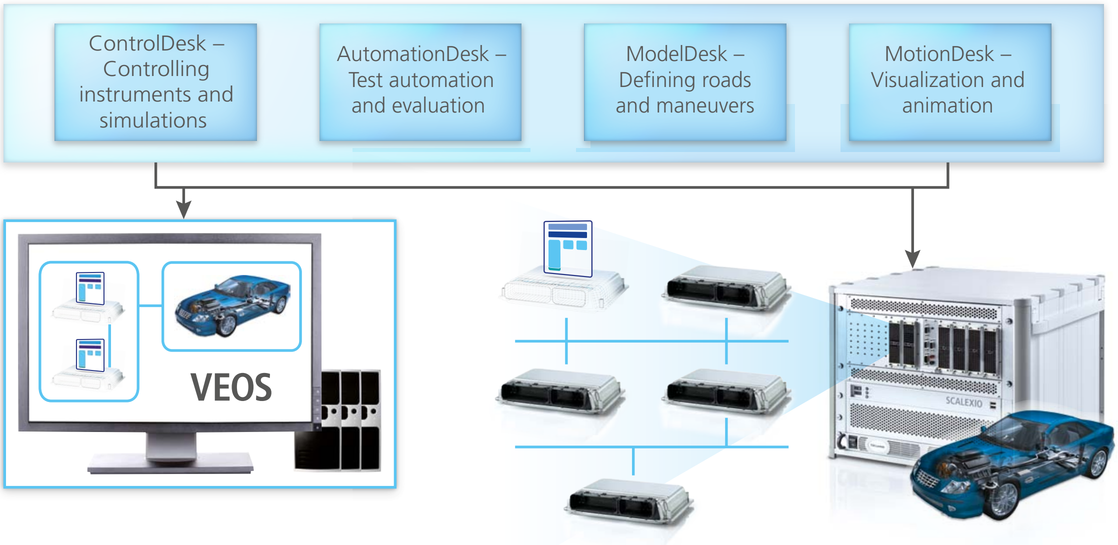


Figure 3: Using the same tool landscape for both VEOS and SCALEXIO.

can involve a considerable amount of modeling. However, no extra modeling is required if the ECU software is already available as a V-ECU, because V-ECUs themselves contain network communication settings. As usual with dSPACE restbus simulation, the V-ECU configuration is based on DBC, FIBEX or ARXML files. The imported V-ECUs can easily be connected to the physical interfaces of the SCALEXIO system with ConfigurationDesk® – without modifying the plant model. If a SCALEXIO system includes V-ECUs as part of the restbus simulation for the object under test (usually another ECU), they can be replaced by real ECUs later, also without changing the plant model. V-ECUs are described by ASAP2 files and accessed via Ethernet according to the XCP protocol. Any calibration tools that support these standards can be used, and layouts and test descriptions can be applied efficiently.

The practicability of the new methodology has been confirmed by a pilot application at Daimler AG[2]. ■

Further reading:

[1] Real Tests for Virtual ECUs, dSPACE Magazine, 1/2012, pages 46 - 49

[2] Virtual integration and testing of vehicle E/E systems, ATZ Elektronik, 05/2013, Artur Honisch (Daimler AG), Dr. Karsten Krügel (dSPACE GmbH)

Conclusion

With V-ECUs, many aspects of ECU real-time behavior and bus behavior can be simulated more easily and more realistically by reusing software parts from ECU development. This approach provides realistic results and enhances the quality of functions at an early stage, before the final ECU is available. Moreover, being able to configure the SCALEXIO systems via software and perform PC-based simulation in advance (figure 2) means less time is required for commissioning and setting up the HIL simulator. This is why these new technologies – virtual validation and V-ECUs – are being incorporated into existing validation and testing processes for ECU software. dSPACE will continue to promote this integration, focusing mainly on the reusability of existing hardware, software and models.

Convenient AUTOSAR-compliant development with SystemDesk

All-Round Integration

Software architects all over the world are using dSPACE SystemDesk to create the architectures for their ECU software. Why? Because of its clear views and convenient handling in development and configuration tasks. Its graphical representation of their entire overall model. And its easy integration into their existing tool chain.

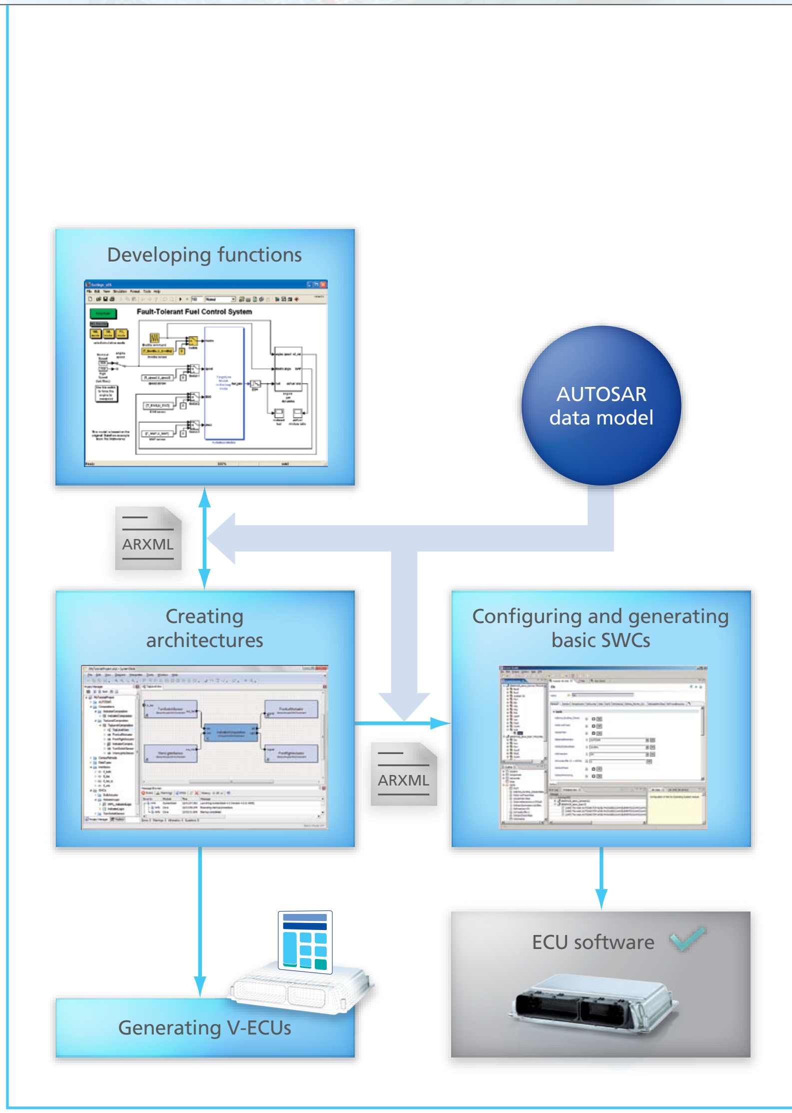


Figure 1: Standardized description formats allow iterative data exchange between different tools in the chain. SystemDesk also makes it possible to validate virtual ECUs at an early stage of the process.

Since its announcement in 2003, the AUTOSAR standard has become an important component in the development process for ECU software. The standard defines description formats for system architectures, software components and interfaces so that data can be exchanged reliably and consistently by all project stakeholders – between OEMs and their suppliers, between different development teams, and between different development tools.

In 2007, dSPACE published its system architecture software SystemDesk®. Right from the start, SystemDesk was completely oriented toward providing AUTOSAR support. All subsequent modifications to the standard were immediately incorporated in the very next SystemDesk version, and the software has undergone continuous further development. The latest version, SystemDesk 4.1, supports AUTOSAR R4.0, together with complete support for the AUTOSAR R4.1 data model, and integrates seamlessly into AUTOSAR-based development.

The AUTOSAR Development Process

The AUTOSAR-based development process comprises several steps (figure 1) that require different, specialized software tools. Thanks to standardized interfaces and exchange formats, the tools interact smoothly to guarantee users comprehensive data exchange.

The development process can be roughly divided into three steps:

1. The software architecture, including the individual software com-

ponents and interfaces, is created in SystemDesk.
2. The AUTOSAR description files for the software components are exported from SystemDesk and then imported into dSPACE TargetLink® for function development. The functions are integrated into the software components in SystemDesk.
3. The description files for the software architecture, including the software components, are exported from SystemDesk. The basic software is configured and generated with a tool such as EB tresos® from Elektrobit.

Structured Diagrams and Dialogs for High Usability

One particular challenge for system architects is to keep track of all the data elements, software components and connections involved in complex system architectures. SystemDesk diagrams visualize the architectures, making the relationships and dependencies in them easier to understand. Users can also define different views of their systems to organize how they access the software architecture or ECU topology.
Configuration dialogs provide a clear view of the attributes connected with individual AUTOSAR elements. The dialogs also ensure that all the data is in the correct format and automatically keep the relationships between data items consistent. Table editors help users enter large quantities of different mapping information (figure 2), for example, for mapping software components to ECUs or data elements to system signals.

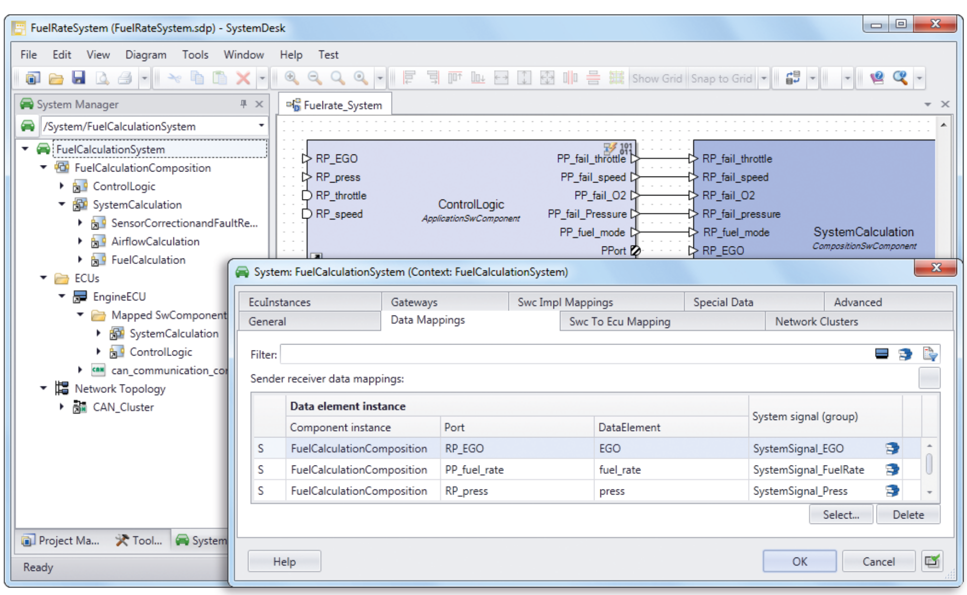
Importing and Exporting AUTOSAR Description Files

The development of individual components and functions is usually distributed across different teams. For developers to exchange project information with others and integrate that information into their own workflows, compliance with the AUTOSAR standards is essential. SystemDesk 4.1 provides complete support for the AUTOSAR data model, guaranteeing the lossless import and export of AUTOSAR description files. The scope and contents of exported descriptions can be adjusted to fit individual application cases: system architectures with one or more ECUs, for example, or data exchange between an OEM and different suppliers, or export to third-party tools.

Validating a Software Architecture

AUTOSAR defines numerous rules and restrictions that software architects have to observe in order to produce correct models. A special SystemDesk mechanism validates project contents according to the AUTOSAR rules. At the push of a button, the mechanism checks for out-of-range values, incompatible data types, etc. Users can even select an individualized subset of rules and

Figure 2: SystemDesk 4.1 provides various ways to access AUTOSAR data: a project tree, diagrams with software components, dialogs with a mapping editor, and so on.



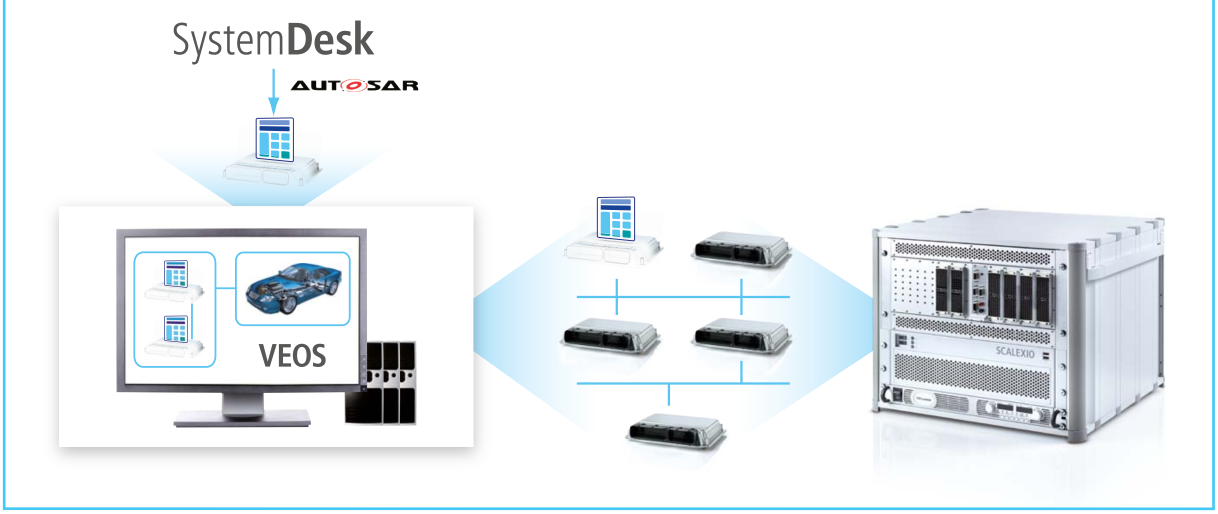


Figure 3: Virtual ECUs can run on dSPACE VEOS and on SCALEXIO. The same software is used to configure and handle them in both cases.

develop new rules themselves. Additional predefined rules in SystemDesk cover the requirements for data export and import between SystemDesk and dSPACE TargetLink, the production code generator, or EB tresos. Users have complete confidence that the descriptions they create can be processed correctly by downstream tools.

Automating Routine Tasks

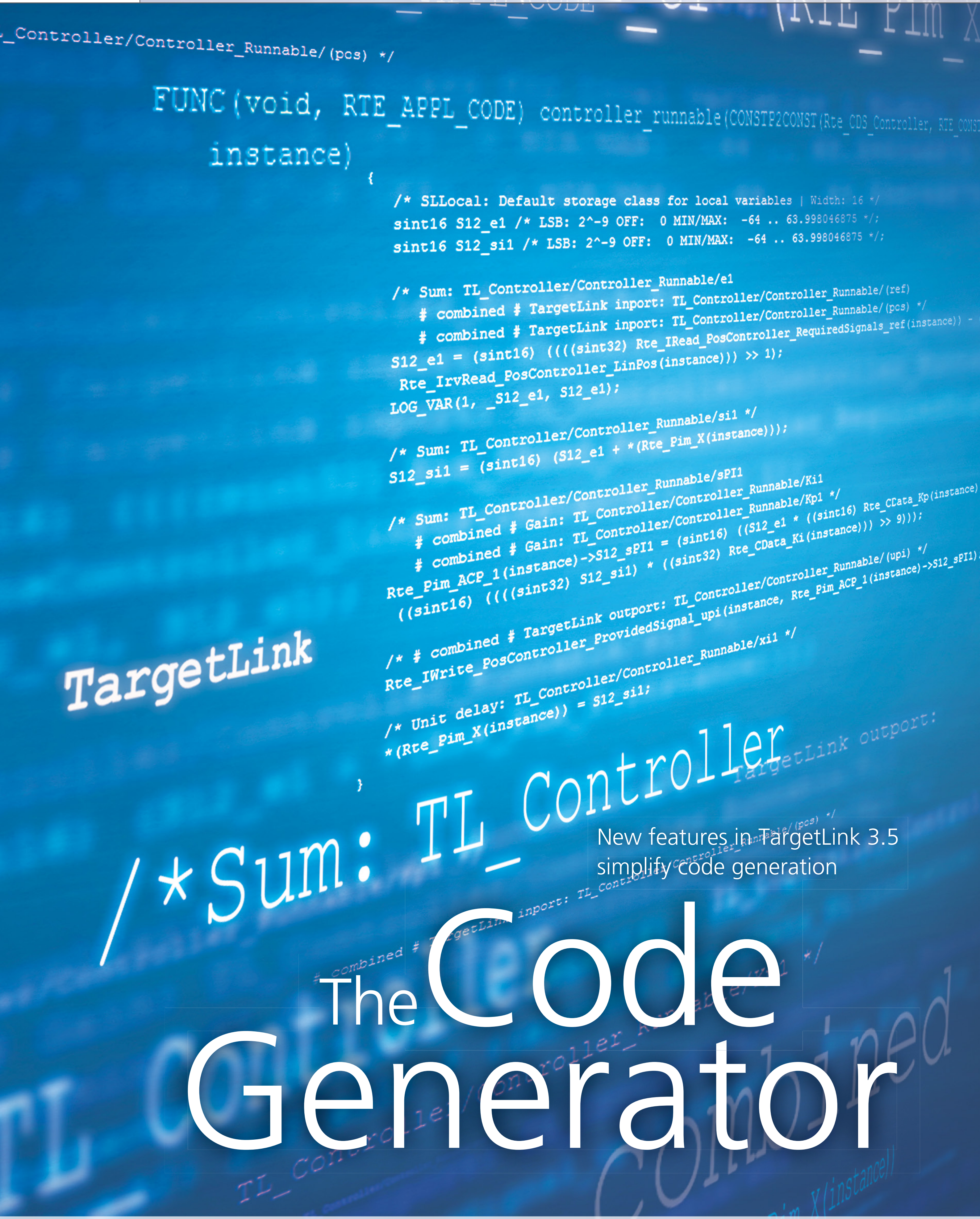
With SystemDesk's open API interface, users can conveniently edit the software architecture by inserting additional software or customized scripts. This means that they can automate a wide range of tasks:

- Creating the project structure for a new software architecture
- Connecting ports named according to a defined schema
- Repetitive, routine tasks
- Generating a report on the current project

Virtual Validation of ECU Functions

SystemDesk 3.2 not only supports all the functions of a standard AUTOSAR development process, it also enables the generation of virtual ECUs (V-ECU) based on AUTOSAR R3.x. V-ECUs contain the same architecture as real ECUs. Like the final ECUs, V-ECUs contain software components, i.e., application software components and basic software components. V-ECUs are used to test the ECU software and validate its functions at an early stage. V-ECUs can be run on the PC-based simulation platform dSPACE VEOS® to perform function or integration tests even before a hardware prototype of the ECU is available. They can also be used together with simulation models to enable the same simulation scenarios as those available with hardware-in-the-loop (HIL) simulation. Configuration and control are performed in a similar way to HIL simulation, with software tools such as dSPACE ControlDesk® Next Generation and dSPACE AutomationDesk®. Later on in the development process, the selfsame V-ECUs can be used alone, or networked with real ECUs, for hardware-in-the-loop (HIL) simulation on dSPACE SCALEXIO® (figure 3). "Virtual ECUs in Action" on page 52 gives details of how virtual ECUs are used in HIL simulation. With SystemDesk 4.2, users will also be able to generate V-ECUs based on AUTOSAR R4. Release of the new version is scheduled for the first half of 2014. ■

	SystemDesk 3.2	SystemDesk 4.1	SystemDesk 4.2
AUTOSAR R3.0, R3.1 and R3.2	✓	–	–
AUTOSAR R4.0 and R4.1	–	✓	✓
Modeling software architectures and system architectures	✓	✓	✓
Generating V-ECUs for PC-based simulation on dSPACE VEOS	✓	–	✓
Support for application scenarios in conjunction with dSPACE TargetLink and basic software configuration tools	✓	✓	✓



New features in TargetLink 3.5 simplify code generation

The Code Generator

The latest version of TargetLink, dSPACE's production code generation, comes with major new features: support for Simulink enum data types for transparent modeling, AUTOSAR 4.1-compliant development, and the generation of multi-instantiable software components. Software rollout in large user groups and process documentation have also become much simpler.

More Flexible Modeling

The new TargetLink® version provides substantial extensions for modeling in Simulink®/Stateflow®. One major new feature: Simulink enum data types are now supported, making models more self-explanatory (figure 1). Users working on the Simulink and Stateflow model level can use symbolic names instead of numeric literals, so their models are much easier to read and maintain. TargetLink 3.5 also makes it very easy to attach C code to native Simulink blocks and use it when production code is generated for the blocks. A comfort functionality helps by generating appropriate file fragments to which users just have to add block-specific parts. Among other modeling enhancements are support for the Stateflow 'Enter Chart at Initialization' semantic, and buffering input signals ("latched inputs") for subsystems addressed via function calls.

Extensions to Proven AUTOSAR Support

TargetLink 3.5 also supports all the relevant AUTOSAR versions: AUTOSAR Revision 4.1.1 has been added, and support for older revisions continues. As usual with TargetLink, software components for different AUTOSAR versions can be generated from the same model, so that models can easily be reused in different projects. A fundamental new AUTOSAR feature is the generation of multi-instantiable software components, which TargetLink 3.5 also supports (figure 2).
TargetLink generates the component code such that several instances of a component prototype, all using the same code, can be formed on one electronic control unit (ECU). Together with instant-specific AUTOSAR calibration parameters, this not only saves ECU resources, but also reduces test effort. Incremental code generation for software components is now even more powerful and flexible. For easier interaction with SystemDesk®, TargetLink-specific validation rules make it possible to check directly whether a SystemDesk architecture is compliant with TargetLink.

More Efficient Code and Improved Variant Support

TargetLink 3.5 gives users extended code optimization for eliminating state variables with static storage duration to save RAM capacity. This ensures more efficient use of valuable ECU resources. Compliance with MISRA has also been extended

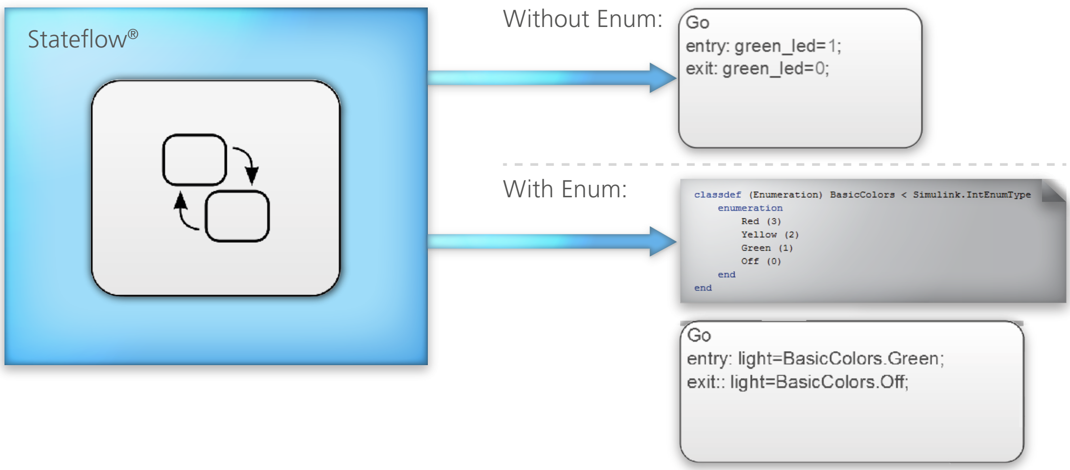
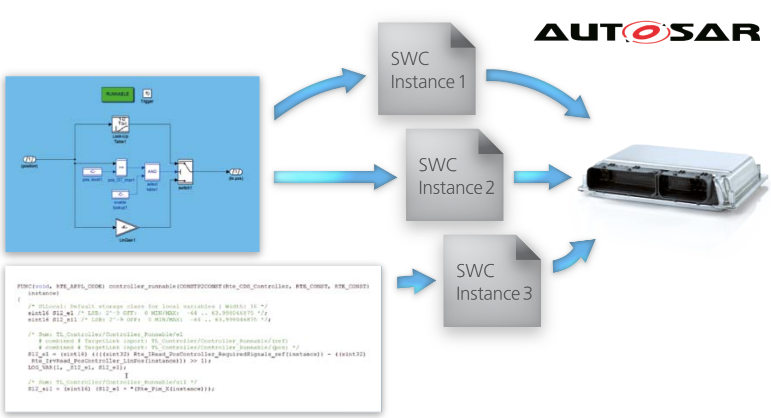


Figure 1: TargetLink 3.5 uses Simulink/Stateflow enum data types to make models more self-explanatory.

and covers all the mandatory rules in the new MISRA C:2012 standard. A new code generation report introduced with TargetLink 3.5 helps with issues such as the code generation options used, and implicit type conversions and rescalings for ports and their predecessor blocks. The latter are often the result of misspecification by the user, and the report helps users to find and eliminate them. Code generation for function variants has also been further improved: For example, Simulink modeling constructs, subsystems with variants, and model references can be used to create variants during code generation. This means that a single model can represent all the variants, and users just need to select a variant immediately before running the code generation process. Variant support in Stateflow has been extended so that entire subcharts, states and transitions can be encapsulated with preprocessor instructions to implement a specific variant during the build process, while the inactive variants are eliminated via compiler options.

Figure 2: TargetLink 3.5 can generate multi-instantiable AUTOSAR software components, i.e., code that can be instantiated on an ECU multiple times.



Enhanced Test Support and Usability

TargetLink 3.5 provides enhanced support for module and integration testing to make verifications in Simulink/TargetLink more efficient. For example, tool integration with the code coverage tool CTC Testwell allows the coverage provided by the TargetLink-generated code to be measured during software-in-the-loop simulation and later analyzed. This provides values for decision coverage and modified condition decision coverage (MCDC), as may be required for ISO-26262-compliant projects. Custom connections to specific target platforms for measuring code coverage during processor-in-the-loop simulations can be

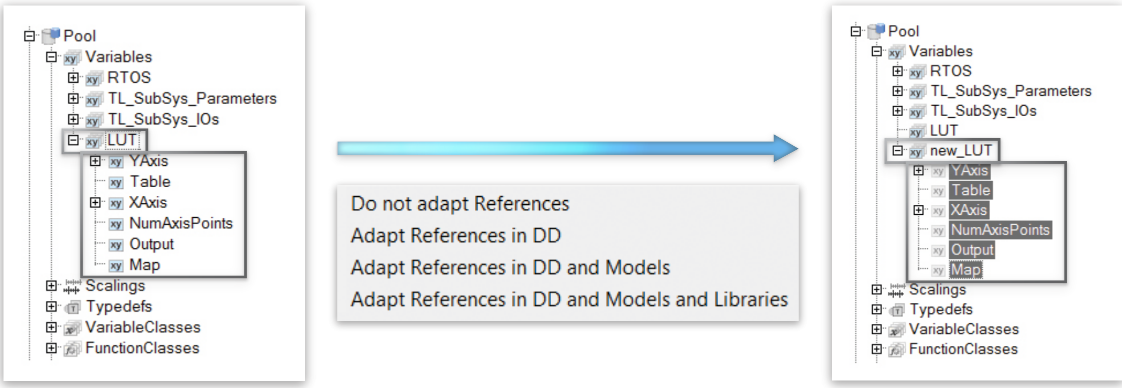


Figure 3: Simplified refactoring (structural improvement) of Data Dictionary specifications, for example, adapting object names.

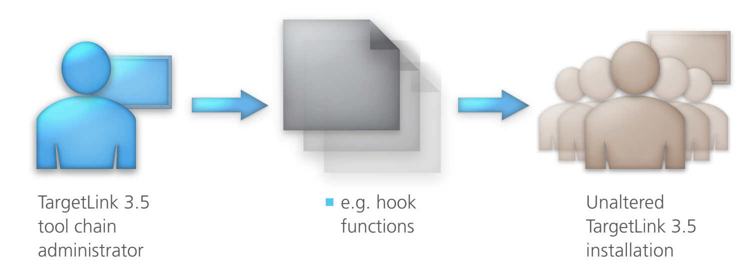
> TargetLink's proven AUTOSAR support has been further extended in Version 3.5. Whether you need AUTOSAR 4.1 or multiple instantiation of components – TargetLink provides the solution.

developed on request. For testing, TargetLink includes a powerful mechanism for feeding stimuli to a TargetLink subsystem, and retrieving signal values from it, without a visible connecting line and without affecting the actual production code. This is helpful when stubs are used to implement missing model and code parts for test purposes, and the stubs have to be appropriately stimulated during simulation. There are also significant enhancements to TargetLink's usability, such as a more powerful selection of multiple Data Dictionary objects for visualization and processing, and refactoring functionality (structural improvement) for changing the names and paths of Data Dictionary objects (figure 3).

Easier Rollout in Work Groups

TargetLink 3.5 is easier to install for a large number of users thanks to clear separation between TargetLink installation data and project-specific adaptation files such as hook functions. The project-specific parts can be cleanly versioned and used together with the unaltered TargetLink 3.5 installation (figure 4). All project team members can then work with the same project settings, e.g. hook functions, which greatly increases process safety. TargetLink 3.5 supports all four MATLAB versions current at the time of release, from MathWorks R2013b through MathWorks R2012a, and as usual, it is available as a 32-bit and a 64-bit version. Like its predecessor versions, TargetLink 3.5 will be ISO 26262- and IEC 61508-certified. ■

Figure 4: Working in large groups is much easier with TargetLink 3.5.

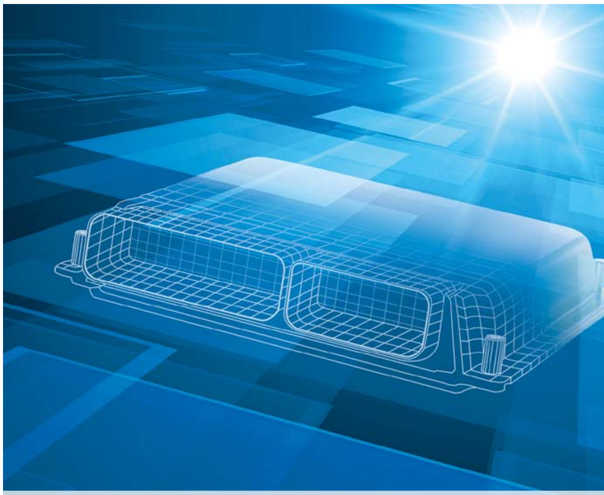


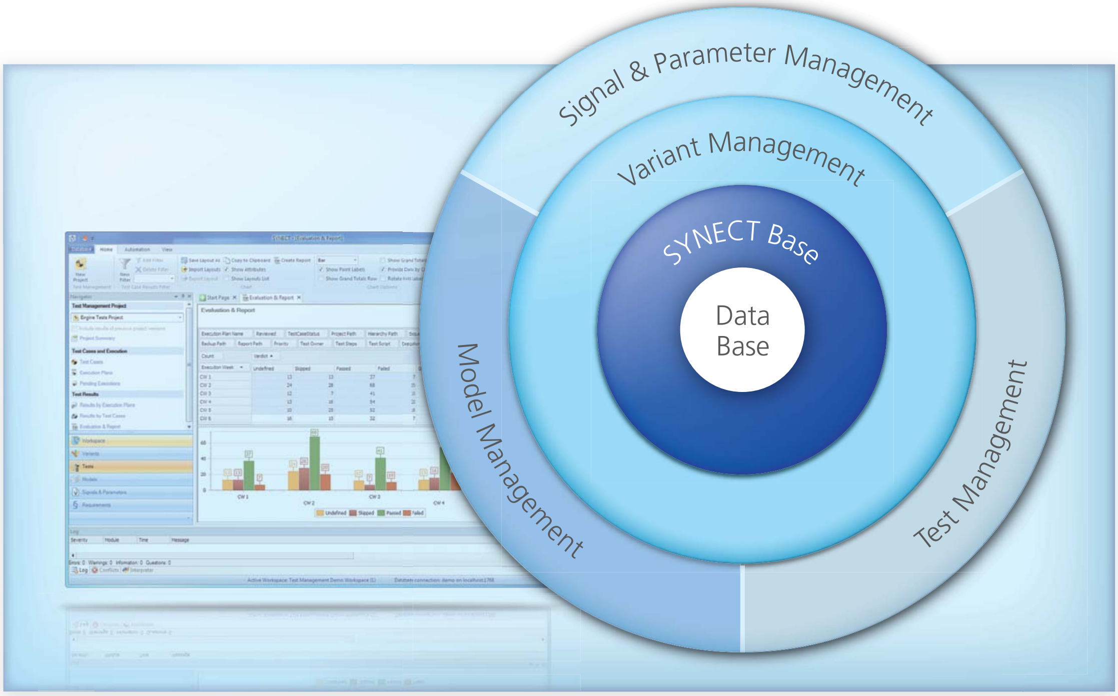
Forward

Model-based development with automatic production code generation and X-in-the-loop test methods have boosted the productivity of the automotive software development process for many years now. Development work and quality assurance for the rapidly growing number of new, software-intensive vehicle functions would be inconceivable without sophisticated tool support. The question now is: How will the development processes evolve in the future?

Ways to achieve greater productivity in the development process

Thinking





Modular data management concept with dSPACE SYNECT.

Status Quo

Today's development tools are typically not stand-alone, isolated tools used by individual developers, but are part of an extensive tool-chain, deeply integrated into the development process and networked with other tools across multiple departments and teams all over the world. Tool workflows and interactions have improved considerably over the last few years, in part because of standards such as ASAM and AUTOSAR. Given this sophistication in the development process, can productivity rise even higher? And if so, what preconditions need to be fulfilled?

First, a general comment: Higher productivity can be understood to mean "developing more functions in the same time". However, we must not forget that as the complexity of automotive systems continues to grow, it will take extra effort just to maintain the current level of productivity. Two particularly tough development challenges are: future advanced driver assistance systems (ADAS), which will prepare the way for semi-automated and fully automated driving, and electromobility. These features are especially challenging, in view of their additional requirements for functional safety. An increase in productivity, therefore, appears to be absolutely essential, even if it "only" means taking the same time to develop the same number of functions to production level as before.

Concepts for Mastering Complexity

When asked what needs to be done to cope with the complexity and costs of software development, development engineers and executives in the automotive industry usually recommend one or more of the following courses of action:

- Simulate more, i.e., include more details and more complex systems, and systematically reuse existing simulation models.
- Continuously generate ECU software versions and test them on their own and in networks.
- Begin system validation early, move more tests from the road to the laboratory, and set up a virtual validation strategy.
- Introduce strategies for reusing models, tests, software components and other data across multiple development phases and teams.

Companies are pursuing two promising approaches to implement these recommendations:

- Setting up active management for the fast-growing volume of models, tests and other data objects in model-based development (MBD). The key issues here are variant management, documentation and retrieval of models and tests, usability criteria (which model and which

Complexity can be mastered safely by active central data management.

test can be used for what), and traceability.

- Establishing a process for virtual validation, that begins with validating functions and software by PC-based simulation very early in development, and that allows models and tests to be reused later in hardware-in-the-loop (HIL) simulation.

Data Management: A Necessity

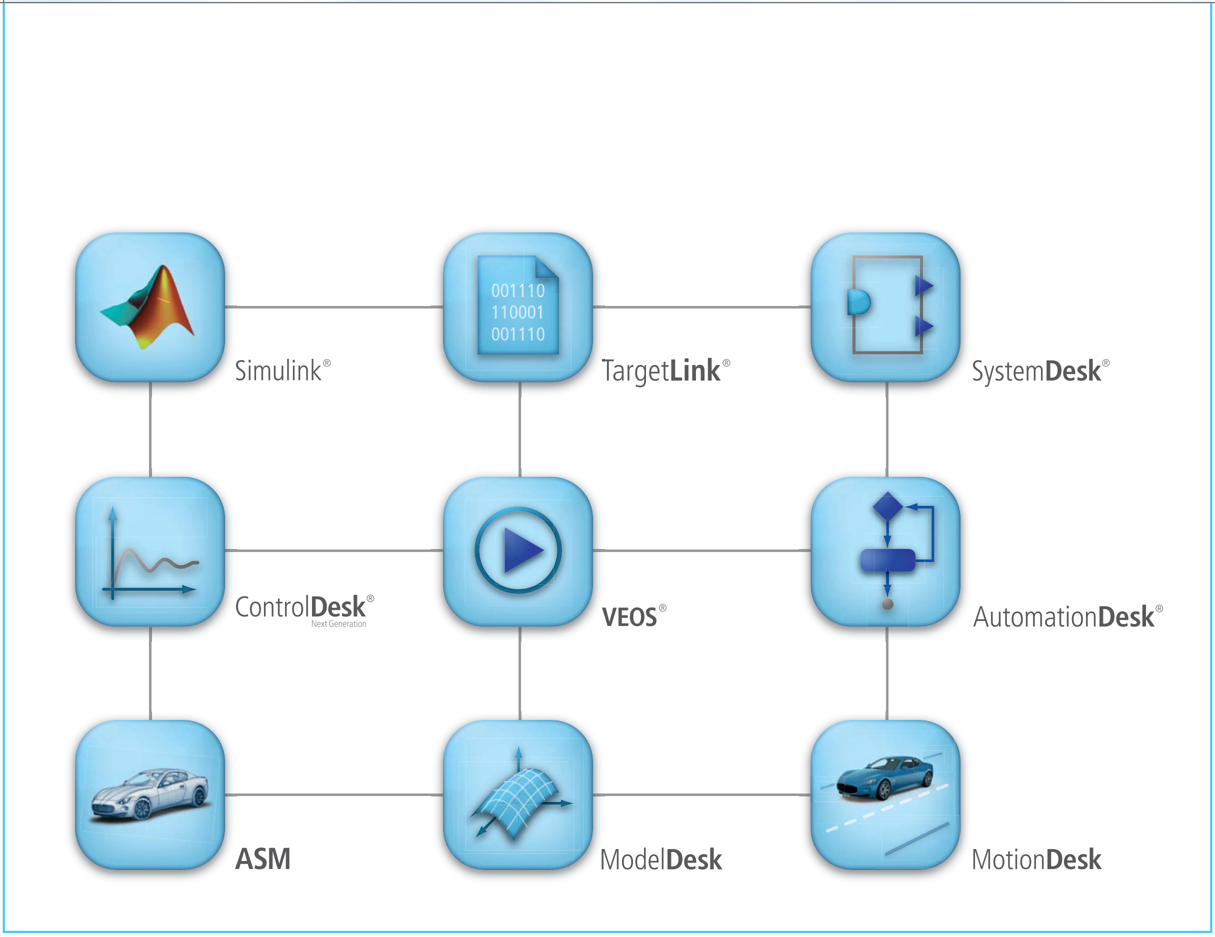
At present, data backbones for model-based development and ECU testing are an exception, rather than a norm in the IT infrastructures of OEMs and suppliers. The pressure to find a solution is revealed by what they are saying:

- "There's a risk that our engineers will sometimes lose track of things in the flood of data from different development phases."
- "We're having to work harder and harder to cope with the exploding number of software variants."
- "We need complete traceability to set up a safety-oriented development process according to ISO 26262."
- "My team spends too much time transferring data from one tool to another."
- "How can we store and retrieve specific data objects efficiently in model-based development?"
- "How can I find out which tests suit my ECU variant, so I don't waste time trying out unsuitable tests on the HIL test bench?"

Activities to find a solution to these challenges are underway in numerous companies. In many cases, this meant (and means) developing solutions in-house, often with only modest success. In-house developments very soon reveal their limitations when it comes to long-term maintenance, and when they have to be extended to meet new requirements. Existing tools for product life cycle management (PLM) and application life cycle management (ALM) cannot represent the artifacts of model-based development and the relationships between them with the necessary granularity. Function models, plant models (with varying modeling depths), source and object code, parameter sets, signal descriptions, topology/architecture descriptions, AUTOSAR objects, test scenarios, test scripts, test results and stimuli are all typical data objects of the MBD process that have to be managed with their contextual semantics.

Example of a Requirement: Data Management for Models

Simulation models are a good example of an MBD object to present requirements for a data management solution. Model properties, such as interfaces, parameters, and variant validity, as well as user-specific data, have to be stored with the necessary fine granularity so that models can be assembled for simulation, ECU testing or software builds. It will not be



Tool chain for virtual validation.

possible to reuse a model across all levels, from the integration model at vehicle level down to individual blocks in a library, unless we stop treating it as a black box and instead use modularization and a hierarchy to represent its insides. Traceability requires that a model part or a signal on any hierarchy level can be linked through to the requirement that its specification is based on.
Similarly, for test automation, it might be necessary to make the usability of a test variant conditional on the value of a specific model parameter. This goes far beyond the file-based storage of models and tests used by current configuration management systems.

Data Management in Model-Based Development

SYNECT® is a new dSPACE product currently evolving as a solution for these requirements. With integrated variant management, it supports the management of tests, models, and other entities. Engineering tools for tasks such as creating and editing models, autocoding, and test development are connected to SYNECT so that defined, consistent data versions are available for daily work and can be fed back to the data base in a controlled manner. SYNECT can also be integrated into an existing IT infrastructure. Data exchange between SYNECT and tools such as ALM/PLM will be established via interfaces like Open Services for Lifecycle Collaboration (OSLC). Bidirectional traceability can be implemented as fine-grained as necessary. For example, the relationships between requirements and items derived from requirements such as function models, tests and test results can be completely documented according to ISO 26262. The result is considerably improved data consistency, more efficient collaboration, and easier data reuse throughout the entire development process.

Validation Strategies with Virtual ECUs

To achieve a high level of validation in the virtual world, there must be

early, continuous software integration of the ECUs involved, allowing them to be tested individually or in a network as "virtual ECUs" in a PC simulation with realistic environment models. This will give engineers a feel for the performance of complex, multi-ECU functions at a very early stage. Errors in the control strategy or software implementation will be detected early (saving time and money). Because the simulation does not have to run under real-time conditions, more detailed environment models and more complex simulation processes can be used than on a HIL test bench, so functions can be optimized with maximum realism.

Models are already configured, parameterized and validated on the PC. All the models, tests and data can then be reused on a HIL test bench with the same tools, so that the HIL system is no longer tied up with "unproductive" tasks such as test development.

Seamless Transition to Testing Real ECUs

Virtual ECUs can run alongside real ECUs on the HIL test bench as substitutes for real ECUs that are unavailable, or even as devices under test. All the virtual ECUs in the ECU network can gradually be replaced by real ECUs, making the transition to testing the real ECU network

Virtual validation brings time and cost benefits.

extremely smooth. This kind of integrated tool chain for testing both virtual and real ECUs enables OEMs and ECU suppliers to define and roll out new validation strategies. The potential benefit to automotive software development of this new addition to test methods has already been demonstrated in initial projects carried out with vehicle manufacturers. ■

The VEOS Simulation Platform

For virtual validation, dSPACE offers VEOS®, a PC simulation platform for virtual ECUs, distributed functions and environment models. Virtual ECUs are typically generated from software components, according to the AUTOSAR standard, but can also be created directly from Simulink®/TargetLink® function models. Basic software modules such as services, the operating system, and communication stacks can be added in order to represent ECU behavior realistically. Environment models from different modeling tools are integrated via the new Functional Mock-up Interface (FMI) standard. What makes PC simulation particularly efficient and powerful is that all the test and experiment tools that are available on a HIL test bench can also be used in conjunction with VEOS. Extensive simulation runs and tests are developed in the usual tool environment and implemented and executed on a PC.

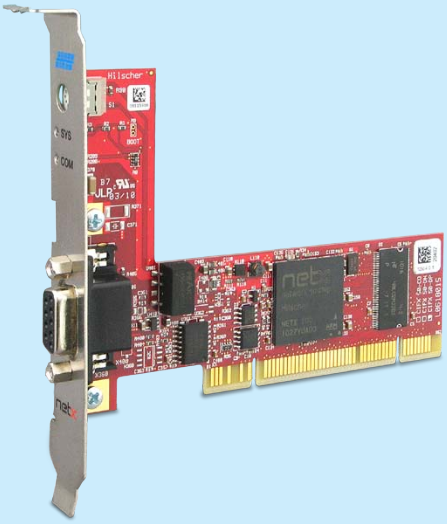
Dr. Rainer Otterbach,
dSPACE

Conclusion

With the enormous growth in the number of high-quality, software-based vehicle functions, new approaches to mastering complexity are needed in order to maintain or even increase the productivity of automotive software development in the future. Active data management and virtual validation strategies are two effective approaches that build on current state-of-the-art model-based development and have great potential for further optimizing development processes. At dSPACE, we look forward to setting out on new roads to innovation with our customers and to introducing requirements-driven solutions based on our new products SYNECT and VEOS.

Dr. Rainer Otterbach
Dr. Rainer Otterbach is Director of Product Management at dSPACE GmbH.

SCALEXIO Field Bus Solution for HIL Simulation



The new dSPACE SCALEXIO® Field Bus Solution lets you connect a SCALEXIO hardware-in-the-loop system to various field bus types, such as Profibus and EtherCAT. The solution is based on a PCI card, which is plugged into the SCALEXIO processing unit to provide the optimal bandwidth to the real-time model. Specially developed device drivers ensure real-time simulation capability. Different licenses are required according to the type of field bus. Configuration is performed in dSPACE ConfigurationDesk®.

Connection to Profibus

- Bus master and slave supported
- Cyclic data exchange by selectable bus cycle time
- Profibus-specific settings performed in SyCon.net

Connection to EtherCAT

- Bus master and slave supported
- Cyclic data exchange by selectable bus cycle time
- Bus-synchronous interrupts
- Distributed clocks
- EtherCAT master bus cycle 500 µs or larger
- EtherCAT slave bus cycle depending on the EtherCAT bus master

Virtual Pneumatics for Brakes and Suspension

Beginning in early 2014, dSPACE will offer simulation models for pneumatic brake and air suspension systems. The ASM Pneumatics model library expands the **Automotive Simulation Models (ASM)** product family by realistic brake simulation for commercial vehicles and for comfort functions in passenger cars. The model library targets design and test of electronic brake systems (EBS), pneumatics control units and control units for level control. ASM Pneumatics adds a complete realistic pneumatics system to the models for passenger vehicles (ASM Vehicle Dynamics), trucks (ASM Truck) and trailers (ASM Trailer).
The virtual pneumatic system contains a number of click-selected, ready-to-use configurations for the simulation of air brake systems and air suspension systems. Case-specific parameters can be assigned via a graphical user interface. All models, parameter sets and simulations are handled with one single tool. This results in consistent data handling from offline simulation to hardware-in-the-loop (HIL) simulation.
Modelled after real-world pneumatics systems, ASM Pneumatics is furnished with typical pneumatics components like compressor, tanks, valves, and brake chambers. The model supports fall-back functions to a purely mechanical/pneumatical brake system.
In addition, ASM Pneumatics supports stringing together multiple trailers, thus enabling the configuration of Road Trains, equipped with pneumatic brakes.

MicroAutoBox II: More CAN, More Analog, More Applications

MicroAutoBox II is now even more able to provide the higher number of CAN channels required by engineers to prototype advanced controls systems for electric/hybrid drives. Additionally, increased analog input and output channels (I/O) address the requirements for advanced emission control applications for combustion engines. The new DS1513 I/O board for MicroAutoBox II increases the number of CAN channels to 6, and analog I/O to 32 ADCs and 8 DACs. These I/O interfaces can be easily configured via a user-intuitive dSPACE Real-Time Interface (RTI) blockset in the Simulink® environment. The CAN messages and communication strategy can be programmed using the RTI CAN or RTI CAN MultiMessage Blockset. The DS1513 hardware is designed to meet future requirements for partial CAN networking. This feature will enable engineers to prototype energy optimization strategies by allowing selective switching of CAN nodes. The software functionality to benefit from this hardware capability will be included in a future dSPACE release. The DS1513 I/O board can be combined with a freely programmable FPGA to help prototype software functionality requiring very high-speed computation. Connection to the optional Embedded PC enables further functionalities to integrate various new sensors required for developing advanced driver assistance systems controllers. MicroAutoBox II with this new integrated DS1513 I/O board will become available in early 2014. ■

Switch to Python 2.7

In response to growing demand from customers, in Release 2013-B dSPACE has switched the Python interpreter used by its software tools to the current version, Python 2.7.5. dSPACE decided to use the Python 2.7.x development series because unlike Python 3.x, it is essentially compatible with Python 2.5, the previously supported version. At the same time, dSPACE has integrated the standard Python installations and the provided Python libraries so that users can make updates and implement extensions themselves.

These changes give users the following advantages:

- They can add/remove Python packages.
- They can install current Python extension modules.
- They can use language extensions.
- They benefit from bugfixes.
- It is compatible with current operating systems.

For helpful information on the switch to the new Python version, including incompatible changes and ways of handling them, refer to:

http://www.dspace.com/go/Python27Migration ■

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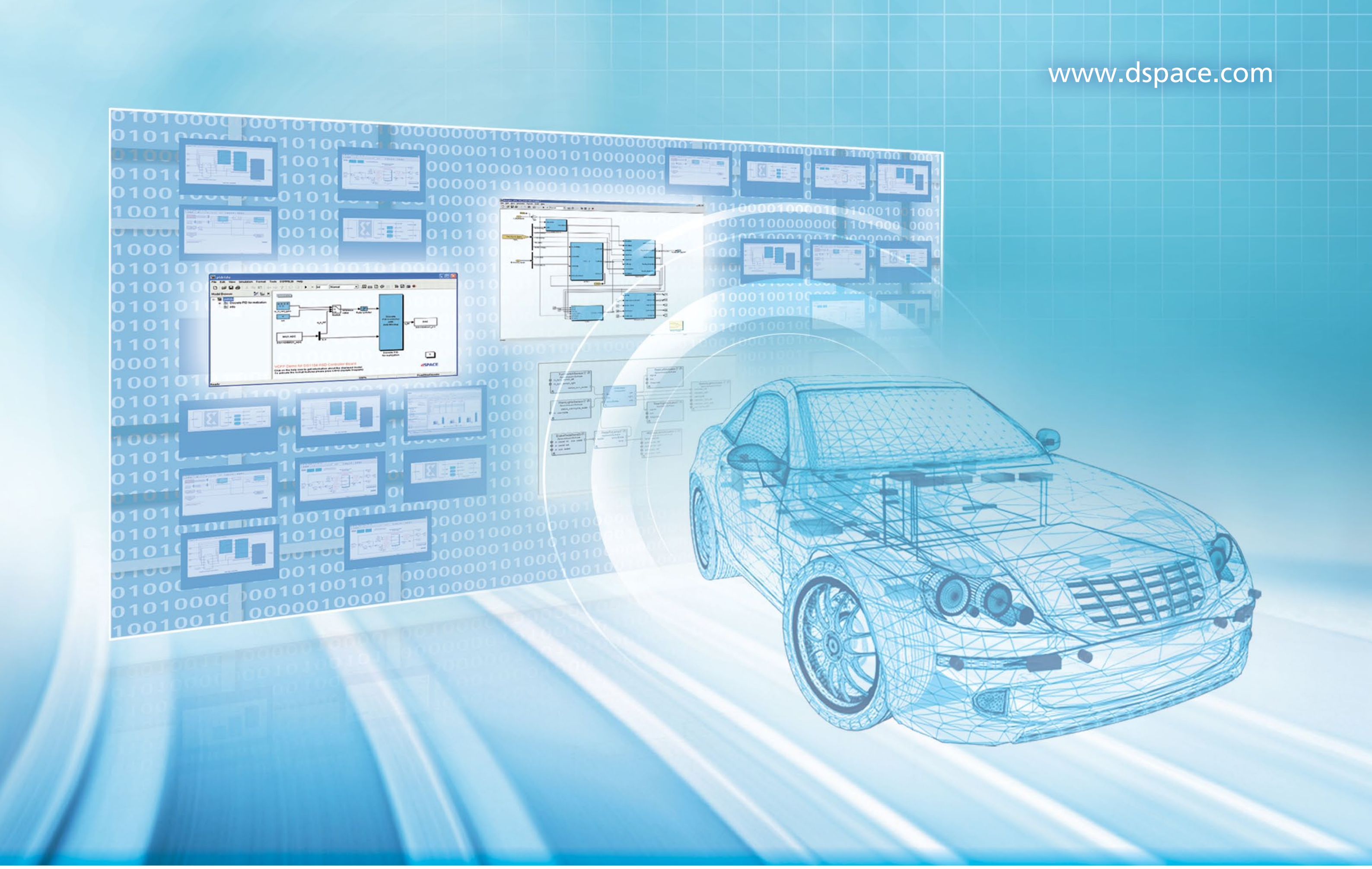
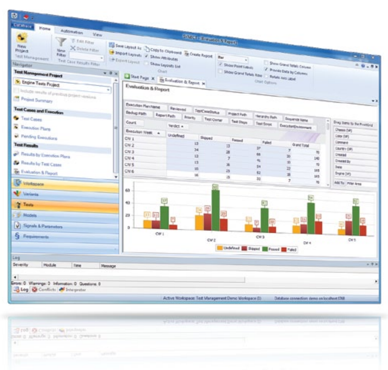


Get a Grip on Your Data with dSPACE SYNECT®



Your development data is your prime asset!

So why accept compromises when handling all your data: models, parameters, variants, tests and test results?

With SYNECT, the central data management tool from dSPACE, you can be sure that your data is consistent, traceable and easy to reuse – throughout the entire model-based development process. From requirements to ECU tests.

SYNECT – Your solution for efficient data management!

Embedded Success dSPACE