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dSPACE MAGAZINE

2/2017

Schlumberger

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The NAVYA ARMA is considered to be the world's first driverless production vehicle for regular traffic. The autonomous shuttle bus can carry up to 15 passengers and reaches a speed of 45 km/h. Fifty electrically operated vehicles have already been deployed for passenger transport worldwide. As of September 2017, they have safely transported 180,000 passengers. NAVYA is a French company specializing in designing electric, autonomous systems. For developing the complex autonomous driving functions, NAVYA relies on the multisensor development environment RTMaps from Intempora.

www.navya.tech

"The performance and ease of use of RTMaps have played a decisive role in prototyping, testing, and benchmarking perceptual and data fusion algorithms for our level-5 autonomous driving system."

Pascal Lecuyot, R&D Director - Perception, NAVYA

Picture credits: © NAVYA, Valentin CHETELAT

"Whether over the air or virtually and in parallel – dSPACE offers powerful test solutions for the challenges of tomorrow."

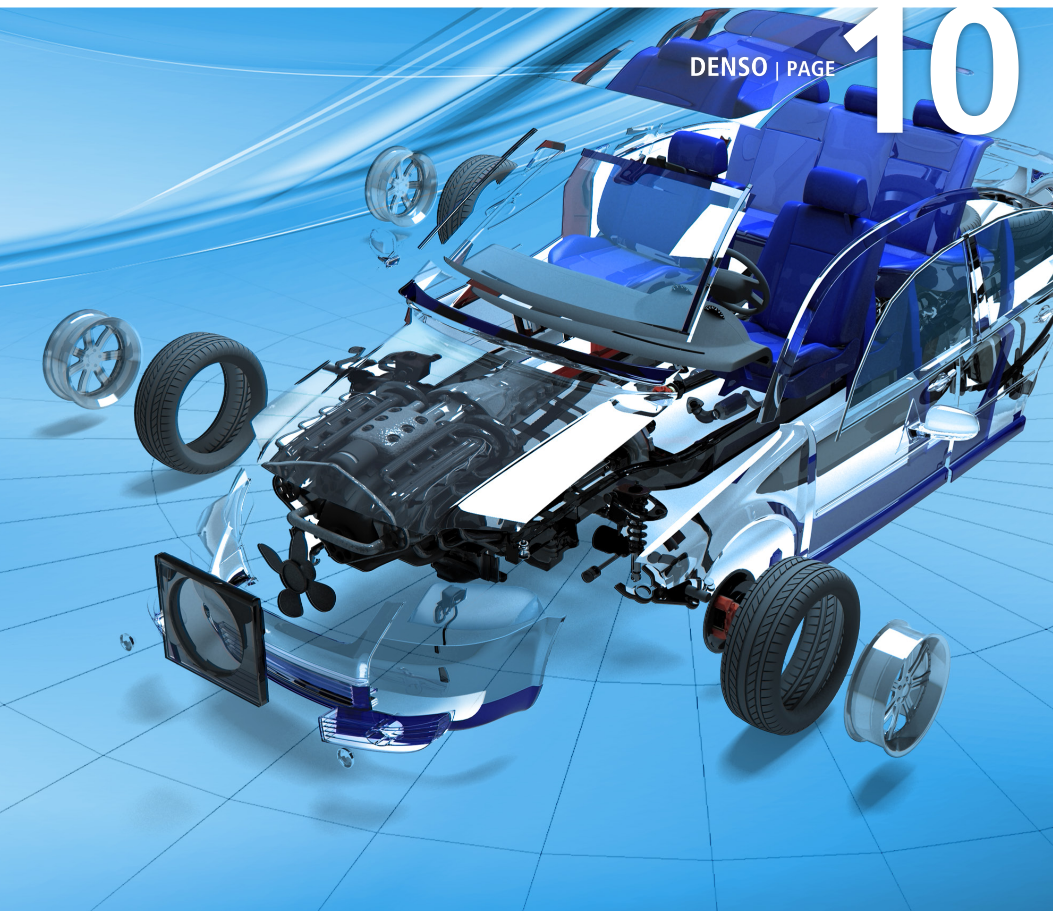
The automotive industry would already have enough on its plate if it only had to concern itself with the regular technological advances and adhering to emission regulations. Now, autonomous driving also has to become possible. ASAP. It seems to me as if society, politics, and the industry itself are already overwhelming the development departments with excessively high demands, all of which have to be met at the same time. Technical experts are scarce. Existing electronic architectures no longer suffice. All development goals have to be achieved, but only few people know how. The heat is on.

At dSPACE, we can tell by the growing demand for our existing products and solutions. At the same time, entirely new tasks arise on the spot, spurring us to give our best to develop suitable solutions.

One example is testing driver assistance systems and systems for autonomous driving. How can you test the integration of a radar sensor in the vehicle system on a hardware-in-the-loop test bench in the lab? Without intervening with the sensor, when this is not desired or possible? We took an important first step together with one of our partners. You can read more about it on page 48. Today, it is already possible to simulate multiple target vehicles "over the air" at the same time. But we are also aware of the even larger challenges that await, because the sensor technology is making rapid advances toward imaging processes with new sensor technologies. We are already addressing these new demands by extending our ASM simulation tool suite so you can now simulate the sensor signals that occur in driving scenarios. After all, not everything happens "over the air". In particular, these virtual approaches are needed to execute a high number of simulations faster than in real time and in parallel. dSPACE is making this possible with VEOS while the complex test data is managed in SYNECT.

Many customers tell us: The development tasks are multiplying at an unprecedented speed. Therefore, dSPACE also has to grow and invest in the future in the same manner. We are prepared to take on this challenge.

Dr. Herbert Hanselmann



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Simulating extreme environmental conditions for control units

Intelligent Drilling

Temperatures of up to 200 °C and pressures of up to 1,500 bar, all this thousands of meters beneath the earth's surface – these are potential conditions in mineral oil and natural gas reservoirs. Because electronic controllers must be robust and reliable in this environment, Schlumberger uses dSPACE's MicroLabBox to simulate these harsh conditions during development.

Deeper, wider and faster – these are the requirements for drilling wells to develop new mineral oil and natural gas fields. At the same time, the geological conditions are becoming increasingly complex, because easily accessible oil and gas reservoirs have already been exploited. This raises the demands for drilling technologies. Schlumberger, one of the world's leading service providers for exploration and production in the oil and gas industry, uses innovative drilling technologies to access reservoirs that could not be exploited until now. The company invests intensively in research and development to improve the efficiency and reliability of the tools used.

Detour to Destination

For the last few decades, with advancement in drilling technologies such as rotary steerable systems and monitoring while drilling systems, mineral oil and natural gas were no longer extracted with only the classic vertical drilling methods. Increasingly, directional and even horizontal drilling are being used. Although the latter two technologies are more complex, they increase the yield and allow for greater flexibility with regard to the drilling location. This means reservoirs that are normally hard to reach can now be exploited. Therefore, one production facility that allows exploitation of multiple wells or different reservoirs is often enough. This reduces costs significantly, especially in offshore drilling (figure 1). Drilling along severe side slope poses risks associated with horizontal directional drill (HDD) since you cannot run in defined rock layers or soil strata. It is difficult to drill the borehole when intercepting strata at low angles, which can create deflection of the borehole and steering misalignment. However, this means the drill string must be stopped whenever there is a change of direction. For "intelligent drilling", multiple adjustable bias units are placed close to the drilling head (steering actuator pads, figure 2). To ensure that the adjustment leads to the required drilling direction, sophisticated control electronics are used.

Information from the Depth of the Earth

In addition, these drilling systems can be equipped with modules that gather various types of information about the surrounding rock and fluids during the drilling process (logging while drilling, LWD). In previous years, only data such as pressure and temperature could be determined (measurement while drilling, MWD). To improve the existing drilling technology, Schlumberger uses a test environment that consists of dSPACE tools with which the control algorithms for the drive of the steering actuator pads at the drilling head can be

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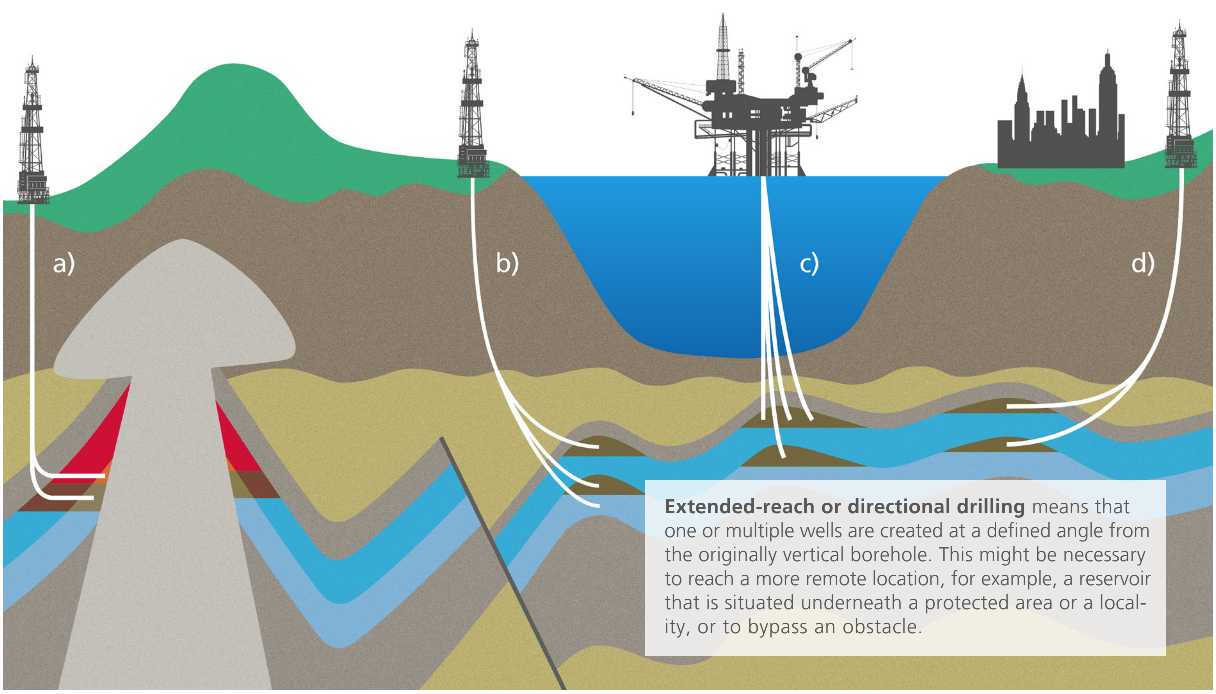


Extended-reach or directional drilling means that one or multiple wells are created at a defined angle from the originally vertical borehole. This might be necessary to reach a more remote location, for example, a reservoir that is situated underneath a protected area or a locality, or to bypass an obstacle.

Figure 1: Examples of directional wells (red: natural gas, dark brown: mineral oil): Bypassing a geological obstacle (a), production from reservoirs that are not vertically below a production facility (a, b, d), production from multiple reservoirs through one borehole (a, b, c, d), using multiple wells with one production facility (c).

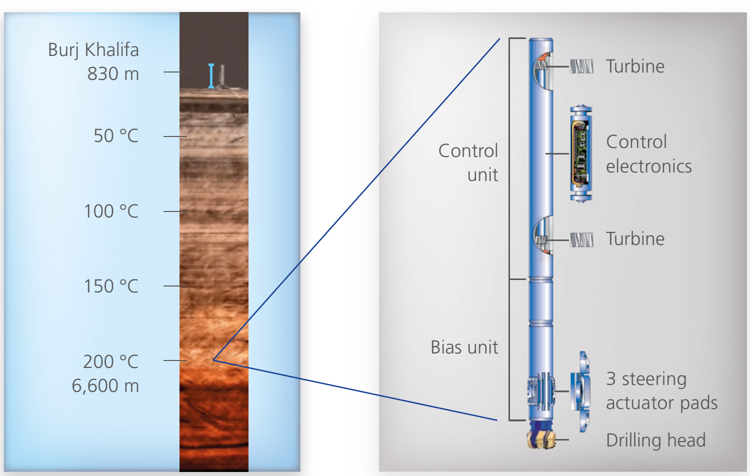
developed and optimized in the lab under the same thermal, pressure, and working fluid conditions as the while-drilling environment. "This testing platform provides engineers with real-time information that lets them make important decisions with regard to the continued drilling path or zoned production tests," says Dr. Mustafa K. Guven, Electrical Machinery and Controls Division at Schlumberger.

The Environment – Pressure, Heat, Vibrations

"One of the biggest challenges when accessing oil and gas reserves are the extreme environmental conditions in the reservoirs," Guven resumes. Heat, pressure, and vibrations as well as geomechanical stress influence the durability of the expensive electronic equipment. Several data acquisition modules that are attached close to the drilling head transmit data to report its position and location to the surface in real time and enable the drilling team to precisely drill towards the reservoir. For this, the reliability of these data acquisition modules and the electronic control units (ECUs) is decisive.

If control units or sensors fail during the drilling process, either the drill string has to be pulled out of the borehole, which is costly and time-consuming, or the data is so inaccurate that the team will not be able to reliably get to the reserve. Additional costs reaching millions of dollars or the complete failure of the drilling program become a possibility.

Figure 2: Position of the control electronics and the control pads near the drilling head.



Directional Drilling – Getting to the Point with dSPACE

The Challenge:
Extreme conditions in an environment that is not accessible require robust and reliable equipment that is maintenance-free during operation.

The Solution:
Creating a test platform for control unit development that can simulate the conditions of a reservoir during an active drilling process in the laboratory.

The Benefit:
Control units can be developed and tested without risk and without cost-intensive disassembly.

Testing in a Reservoir Environment

To reduce the risk of losing time and incurring exorbitant costs, Schlumberger uses engineering methods, such as the failure mode effects analysis (FMEA), reliability qualification testing (RQT), and computer simulation. These methods help predict the maintenance requirements of systems, components, and prototypes. Schlumberger is currently developing a prototype drive for the laboratory, the D3S (figure 3). D3S stands for DEMT Development Drive System, where DEMT means Down-hole Electric Machine Technology. The drive system is intended for supporting the development and test phases of individual components and complex systems. D3S is a flexible drive system with state-of-the-art electronic hardware. It includes a dSPACE MicroLabBox as the tool for rapid control prototyping (RCP). "The system offers a platform for testing and optimizing the controller software as well as for setting parameters in real time," explains Guven.

Building an Efficient Test Platform

By building an efficient test platform, Schlumberger achieves multiple goals at the same time. The platform determines the performance and the behavior of engines in the environmental conditions of a mineral oil or natural gas reservoir. Among others, parameters such as torque, rotational speed, and efficiency can be evaluated. The platform also tests and evaluates the sensors of the engine drive and generates algorithms for developing the model-based control unit. According to Dr. Guven, this is to help the engineers ensure that validation is performed during the early phases of tool development, before the electric drive components become

"Several kilometers below the earth's surface, the reliability of all components is vital, because every failure costs millions of dollars. dSPACE MicroLabBox emulates the real, often harsh, conditions at great depths and thus supports testing and validating the controller during development."

Mustafa K. Guven, PhD, Principle Engineer at Schlumberger Ltd., Sugar Land, Texas, USA, is responsible for developing a new tool for testing machines and generators as well as for writing the relevant control algorithms as part of the Electrical Machinery and Controls – 3MT project.

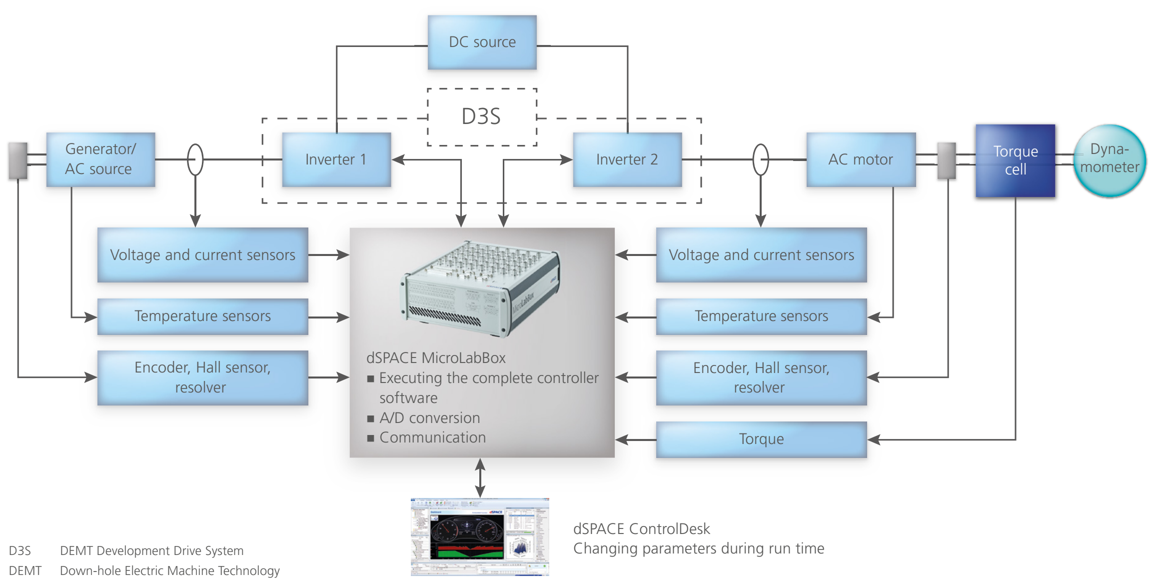
available. The MicroLabBox not only serves as a main I/O interface for communication between peripherals (actuators, sensors, etc.), it is also the central computation unit for executing the controller software. dSPACE Real-Time Interface (RTI) is used for the model-based I/O integration and dSPACE ControlDesk helps access the real-time applications during run time.

Tackling Test Obstacles

Before the D3S drive system, Schlumberger had no standard platform for testing new electromechanical drive systems. There was also no defined optimization process that helped coordinate individual tasks. In addition, only few control electronics were available to support the evaluation and validation of new concepts and additional systems. The D3S, equipped with a MicroLabBox, made it possible for Schlumberger to successfully tackle many of these challenges. The D3S is currently in its development phase. Once this system is proven, it will be employed in every project that requires an electromechanical drive system. ■

With the kind permission of Schlumberger Limited

Figure 3: System configuration of the D3S with the MicroLabBox as its central communication system. Signals that are used for spatial orientation (incremental encoder, Hall sensor, torque transducer, and resolver) are digital, signals for temperature, voltage, and electrical current are analog.



Virtual Modeling Toolbox

Setting up an efficient tool chain for FMI-based development

Functional Mock-up Interface (FMI)

The Functional Mock-up Interface (FMI) with its variants FMI for Co-Simulation and FMI for Model Exchange is an open standard for the tool-independent exchange and joint simulation of plant models provided by different vendors. Both variants of FMI can be used to exchange models but they differ in their benefits and drawbacks for certain use cases. The main benefit of FMI for Model Exchange is the easier, numerically stable simulation of strongly coupled system parts (e.g., component submodels of a domain), because all the required information an external central solver needs for computing the simulation results is provided. FMI for Model Exchange therefore has a complex interface that requires a higher degree of compatibility and information exchange between the tools and partners in the tool chain. In contrast, the lean interface of FMI for Co-Simulation reduces the number

Long before the first prototypes start their test drives, a vehicle can already be driven and tested virtually. The FMI standard helps the developers of automotive supplier DENSO carry out such virtual test drives with a combination of diverse component models. The basis: simulation platforms by dSPACE.

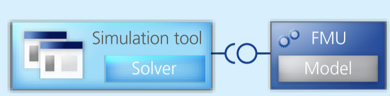
Today's vehicles are based on complex systems whose further development and integration require knowledge and models from different disciplines and domains. Having a virtual overall system that contains all individual systems is therefore becoming increasingly important in vehicle development. In addition to the technical challenges, the market expects ever shorter innovation cycles. The short time to market poses a particular challenge for the developers: Early tests of individual systems have to be performed in the system network before the hardware and software of all systems is complete and integrated with each other. This applies not only to the actual vehicle components, but also to the environmental conditions and driver behavior. These two factors play an important role for the behavior of the overall system.

Standardized Cooperation

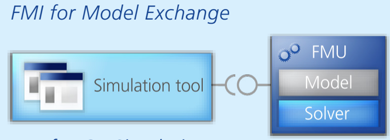
One solution is to simulate the plant models of all components and systems at the overall system level.

>>

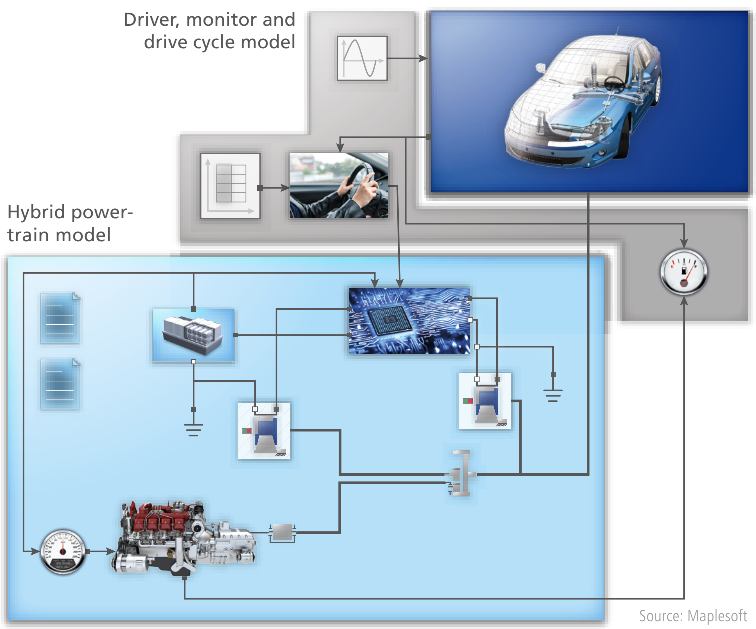
of potential compatibility issues in tool chains that include various types and versions of FMI-supporting tools by systematically separating the Functional Mock-up Unit (FMU) functions (including solver implementations) from the importing tool functions. Thus, co-simulation FMUs can transport verified combinations of solver code and model code, and make it easier to combine models of different physical domains and system dynamics.
www.dspace.com/go/fmi



FMI for Model Exchange



FMI for Co-Simulation



Setup of the commercial simulation model of a power-split HEV. The highlighted areas indicate to which domain models the overall system model is divided.

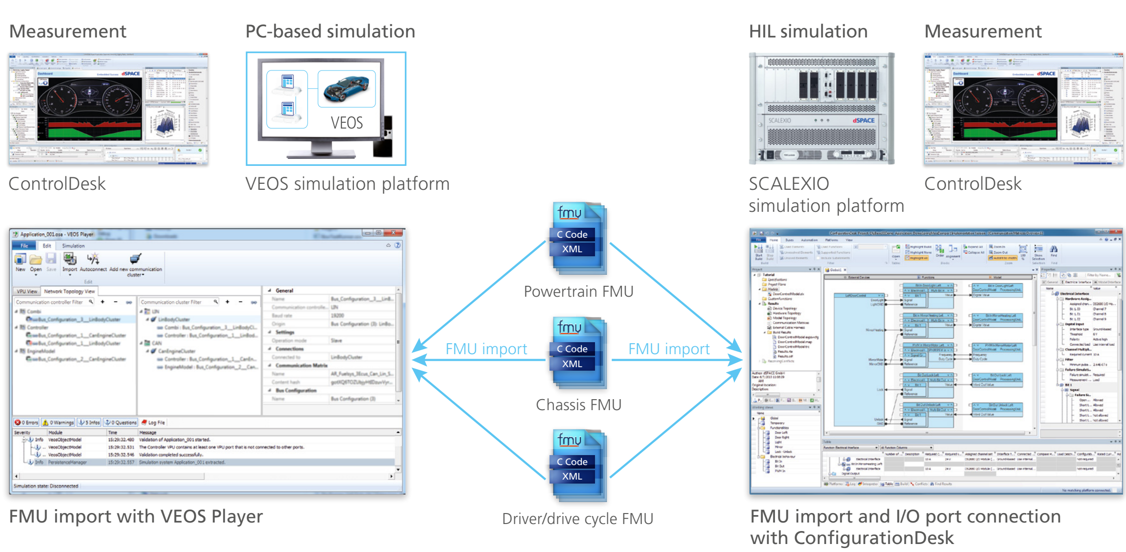
Since the available models usually differ in format and complexity, this requires a standardized intermediate level for easily combining the models. Therefore, the Functional Mock-up Interface (FMI) standard was established. The standard makes it possible to exchange models from different domains with different tools and simulate them together. To enable simulation, the models are prepared as standardized Functional Mock-up Units (FMUs), which contain the model implementation, its metadata, and the implementation of the FMI interface. The standard has two variants: FMI for Co-Simulation and FMI for Model Exchange. Both allow for model exchange but are based on different technological approaches.

Evaluating FMI with the Installed Tool Chain

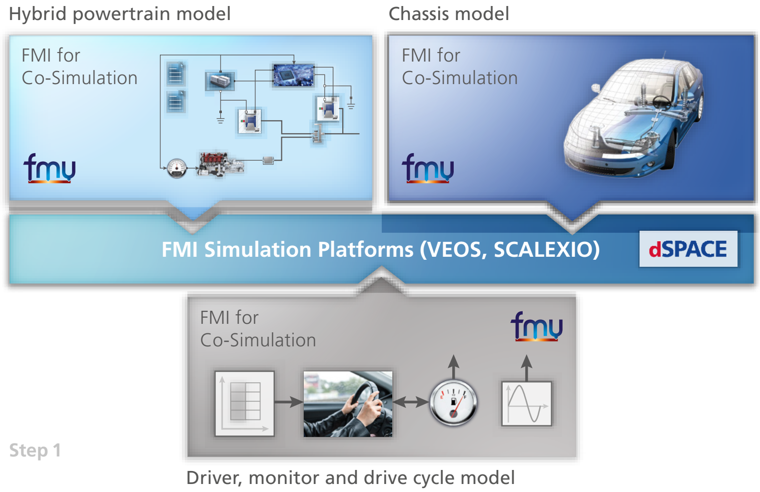
DENSO's goal was to analyze the benefits of an FMI-based approach for the development process. Taking into account the tool chain used by DENSO, two main methods were observed:

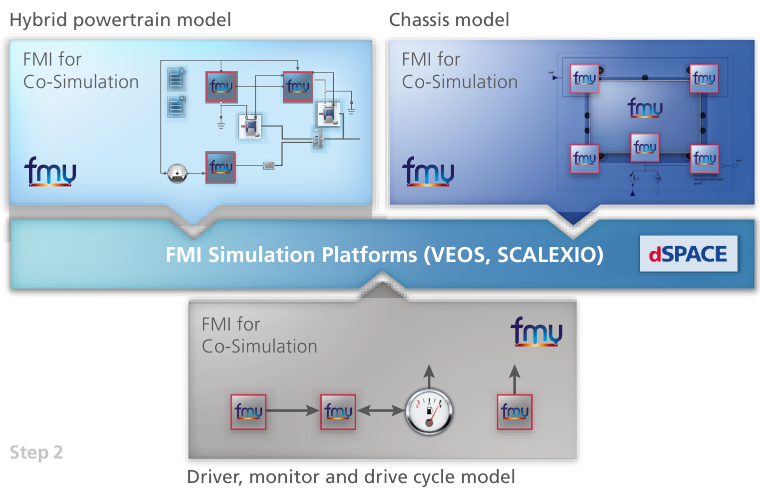
- In step 1, DENSO analyzed whether a vehicle model that is divided into multiple FMUs can be used for PC-based simulation with VEOS and for hardware-in-the-loop (HIL) simulation with SCALEXIO by reusing project parts, and whether the simulation results of the overall system model can be reproduced in this way. The FMUs were set up according to the FMI for Co-Simulation standard.

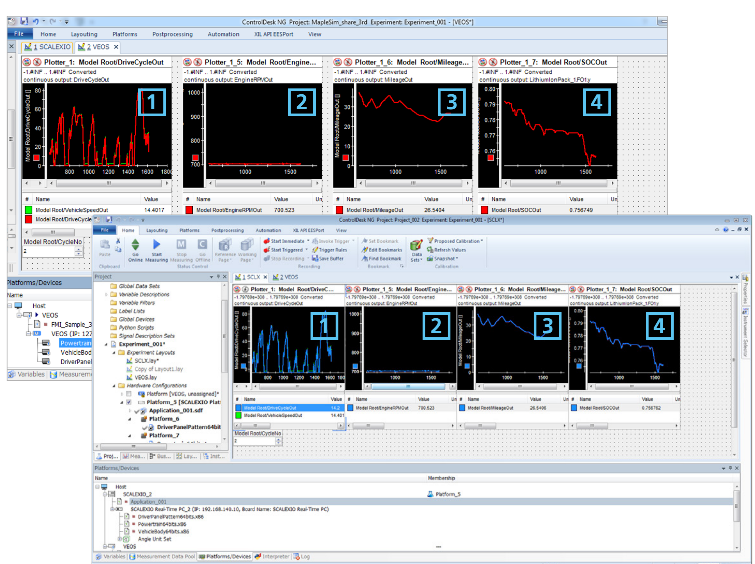
The prepared FMUs are integrated on the simulation platforms VEOS (left) and SCALEXIO (right).



Top: The overall system model is divided into domain model FMUs (FMI for Co-Simulation) and executed on the simulation platforms VEOS and SCALEXIO.
Center: Some individual component model parts are replaced by FMUs (FMI for Model Exchange) in the domain models. These domain models are exported as FMUs (FMI for Co-Simulation) and executed on the simulation platforms VEOS and SCALEXIO.
Bottom: Qualitative overview and comparison of the simulation results obtained with VEOS (red) and SCALEXIO (blue) in dSPACE ControlDesk. In the illustration: (1) Vehicle speed, (2) engine speed, (3) fuel consumption, (4) state of charge.







- For step 2, DENSO plans on first connecting multiple components, i.e., strongly coupled model parts of one vehicle domain that are modeled as FMUs, according to the FMI for Model Exchange standard. The resulting domain model will then be exported as an FMU according to the FMI for Co-Simulation standard. Finally, DENSO will check whether step 1 is possible.

The Evaluation Model

A commercial model of a power-split hybrid vehicle (power-split HEV) from the MapleSim® library was used for the analysis. Using this model makes it possible to check the suitability of the FMI-based workflow for existing overall vehicle models. The following terms are used to describe the model in more detail:

- *Overall system model:* The complete vehicle model consisting of multiple FMUs.
- *Domain model:* Model of a functional unit, e.g., the drivetrain consisting of the combustion engine, electric motor, transmission, etc.
- *Component models:* Models of the components that make up a domain, e.g., the transmission.

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> "We successfully implemented the model of a hybrid vehicle, which consists of multiple Functional Mock-up Units, on the simulation platform dSPACE SCALEXIO and simulated it in real time."
>
> *Fumiyasu Shirai, DENSO*

The power-split HEV model consists of the component models of an engine, a transmission, a throttle valve, a simple controller, a motor-generator, a battery, an inverter, the wheels, a differential transmission, and the chassis.

Preparing the FMUs

In the first step, the overall system model was divided into three domain models that were prepared as FMUs according to the FMI for Co-Simulation standard. The division into the hybrid system, chassis, and driver/drive cycle models was made to be able to assign each FMU to one dedicated processor core on a quad-core SCALEXIO Processing Unit. The fourth core is used for communication with the host PC.

Implementing and Evaluating the FMUs

The prepared domain FMUs were used first on the PC-based simulation platform VEOS and then, with identical parameterization, on the SCALEXIO HIL simulator. The aim was to check the correct function and the performance of the FMUs on both platforms.
All tests indicated a strong correlation between PC-based and HIL simulation, and they matched the simulation results of the overall system model in MapleSim. The complex, dynamic model can therefore be executed in real time, and the powerful SCALEXIO processor platform has even more reserves for more complex models, I/O, and bus simulation.

Seamless, Efficient Development

The dSPACE tool chain not only ensures continuous simulation and parameter access on both simulation platforms for the used FMUs. It can also be seamlessly used with other tools for HIL testing and virtual validation. This means that developers can reuse the real-time-capable FMUs as well as the associated tests and experiments with tools like dSPACE ControlDesk and AutomationDesk as well as the XIL API standard. This completes the FMI concept of easy, direct model reuse for both virtual validation and HIL testing, allowing for an efficient and seamless development process.

Using FMI More Broadly

DENSO will successively integrate the

> "The PC-based simulation platform dSPACE VEOS lets us frontload complex, FMI-based simulations to earlier phases of the development process."
>
> *Nobuya Miwa, DENSO*

FMI Models for SCALEXIO Multicore Processors

Real-time-capable Functional Mock-up Units (FMUs) of a wide variety of modeling tools can be integrated directly in SCALEXIO-based HIL projects. The FMUs can be integrated with further FMUs and other supported model formats to an overall model. To achieve the best possible computation performance, the FMUs can be assigned to specific SCALEXIO processor cores. With dSPACE Release 2017-B, SCALEXIO also supports the execution of multiple FMUs on one SCALEXIO processor core. By providing consistent support for the FMI standard with SCALEXIO, dSPACE offers an open system for integrating models from different sources.

> "The seamless dSPACE tool chain makes our FMI-based development process more efficient."
>
> *Satoshi Koike, DENSO*

insights of its experience with the power-split HEV model in the development of the simulation models. This will make it easy to exchange models in vehicle development projects that involve multiple parties. DENSO's aim is to prepare the existing component models of the vehicle under development as FMUs according to the FMI for Model Exchange standard and combine them to a domain FMU according to FMI for Co-Simulation. This approach makes it possible to combine the benefits of both variants of the FMI standard and thus set up a flexible, real-time-capable and numerically stable overall system model. ■

Satoshi Koike, Nobuya Miwa,
Fumiyasu Shirai,
DENSO CORPORATION

At a Glance

The Task

- Evaluating an FMI-based development approach.
- Using submodels from potentially different sources to simulate a complete automotive system.

The Challenge

- Implementing the FMI-based workflow on the installed tool chain.
- Ensuring an efficient development process.

The Solution

- Integrating FMUs on the simulation platforms VEOS (MIL/SIL-based) and SCALEXIO (HIL-based).
- The seamless and open tool chain from dSPACE enables the efficient reuse of the project data.

FMI/FMU: Functional Mock-up Interface/Unit
MIL/SIL/HIL: Model-/software-/hardware-in-the-loop

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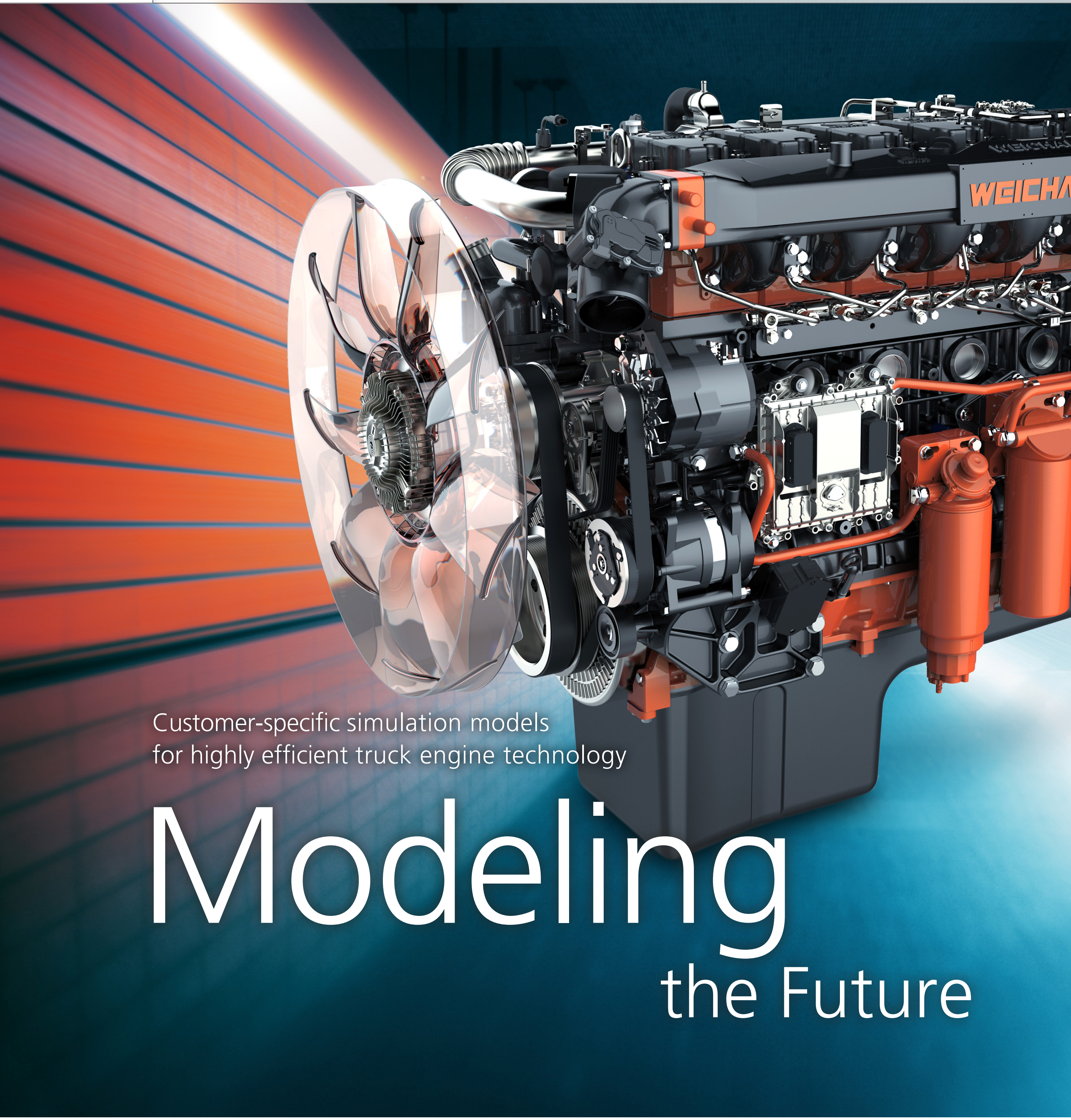
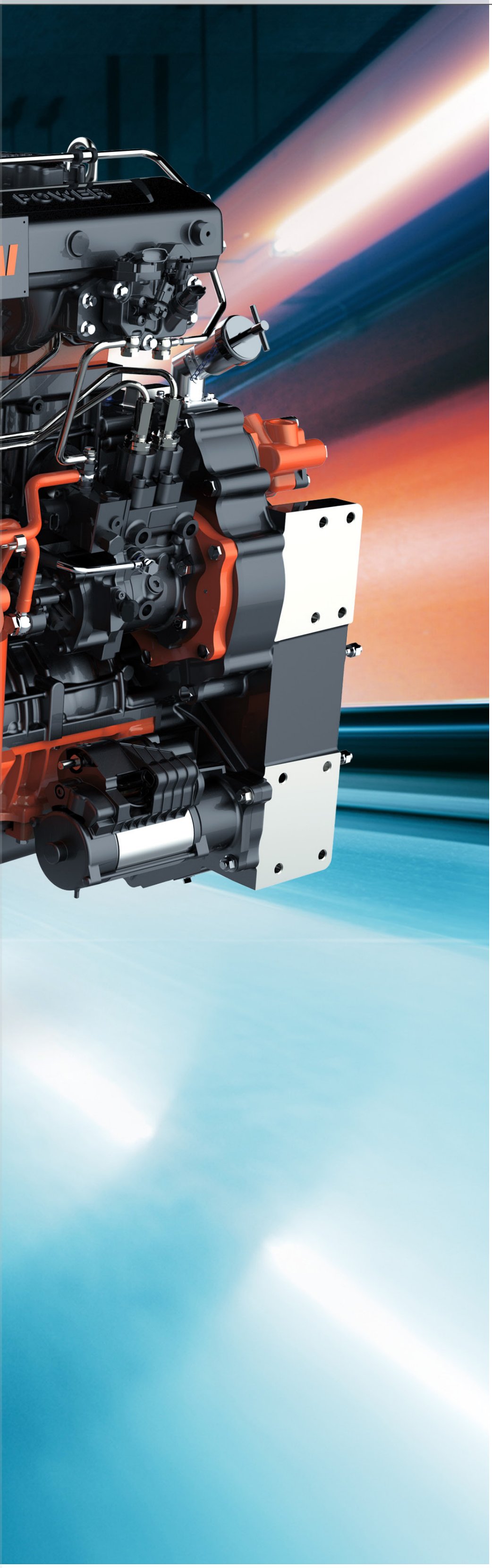


Customer-specific simulation models for highly efficient truck engine technology

Modeling the Future

To meet new requirements for the exhaust behavior of combustion engines, the relevant development and test environments have to be continuously developed as well. For new engine generations, Weichai therefore uses dSPACE Automotive Simulation Models and dSPACE SYNECT.



Since the emission regulations for passenger cars and trucks are becoming stricter, the controls for diesel engines are becoming more complex. In addition to engine speed and torque, a growing number of emission-relevant factors, such as injection volume, nitrogen oxides and particulate emissions, have to be captured and controlled. To comply with the stipulations of the Euro VI standard, the Chinese engine manufacturer Weichai introduces numerous technological innovations for its existing Euro IV/V engines (figure 1). To precisely simulate these innovations in a hardware-in-the-loop (HIL) environment, the simulators for validating the electronic control units (ECUs) had to be modified to fit the new functionalities.

Models and Parameterization

In addition to its own models, Weichai uses the dSPACE Automotive Simulation Models (ASM) for engine modeling, e.g., the real-time-capable ASM InCylinder models. They can not only be used to simulate the in-cylinder pressure and the temperature in diesel engines. They can also perform specific calculations for fuel injection, such as an immediate calculation of the rail pressure (figure 2). Because the ASMs act as an open model library, dSPACE Engineering Services was able to precisely adjust them to the technological requirements of Weichai's latest engine generation. The ASM InCylinder model can also be parameterized in a way that lets it simulate various diesel engine variants (figure 3). These include inline engines with a fuel system, one air path, and one exhaust path, V engines with two air paths and exhaust paths, as well as V engines with two air paths and one exhaust path. Therefore, Weichai no longer has to change the entire model structure when it wants to test a different engine variant. The company only has to modify a few parameters.

Flexibility

In addition to the HIL tests for diesel engine ECUs, Weichai modifies the HIL simulators for developing and testing ECUs of alternative drives as well. This includes hybrid drives and compressed natural gas (CNG) engines, that comply with the Chinese emission regulations China IV and China V and are produced in smaller numbers. The simulation model used for the CNG engines is based on the ASM InCylinder Gasoline model, in which fuel and ignition systems as well as the air paths are adjusted to the real characteristics of the Weichai engines. Only little effort was required for the commissioning and parameteriza-

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> "With dSPACE SYNECT, we succeeded in significantly simplifying model management and test management."
>
> *Yupeng Wang, Weichai Technology Research Institute*

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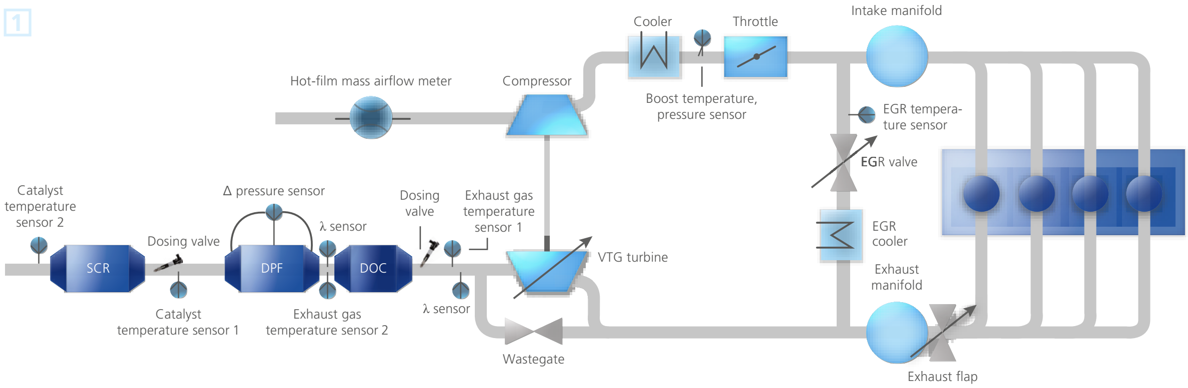


Figure 1: Technical diagram of Weichai's Euro VI diesel engine. A wide variety of components must be precisely controlled to comply with the more stringent emission regulations. This includes the throttle valve, the exhaust gas recirculation (EGR) valve, the variable turbine geometry (VTG) of the turbocharger, the diesel oxidation catalyst (DOC), the diesel particulate filter (DPF), and the selective catalytic reduction (SCR) of the exhaust emissions.

> "With the dSPACE HIL platform and the ASM tool suite, we were able to perform the many challenging ECU tests for the Euro VI engines of our fleet."
>
> *Hengfeng Yu, Weichai Technology Research Institute*

tion in order to use the models for HIL testing. The development of the HIL platform for testing engine ECUs of hybrid drives was similar (figure 4). Here, the ASM libraries and dSPACE Real-Time Interface (RTI) were also able to help increase the development efficiency, which resulted in a shorter time to market for new products.

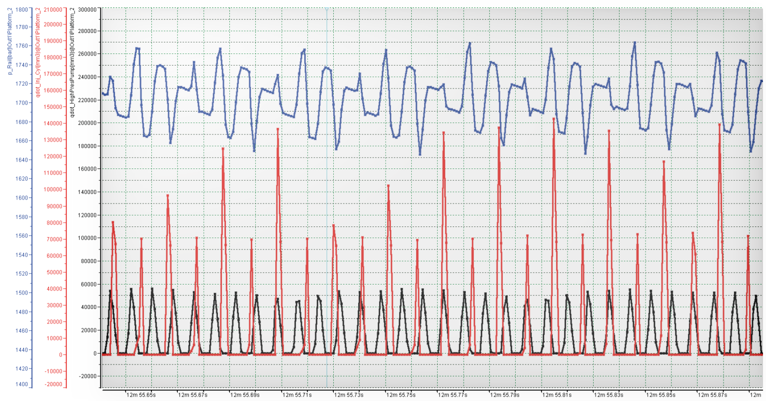
Test Management

In the past, the great variety of plant models, test cases, and test plans made it difficult to manage the data for the HIL test platform at Weichai. Now, with the centralized management of data in dSPACE SYNECT, the developers are supported in their day-to-day work (figure 5). In SYNECT, Weichai manages all HIL plant models for diesel engines, CNG engines, parallel and power split hybrid drives as well as drives for heavy construction equipment. Even tests for the same ECU can vary between the individual development phases, depending on the test requirements, test plans, and test cases. This is why Weichai prepared specialized test cases for each function and created its own test plans to implement an efficient test process. In dedicated test projects, the engineers used SYNECT to collect all data required for each ECU to be developed, from the basic test plans to the final reports on the results of the various tests. The results are particularly useful for assessing the test status, progress,

Yupeng Wang
Yupeng Wang is the director of the Test Validation department at Weichai Technology Research Institute in Weifang, China.

Hengfeng Yu
Hengfeng Yu is an engineer in the Test Validation department at Weichai Technology Research Institute in Weifang, China.

Figure 2: The model modified by dSPACE Engineering Services for the customer now allows for an immediate calculation of the rail pressure, among other things.
Figure 3: The ASM InCylinder model can be parameterized to represent different combustion engine designs.
Figure 4: Setup of the HIL Test platform for Weichai hybrid drive ECUs.
Figure 5: dSPACE SYNECT helps the developers at Weichai manage the high volume of test and model data sets.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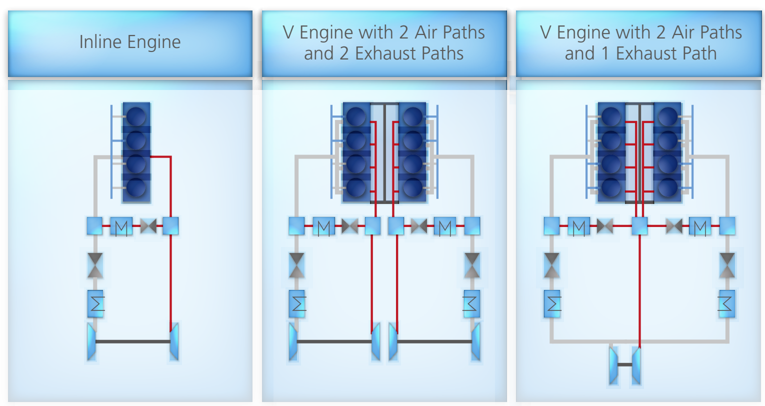

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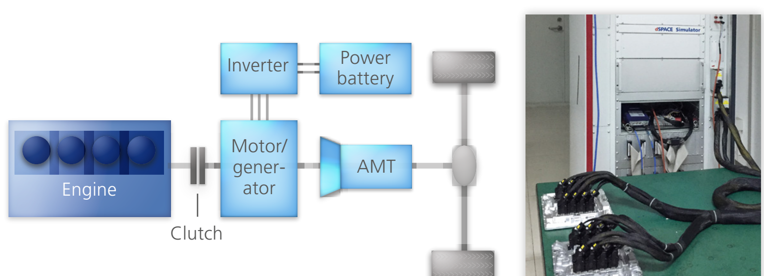

AMT = Automated Manual Transmission

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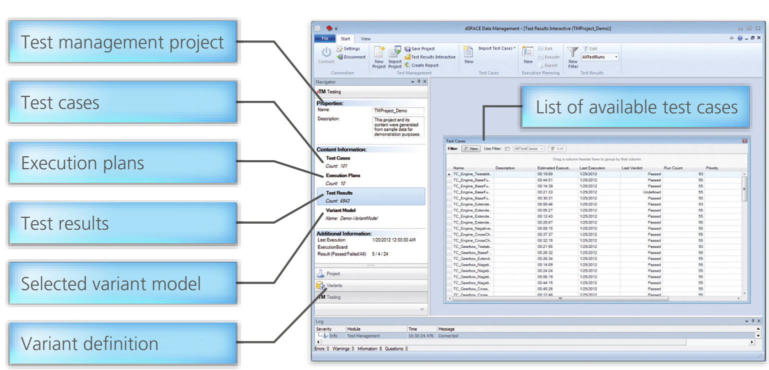

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and quality. Weichai defined different roles for the team leader and all engineers involved in the development to regulate the access to the HIL test data. In SYNECT, each role has individual read/write privileges for the HIL system, the test case, and the test implementation.

Conclusion and Outlook

With the dSPACE HIL platform, Weichai was able to meet all the requirements for the ECU tests of Euro VI engines. The support of dSPACE Engineering Services made it possible to implement more specific requirements in a customer-specific model. The dSPACE ASM models, which can be adapted for different model variants, were easy to integrate into the models developed by Weichai. Moreover, the use of dSPACE SYNECT made model management and test management much simpler. Therefore, the engineers were able to use the dSPACE tools to establish their own processes for plant model development and parameterization with little effort. Finally, the dSPACE HIL platform gives Weichai more flexibility, which not only reduces the time to market for new conventional combustion engines but is also suited for alternative drives, such as CNG and hybrid drives. ■

Yupeng Wang, Hengfeng Yu,
Test Validation Department,
Weichai Technology Research Institute

Setting up a closed-loop test system for precisely controlled fuel injectors

The Perfect Dosage

In gasoline engines, the prerequisite for efficient combustion is a perfectly adjusted air/fuel mix. Continental has developed a new controlled injection system that always provides the exact fuel quantity needed throughout the entire life cycle of the engine. A test system from dSPACE enables precise testing in the lab.

Stricter emission regulations lead to new challenges when developing spark-ignition engines. Therefore, new, innovative approaches in technology are necessary to help comply with ever more stringent emission thresholds. A particularly relevant aspect for the ideal air/fuel mix and efficient combustion is the exact dosage of the required fuel quantity. This process uses electrically controlled injectors that provide the needed fuel quantity by varying the opening and closing intervals of the nozzle. The intervals and current levels of the injector control influence the injection process. The fuel pressure also contributes to lifting the injector needle. The classic injection processes use precontrolled injection where the opening and closing intervals of the injector are determined by the electronic engine control unit (EECU). However, mechanical manufacturing tolerances and the aging of the injector cannot be captured and corrected with this injection method. Thus, the actual opening intervals can vary over time, which leads to measuring variances. The automotive supplier Continental has now developed a process that helps measure and control the opening intervals and the injected fuel quantities.

Precise Injection with COSI

The sensorless evaluation system called Controlled Solenoid Injection (COSI) is specifically used to detect the closing time of the injector. The basis for this is the position-dependent inductivity, which is created by the injector coil and the moving injector needle. If the needle touches the needle seat, a characteristic current profile can be measured at the coil. The difference between the desired and the measured closing interval is used by the controller as the control deviation to determine the opening interval for the next power stroke. This type of control allows for even minute injection quantities with minimal tolerances. This significantly improves the fuel injection and stabilizes the combustion process. Both aspects are maintained throughout the complete life cycle of the components because of an adaptive control process.

Validation Requirements

The validation of the EECUs with COSI function requires functional software tests for detecting the injector opening intervals. For this, the characteristic voltage and current curves of an injector under pressure must be simulated. It is not sufficient to use substitute loads or real parts because they are generally used for dry tests, in which no fuel is used. This means, the pressure variances in the intake manifold or the cylinder that are caused by fuel injection do not occur. Therefore, it is necessary to find a solution that can simulate the electric behavior of the injector in real time, taking into consideration the operating pressure at each working point of the engine. A special challenge is the extremely short opening intervals of the injectors that last only a few milliseconds. Because in this range of minute quantities even minor variances of the components used are relevant, the test solution must be sufficiently flexible with regard to their simulation but also easy to handle.

Tests with Virtual Injectors

The validation of EECUs is typically performed with hardware-in-the-loop (HIL) simulators. Therefore, it is only natural to aim for an expansion of the HIL simulators to test the

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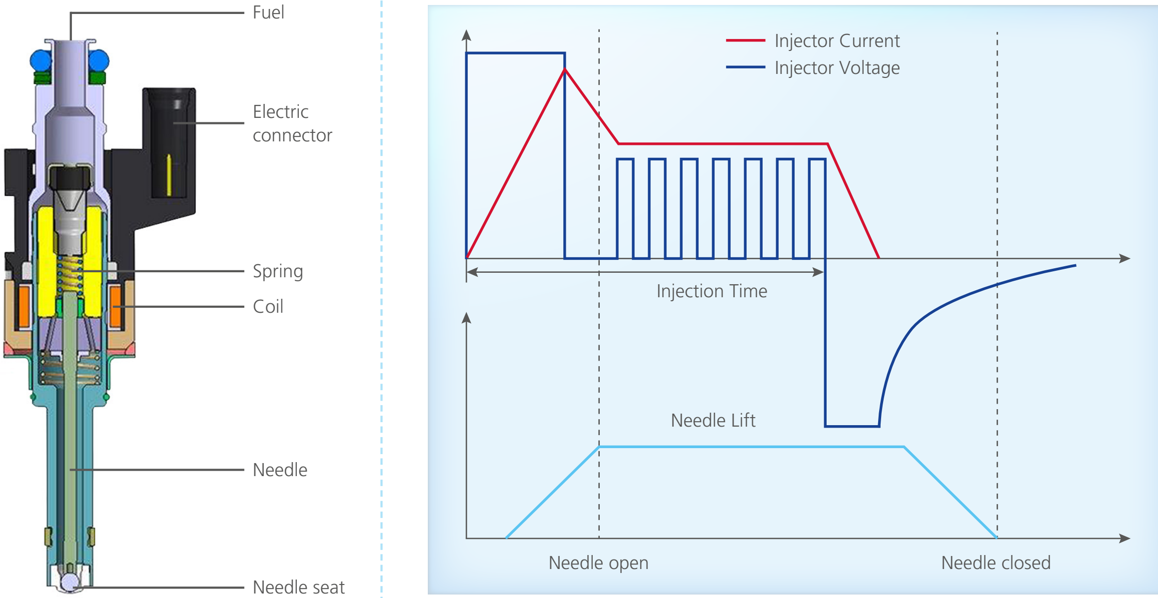


Left: Setup of a high-pressure magnet injector: The coil and the moving needle (magnetic core) create a variable inductance.
Right: Idealized representation of the injector control, needle lift, and injection time.

COSI functions. Because highly dynamic processes happen during a short time interval, the injector behavior can only be calculated fast enough if a field-programmable gate array (FPGA) is used. For the dSPACE SCALEXIO HIL systems that were set up in the test area, the solution that appeared most suitable was one that consisted of an FPGA Board (DS2655) and a newly developed electronic load module (EV1139) for each injector. The electronic load module is set up as a galvanically isolated interface to the EECU that is independent of the operating voltage. It emulates the real currents and voltages of the injector that is connected to the EECU. For this, it uses the injector behavior with inductive electric characteristics as calculated by the FPGA model. The underlying open model from dSPACE can be precisely adjusted to the injector properties. The setup also supports other tests for electrical fault simulation, such as tests for short circuits and cable breaks. It can also generate functional faults to evaluate information from system behavior to emission values. To do this, the times for the early or late opening and closing of the valves can be manipulated. The influence of component variances and ageing can moreover be tested quickly in a simulation by parameterizing the relevant model components.

Use in a Project

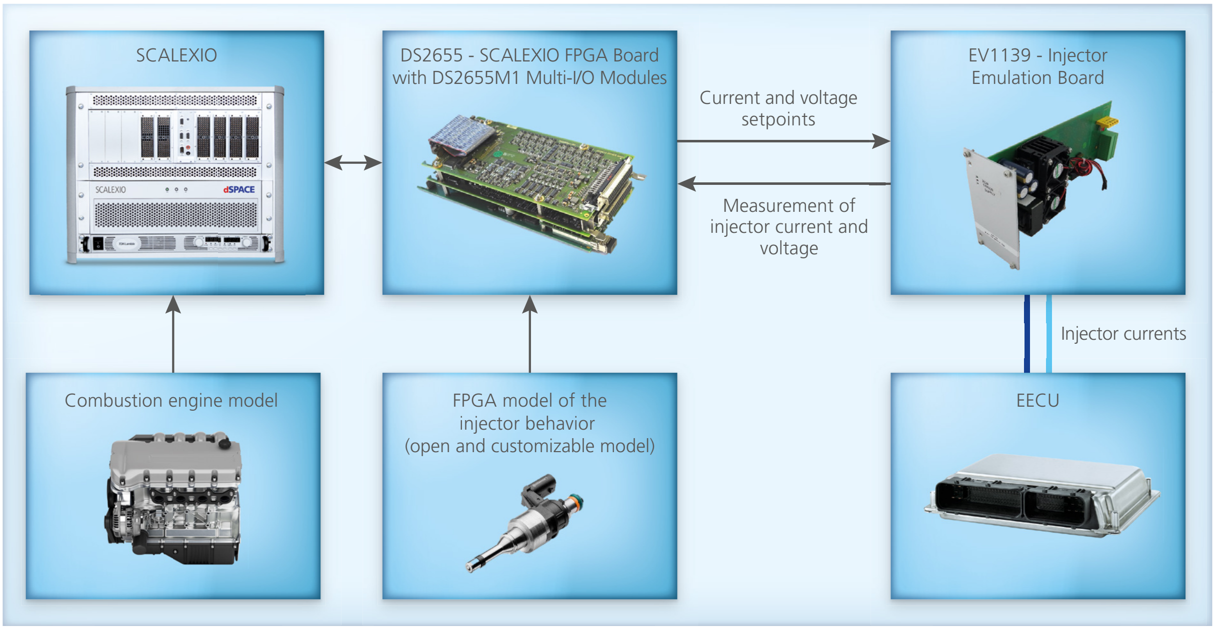
The setup of a test system was driven both by Continental and dSPACE. The first tasks included procuring information, clarifying patent-law-related questions and the creation of a requirements document. Based on these first steps, the companies developed a powerful prototype. The dSPACE developers were provided with access to fully set-up SCALEXIO simulators and ECUs to integrate the new COSI test solution. During the commissioning at the test lab, the test system was optimized for additional tasks:

- Precise single and multiple injection
- Accurate shifting of the injector closing times
- Parallel injection in two cylinder banks

The test system is now fully tuned and has since been firmly implemented

> "The sensorless Controlled Solenoid Injection validation procedure leads to high requirements for ECU testing. The SCALEXIO simulator and its expansion solutions can represent highly dynamic processes with precision and thus reliably validate ECUs."

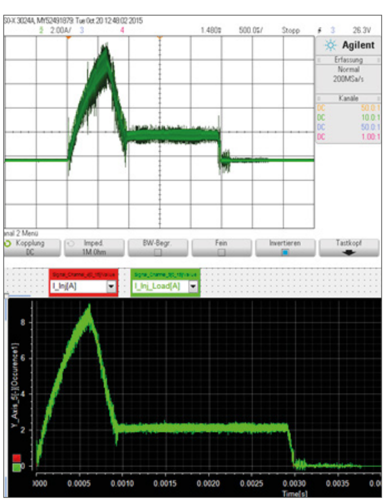
Michael Mench, Continental



Setup of the SCALEXIO HIL simulator for the injector simulation: The combustion engine is simulated on the SCALEXIO Processing Unit. The injector is simulated with an FPGA board that controls the EV1139 electronic load module. The load, in turn, behaves like a real injector towards the EECU and inserts the real voltages and currents. It then returns the measured current and voltage values to the FPGA board.

in the validation process for EECUs. It has the flexibility and performance to verify the correct functioning of EECUs with COSI function in a closed loop and validate the requirements for the EECU software. At the same time, the diagnostic functions of the EECUs can be tested as well.

Figure 4: Comparison of the measured (above) and simulated injector currents as represented in dSPACE ControlDesk (below): The high congruence of both waveforms is instantly visible.



Summary and Outlook

Using controlled fuel injectors leads to new challenges when validating EECUs. To test and validate the controllers, Continental and dSPACE designed a new test solution. It simulates the injector behavior and emulates its real currents. A fast FPGA-based computation unit and an electronic load form the basis. This allows for operating the EECUs in a closed loop and thus for flexible testing in the lab. Currently, Continental uses the test system to validate the latest generation of EECUs. Because the setup is highly flexible, it can easily be used for the development of future ECU functions. ■

Michael Mench, Alexander Zschake, Continental

Michael Mench
Michael Mench is responsible for the validation of injection systems at Continental in Regensburg, Germany.

Alexander Zschake
Alexander Zschake is responsible for the validation of injection systems at Continental in Regensburg, Germany.

NSK is a Japanese component manufacturer headquartered in Tokyo that primarily produces bearings and vehicle components. At the end of 2016, the company introduced its new wheel hub motor with an especially effective transmission mechanism (figure 1). Although this type of motor has a comparably small size, it can achieve a high driving performance. NSK's aim is not the series production of the motor as a whole but rather establishing its individual components on the market. The primary focus is on wheel bearings with an integrated reduction gear, one-way clutches, small roller bearings, and corrosion-resistant bearings.

More Safety and Comfort and an Improved Environmental Footprint

Since wheel hub motors are mounted directly on the wheel, some of the drivetrain components required for traditional vehicles with central engines are no longer necessary. This reduces the weight of the vehicle, which in turn results in lower energy consumption and an improved environmental footprint. At the same time, components such as a transmission tunnel are no longer required for rear-wheel drives, which adds more space in the vehicle's interior, improving comfort for passengers. There is also an improvement in vehicle safety, because the wheel drive can be controlled much more directly and individually than for a central combustion engine with the traditional drivetrain components.

High Performance Requirements for Small Motors

During the development phase, NSK faced a range of challenges. One of the most difficult tasks was to keep the motor as small as possible despite the high performance requirements. To deal with all types of everyday situations, the motor must be able to provide a high torque at a comparably low rotational speed during acceleration and when moving uphill. In contrast, maximum rotational speed and low torque are required when driving on highways. Because this range of requirements can quickly have a negative impact on the motor size, NSK focused its development on reducing the size of the wheel hub motor and its components.

The Solution: A Wheel Hub Motor with a Transmission Mechanism

While NSK was searching for a compact solution, it developed a wheel hub motor with an integrated transmission mechanism. This novel drive consists of two motors, two planetary gear trains, and a one-way clutch (figure 1). This setup makes it possible to reach the required high torque and a sufficiently high maximum speed. In contrast to combustion engines, electric motors can also rotate in reverse direction. The team used this as a basis for their development work. In high gear, both motors rotate in the same direction, in low gear, they run in opposite directions. Both motors of the wheel hub drive are connected to the wheel via the gear unit, which consists of two planetary gear sets and a one-way

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> "It was very useful for us that the Tandem-AutoBox is able to simultaneously perform control tasks and measurements. The fault analysis and correction was also very quick, easy, and reliable with the help of the dSPACE systems."
>
> *Yasuyuki Matsuda, NSK*

Highly Efficient Wheel Hub Motor

NSK is developing a compact wheel hub motor with an integrated transmission mechanism

Picture credit: © NSK Ltd.

Increasingly stricter environmental regulations for vehicles accelerate the trend towards electric drives in automotive engineering. In view of this, the Japanese company NSK developed a novel wheel hub motor with an integrated transmission mechanism, which was evaluated with a Tandem-AutoBox from dSPACE.

Technical Data

Wheel hub motor	
Maximum power (per wheel)	■ 25 kW
Maximum drive torque	■ 850 Nm
Maximum speed	■ 135 km/h
Weight	■ 32 kg

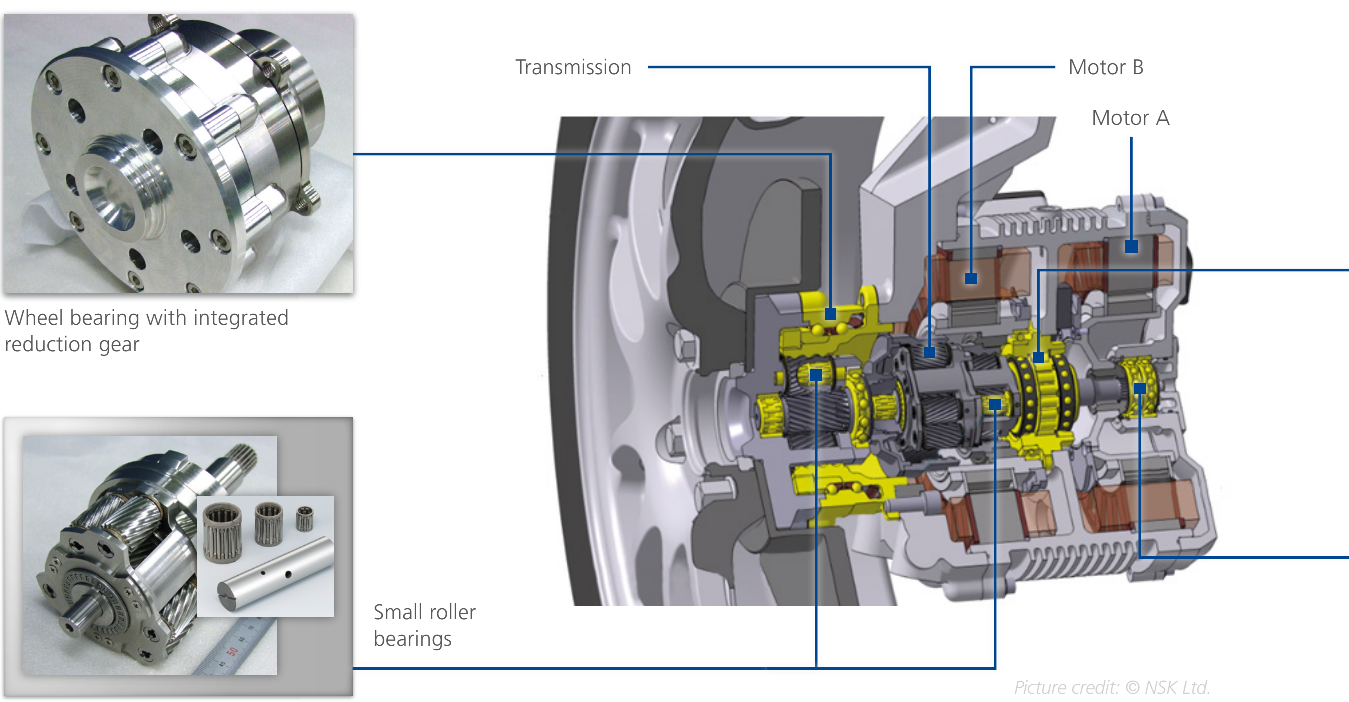
Test vehicle	
Wheelbase	■ 2550 mm
Track width	■ 1484 mm
Weight (without passengers)	■ 1013 kg
Battery voltage and capacity	■ 400 V 10.2 kWh

clutch. Being able to variably actuate the motors in two directions results in two different gear ratios. If the motors rotate in opposite directions, high torque is applied to the drive shaft, which can be used up to a limited rotational speed. For higher rotational speed, both motors can be run in the same direction and thus allow for higher vehicle speed. A wheel bearing with an integrated reduction gear eventually transfers the torque to the wheel. Thanks to this special motor-gearbox configuration, a dedicated shift actuator is no longer necessary. NSK assumes that a setup with two of these drives (one for each front wheel) can reduce the weight by 30% in comparison to a solution with a central vehicle motor of the same performance. Moreover, the transmission mechanism is able to smoothly shift gears during acceleration and braking because of the torque and rotational speed control of both motors.

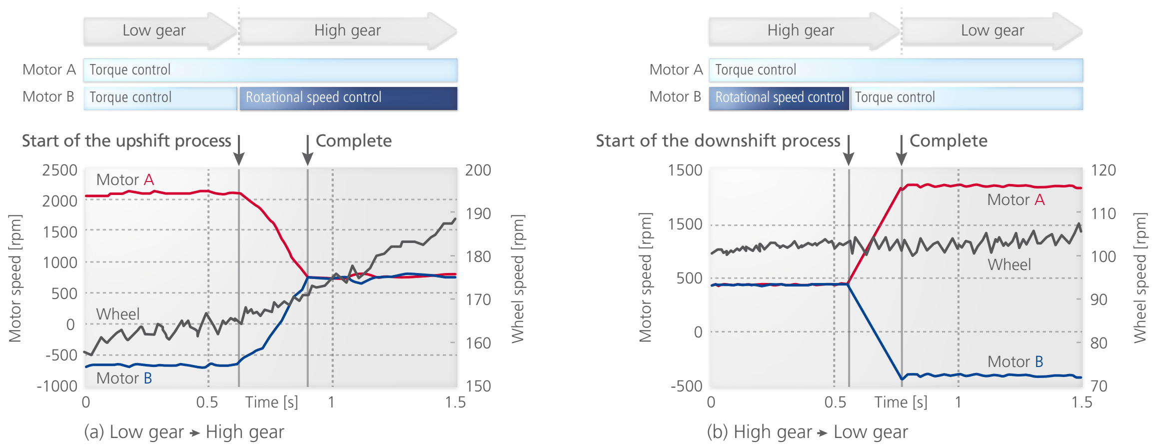
Tandem-AutoBox for Onboard Experiments

To evaluate the motor prototype, the development team built a test vehicle that has wheel hub motors mounted on the front wheels. When NSK produced the complex evaluation equipment, especially while building this test vehicle, it cooperated closely with a large number of companies and a university. dSPACE supported this project since the planning phase and still continues its support. To test the wheel motors in real-life operation, a Tandem-AutoBox was installed into the rear of the vehicle. The Tandem-AutoBox provided the major interfaces required for the test vehicle. Aside from controlling the electric motors in the wheel hub drives, the dSPACE system also took over the control of the electric power steering. The setup of the test vehicle is suitable for additional use cases that

Figure 1: Setup of a wheel hub motor with an integrated transmission mechanism. NSK wants to establish the individual motor components on the market.



Picture credit: © NSK Ltd.



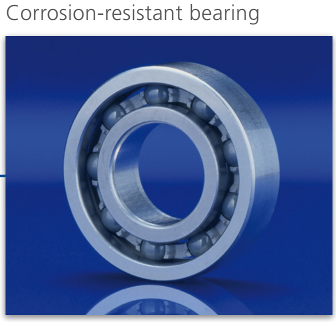
Picture credit: © NSK Ltd.

Figure 2: Processes when shifting up or down:
a) The two motors initially run in opposing directions. When motor B changes direction, the one-way clutch activates the planetary carrier. The motors now rotate in the same direction (high speed, low torque).
b) Both motors initially rotate in the same direction. When motor B changes direction, the one-way clutch stops the planetary carrier. The motors now rotate in opposing directions (low speed, high torque).

go beyond testing the wheel hub motors. To be ready for future challenges, NSK used a Tandem-AutoBox that can be operated with a 12 V vehicle battery.

One-way clutch

Corrosion-resistant bearing



Close Collaboration with dSPACE

When building the test vehicle, NSK trusted the expertise provided by dSPACE Engineering Services, who supported the development team throughout the entire development process. Together, the teams were able to quickly and easily change and enhance device configurations and update control strategies. For the result analysis, dSPACE's experiment software ControlDesk and the Tandem-AutoBox proved to be very helpful. It was particularly useful that the Tandem-AutoBox is able to perform control tasks and measurements simultaneously. This made fault analysis and correction faster, easier, and more reliable.

Conclusion

Because the test vehicle is an electric vehicle, it is usually either connected to the charging station, used for a test (driven), or is under maintenance to update the control software. Therefore, a vital point for the development of the control software was that it would be able to switch between these situations. The engineers also received easily readable code that they could adapt to the different operation states without any problems. This enabled the team to work efficiently during the complete development process. ■

Yasuyuki Matsuda, NSK Ltd.

Learn more about the functioning of the wheel hub motor in this video: www.dspace.com/go/dMag_20172_NSK

Yasuyuki Matsuda
Yasuyuki Matsuda works in the Automotive System Development Department of the Future Technology Development Center at NSK Ltd. in Fujisawa, Japan.

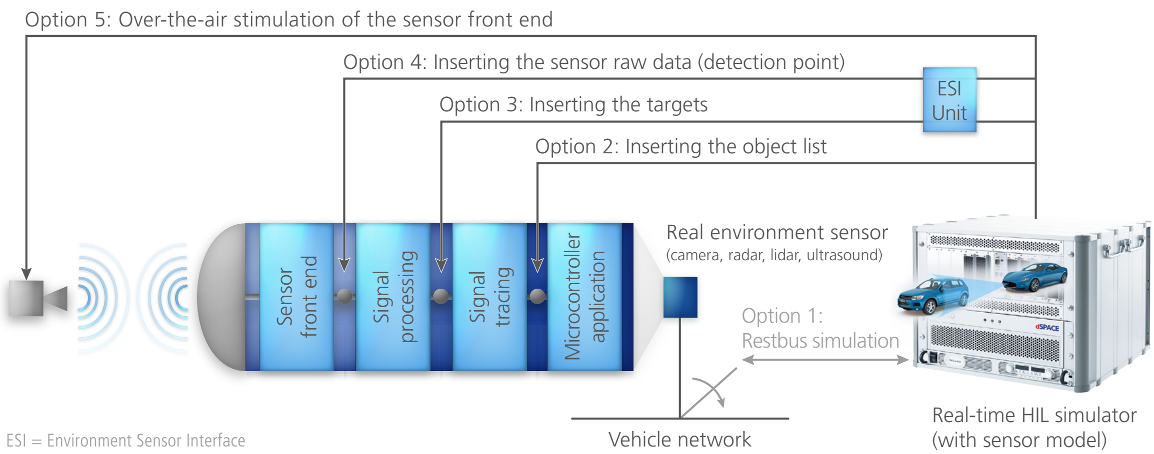
Mastering Variety

dSPACE solutions for highly automated driving

The topic of highly automated driving is the main focus of the development activities of many automobile manufacturers. Karsten Krügel and Hagen Haupt, who are responsible for virtual validation and simulation models at dSPACE, explain what challenges the development of functions for automated driving entails.

Mr. Krügel, everybody is talking about highly automated driving or autonomous driving. Is this also true at dSPACE?
Yes, indeed. Autonomous driving is a central theme at dSPACE, because many of our customers are currently working on solutions for this topic. In the last years, we invested much time and effort into our tools to support the OEMs and suppliers in developing and validating functions for autonomous driving. dSPACE sees itself as a single-source supplier of software and hardware solutions in this area, as can be seen in our webinar series.

Mr. Haupt, what are the core elements for developing and validating these functions?
There are several important aspects: First, you need completely new methods and standards to develop functions for autonomous driving, sensor fusion, and perception algorithms. Adaptive AUTOSAR and Automotive Ethernet are examples for this. Furthermore, the complexity of the real world must be simulated as comprehensively and detailed as possible, because realistic simulations are key to the validation. New description formats, such as OpenDRIVE, OpenSCENARIO, and Open Simulation Interface (OSI) help the manufacturers develop suitable tools. These tools support the configuration for the simulation models to be able to realistically emulate defined scenarios in the simulation.
Naturally, new prototyping solutions are also required for developing the functions. For this, dSPACE has extended its product range with MicroAutoBox Embedded SPU. It offers a unique combination of high computing power, interfaces to automotive vehicle networks and environment sensors, GNSS positioning, wireless communication, and an extremely compact and robust design for in-vehicle use. We introduced this new tool in detail in our article "Multisensor All-Rounder" in dSPACE Magazine 1/2017. >>



Basic principle of a closed-loop test environment with different options for inserting sensor data: Depending on the required level of detail, the sensor signals can be integrated into the HIL simulation in different ways.

What has to be paid attention to during simulation?

Haupt: An especially difficult challenge is the emulation of relevant effects that are specific to a particular use case in the vehicle and environment simulation. Sensor models form an important part of this. They have to bridge the gap between physical reality and highest possible efficiency. To solve these problems, dSPACE offers sensor models with different degrees of detail. The portfolio covers everything from a technology-independent sensor that immediately creates object lists based on the available information to a physical camera model for direct image data input.

What exactly does this mean for supplier and OEM processes?

Krügel: To validate functions for highly automated driving, a large number of tests must be performed with the various degrees of detail, both during the development phase and for the final release. The scope of these tests is enormous and, apart from the established methods, it can be managed only with the help of software-based simulation platforms, such as dSPACE VEOS.

VEOS allows for using PC clusters that let you run a large number of simulations in parallel on hundreds of computation nodes within only a few days. In addition, no ECU prototypes are available during the early development phases, which means that virtual ECUs (V-ECUs) must be used. Since complete chain of effects testing requires many V-ECUs, it is not feasible to integrate software manually. For this reason, continuous integration is becoming increasingly important. Here, V-ECUs are generated fully automatically from the latest integration versions. Because all these changes require the suppliers and OEMs to adjust their processes or create completely new work steps, dSPACE offers comprehensive consultancy and support.

Does this mean that a HIL simulator is no longer required?

Haupt: For release tests according to ISO 26262, the hardware-in-the-loop (HIL) simulation is still indispensable. During the simulation, sensors, such as camera and radar sensors, are integrated into the HIL system because signal preprocessing in the sensor, sensor fusion, and the creation of environment models in the ECU have an important impact on the chain of effects. Integrating the sensors is possible at various levels of detail – from restbus simulations of the object list and inserting raw data streams to simulating complete systems with over-the-air methods. dSPACE offers custom I/O solutions for all these variants. For example, we developed powerful hardware for connecting image sensors to a HIL simulator at raw data level, called the Environment Sensor Interface Unit.

> Developing and testing functions for autonomous driving influences the tool chain and established work processes of the automotive industry.

Hagen Haupt (left) and Karsten Krügel (right) explain about dSPACE's range of solutions for autonomous driving.

How much more realistic do the latest models have to be in comparison to previous models?

Haupt: Sensor models that are based on phenomenological or physical approaches are becoming increasingly important for supplying the previously mentioned raw data feeds. Typically, they are computed in 3-D graphics environments. dSPACE offers a powerful solution with its new sensor for cameras and point clouds in MotionDesk. Additional models for simulating radar sensors are currently being developed.

Does this mean that the complete simulation environment must become more realistic?

Haupt: A realistic representation of the sensor physics certainly directly affects the modeling of the environment and its components, such as road networks, roadside structures, traffic signs, and the representation of road users, because they always interact with sensor models in the simulation. However, it is not just the traffic objects that must be displayed ever more realistically, their behavior must also be realistic. Some key points are intelligent driving while taking road rules into consideration as well as realistic traffic scenarios whose definition would be very tedious if it was done with traditional methods.

How has environment simulation been improved?

Haupt: New and improved solutions include the integration of intelligent driving and traffic systems as well as the connection of established traffic simulation solutions, such as the Simulation of Urban Mobility (SUMO) and the traffic flow simulation software VISSIM. Additionally, dSPACE Automotive Simulation Models (ASM) allow for multi-agent simulations where multiple complete vehicles with functions for autonomous driving are driving in the same environment. It is certainly also important to have methods that keep the definition of scenarios as simple as possible. Using real map information to describe road networks and importing movement data for the traffic objects is therefore of the essence. We make it possible to generate road networks on the basis of navigation data, such as OpenStreetMap or highly precise HD maps. Our established tool ModelDesk offers interfaces for movement data that let you easily import scenario descriptions from real vehicle tests or recorded measurement and accident data, such as the GIDAS-Pre Crash Matrix (PCM).

What is the big difference between previous tests and tests for highly automated driving?

Krügel: One thing is certain, you need to test much more than before. Yet, it is important to not just perform a large number of tests but the right tests. This means we need entirely new, intelligent test methods that can detect critical scenarios or unwanted false positives, because nobody can define a comprehensive and complete test catalog that is based purely on requirements. Here, dSPACE offers support with its tools, for example, its scenario observers that continuously observe the simulation with randomized tests and prepare the simulation results in such a way that the tester can easily make out and analyze interesting situations from the large volumes of data.

Managing large data volumes is an important task. What does dSPACE have to offer here?

Krügel: Our test and data management software SYNECT provides the required infrastructure to support the fully automated validation

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Webinar Series for Autonomous Driving

dSPACE offers six free lectures about the development and testing of functions for highly automated driving.

For more information, see: *www.dspace.com/go/AD-Webinar*

The combined use of real and virtual PCs in one cluster provides an entirely new level of flexibility for testing complex driving scenarios.

of functions for autonomous driving on the relevant MIL, SIL, and HIL test platforms. SYNECT lets you centrally manage the desired test scenarios and the related data, for example, simulation models and parameters. In addition, you can efficiently plan numerous test runs and execute them automatically, which means you can drive millions of test kilometers on a PC cluster in one night.

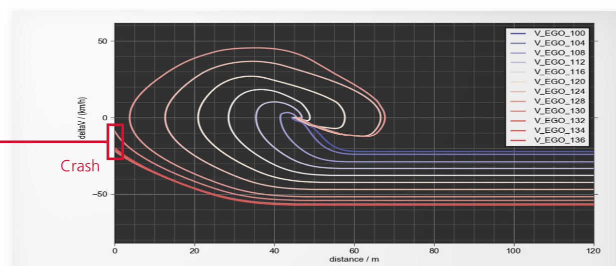
Mr. Krügel, Mr. Haupt, thank you for talking to us.

Dr. Karsten Krügel is a senior product manager for Virtual Validation at dSPACE.

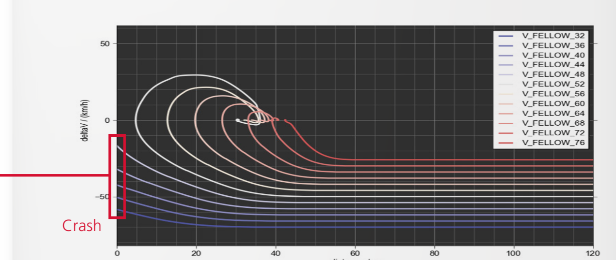
Dr. Hagen Haupt is a section manager for Modeling and HIL Simulation in the Application Engineering division at dSPACE.

The graphical evaluation shows which parameters (driving speed and distance between the two vehicles) are necessary to allow for the fellow vehicle to safely move back into the lane in front of the ego-vehicle. The settings marked in red lead to a collision.

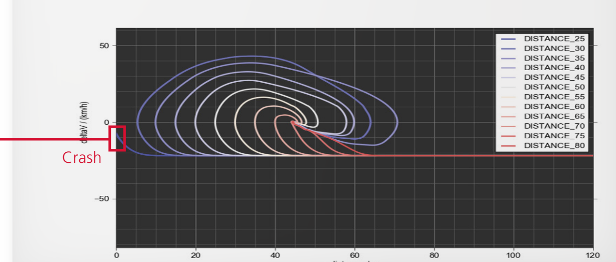
V_EGO [km/h]	V_Fellow [km/h]	Distance [m]
100	80	75
104	80	75
108	80	75
112	80	75
116	80	75
120	80	75
124	80	75
128	80	75
130	80	75
132	80	75
134	80	75
136	80	75



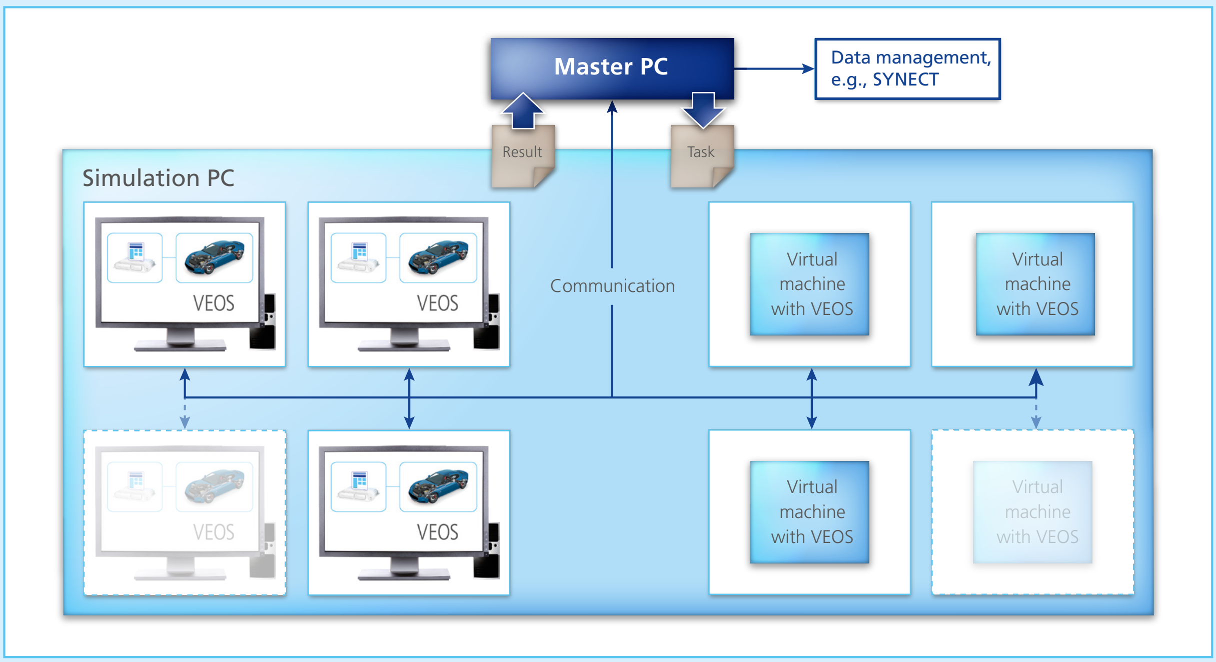
100	32	75
100	36	75
100	40	75
100	44	75
100	48	75
100	52	75
100	56	75
100	60	75
100	64	75
100	68	75
100	72	75
100	76	75



100	80	25
100	80	30
100	80	35
100	80	40
100	80	45
100	80	50
100	80	55
100	80	60
100	80	65
100	80	70
100	80	75
100	80	80



Combined Computing Power for Multi-Agent Systems



An important aspect when validating driver assistance systems and functions for highly automated driving is the interaction of multiple highly automated vehicles with other intelligent road users in multi-agent simulations. This requires that numerous traffic scenarios in which road users behave differently are run, which drastically increases the number of tests required for validation. Using software-in-the-loop (SIL) simulations on Windows-based VEOS clusters makes it possible to significantly increase the test performance and simultaneously ensure scalability. For this, the driving scenarios to be tested are stored on a central master PC. This master PC distributes the individual tests to a network of simulation PCs that are integrated either as PCs or virtual machines. On the installed VEOS simulation platform, the tests are then performed in a batch operation and the measurement results are fed back to the master. Because dSPACE tools are modular and can be automated, every automated SIL test can in principle be performed on a simulation PC.

Test performance increases with the number of nodes as a factor. Integrating the cluster control into the SYNECT test and data management environment enables the ideal integration of existing tests and continuous integration processes.

Central data management for efficiently moving to series production

Agile Model-Based Development

Agile development and test methods make it possible to arrive at deployable software more quickly and to improve it continuously. Transparency and consistency when exchanging data between development teams in different locations is as important as the automation of repetitive processes. Central data management as well as a concerted tool chain prove to be decisively beneficial in this process.

Automotive software development is subject to a continuous process of increasing efficiency and professionalization. More and more development teams jointly work on the ECU software from different locations. Specialized tools and procedures have been established for the different process phases. The shorter cycles for developing and testing functional components as well as their ever more frequent integration into an overall model allow for an agile process when validating and testing modifications. Software versions are thus available faster and continuously.

Central Data Management in the Development Process

During distributed software development, it is essential for architects, function and software developers, testers, and integrators to work with the same data base. This increases the demand for a central system that keeps data and files consistent and traceable for the different roles, tasks, and tools used. The data management software SYNECT, functioning as the data backbone during the model-based software development with MATLAB®/Simulink®, and the production code generator dSPACE TargetLink enable all parties, from software developers to project leaders, to get an overview of all the development artifacts and stages. The complete integration of the data backbone into the tool chain makes it possible to continuously use the established tools of the individual development phases and perfectly cross-connect them, for example, tools for requirements management or testing. This results in the following benefits:

- Full traceability from requirements to models, interfaces, parameters, and tests as well as automated effects analyses by linking data. Transparency and efficient change management based on integrated user rights management and version management.
- A high degree of automation because tools are efficiently connected.
- Efficient multi-user support for all Simulink/TargetLink users because they can work with a uniform, consistent database

The following sections describe the benefits of a tool chain with TargetLink, BTC EmbeddedPlatform, and SYNECT for validating the models for the various development phases.

Consistent Data Management to Ensure Efficiency

The central, cross-phase data management of models, interfaces, parameter specifications, tests, and test results as well as their link to the requirements in SYNECT ensures the efficient support of all parties involved in the development project. Architects use SYNECT to centrally determine the interfaces and parameters to be used by developers for individual components of the overall model. SYNECT offers automated processes for frame model generation and model updates to easily transfer the required data and interface specifications to the TargetLink model and the TargetLink Data Dictionary. This also allows for the simple and easy transfer of subsequent changes to the component models. Therefore, all developers can work with consistent data.
The tests that the component developers or test teams developed to validate the models are managed centrally by SYNECT. The option to directly connect requirements, models, tests, and test results allows for querying the development status of the software and its quality at any time. Moreover, the requirements coverage can be analyzed and tracked. Additionally, components can be integrated into the overall model fully auto- >>

Powerful Tool Chain

- dSPACE TargetLink for generating ECU production code of the highest quality
- BTC EmbeddedPlatform for building a highly integrated test environment
- dSPACE SYNECT as the central data management tool for teams working from different locations

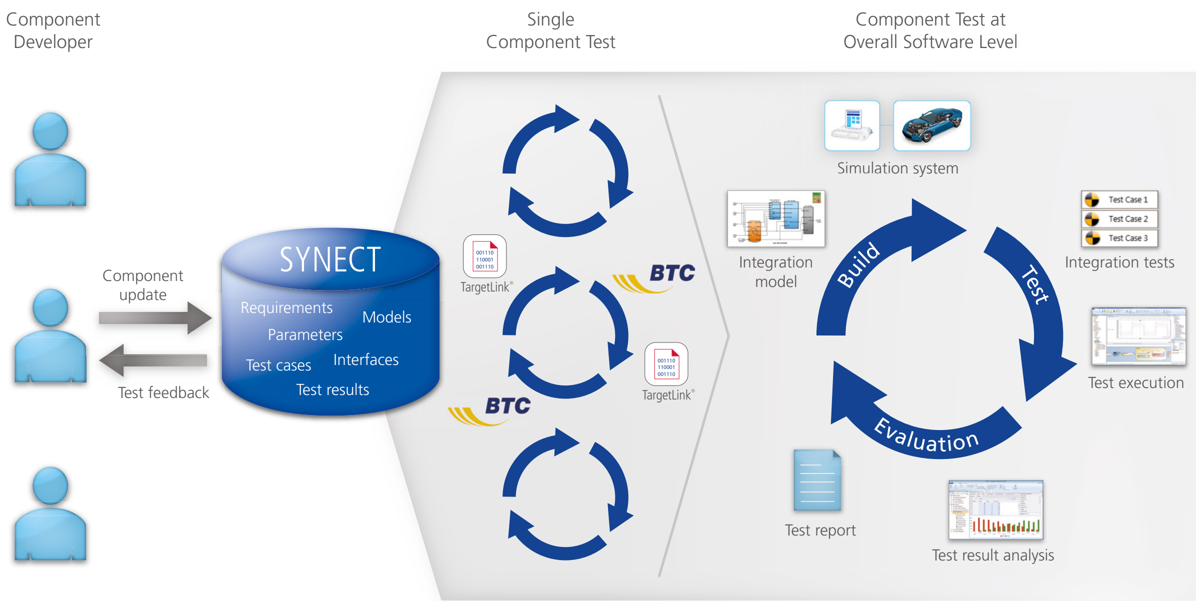


Figure 1: Continuous, automated testing of components – individually and at the overall software level.

matically because interface conformity and quality are constantly ensured. This way, SYNECT supports the developer teams in continuously delivering deployable software versions.

Integration and Test: Automated and Reproducible

To ensure the required quality of a component model while working with ever shorter development cycles, developers must not only develop, perform, and save the unit tests themselves. They also have to test and evaluate the components in the context of the overall software. SYNECT perfectly supports the developers in these tasks by seamlessly integrating commonly used test tools, such as BTC Embedded-Platform (figure 1). This way, developers can use the tools to define the unit tests on the basis of the requirements assigned to the model as well as additional analyses, such as code coverage and back-to-back tests. The increasing number of tests that are required with every new model version can then be performed fully automatically, for example, before the release of a new component. SYNECT offers the possibility to integrate every development version automatically, which allows for continuous testing at the overall software level (figure 1). Central data management with SYNECT makes it possible to directly use existing tests that were developed for validation on the HIL simulator, for example. Even without a real-time simulator, the component developers can carry out a PC-based offline simulation with dSPACE VEOS to identify how the components influence each other. This brings the various phases of software development much closer together, which means that they can be run through in shorter iterations for nearly every software change. Developers also receive direct feedback about the functions they developed from test results and reports. This gives them the opportunity to react quickly and flexibly to input received from the continuous development of the software and creates an agile and highly automated development process that includes reproducible tests.

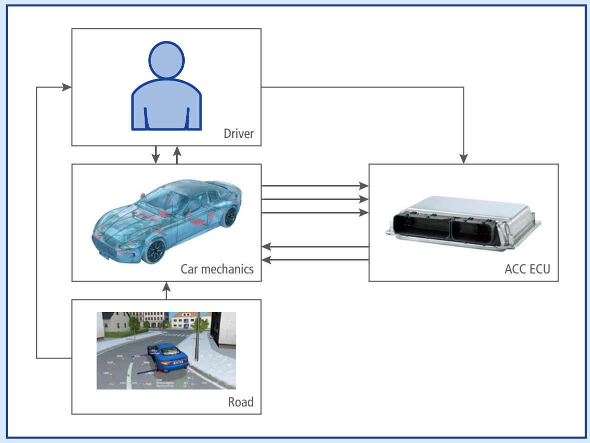
> Continuous Development – Transparent, Automated, and Efficient Thanks to the dSPACE Tool Chain

Implementing Continuous Delivery Scenarios

The fully automated integration offers added value to the component developers and at the same time simplifies the tasks of all persons involved in the ECU development. For example, SYNECT can trigger the

Graphically Editing Models

In the upcoming Version 2.4 (dSPACE Release 2017-B), SYNECT introduces the option to graphically edit the connections of models. The different models, such as individual software components, virtual ECUs and environment models that were created by teams working from different locations, can thus be merged to an overall system model. From this model, a simulation system can be generated for the offline simulation with dSPACE VEOS. Future plans are to also enable creating real-time applications in the same manner. SYNECT supports various model formats, such as MATLAB/Simulink, TargetLink, Functional Mock-up Units (FMUs), and V-ECUs. For connecting the models, both the signal-based communication and the communication via automotive bus systems is taken into consideration. In addition, SYNECT offers the added value that tests can be directly planned and performed automatically for the created simulation systems.



software build process regularly and at defined times, such as every night, for the last approved component of the continuous delivery. Afterwards, the generated virtual ECU (V-ECU) can be validated in an offline simulation using all available tests. As a result, the virtually validated software and the test results can be continuously provided for tests on the HIL simulator or in the vehicle.

Summary

TargetLink, the production code generator; BTC EmbeddedPlatform for building highly integrated test environments; and SYNECT, the data management software, form a tool chain that provides component developers with a high-performance environment for agile software development and continuous delivery strategies. As an integral part of the tool chain, SYNECT makes it possible to fully automate repetitive tasks and put the agile development approach into practice. Central data management throughout the complete model-based development process allows for a tight-knit network of all tools, users, and development artifacts. ■

Universal Real-Time Platform

SCALEXIO now also for rapid control prototyping

Function developers of mechatronic systems from a wide range of industries are now entering the SCALEXIO era. Frank Mertens, lead product manager for rapid prototyping systems at dSPACE, explains what this is all about.

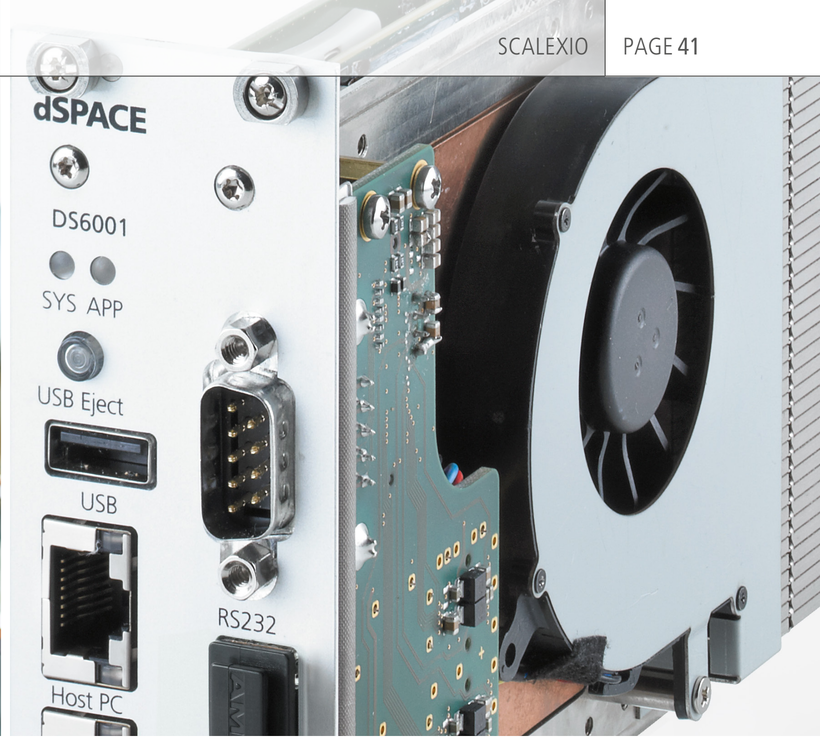

Rapid Control Prototyping
powered by
SCALEXIO
dSPACE
LabBox

Mr. Mertens, the name SCALEXIO is well-known with regard to hardware-in-the-loop (HIL) simulation. It is now used for the first time in the context of rapid control prototyping (RCP). What can you tell us about this?
Indeed, our users know the SCALEXIO product line mainly as HIL test systems. With its innovative technology, SCALEXIO has made a name for itself in this application area since 2011, has seen many new developments over the years, and has achieved a very high level of maturity. During this time, many function developers from the RCP environment wanted to use the technology and its strengths in control, validation, and data acquisition tasks for closed-loop real-time applications. We have now met this demand.

Why was it not possible for function developers to use SCALEXIO for RCP before?
Generally, they were able to use it, and some have. But in the first years, we focused on HIL requirements. For example, many of the I/O boards used for HIL applications have particular functional properties as well as special signal conditioning and integrated fault simulation. This requires a certain board size. In the course of further optimizations and with the introduction of the compact SCALEXIO LabBox as well as the associated compact boards, we have released new components and features over the last years. They are very well suited for HIL testing, but also particularly for RCP applications. Today, we have reached a considerable degree of coverage, so we now officially position the system in the RCP sector.

What is so special about the SCALEXIO technology that the RCP users can look forward to it?
Let us have a look at the entire SCALEXIO system. While each component is very powerful itself, their interaction even increases the system's performance. I used to play volleyball, and it's the same principle: Having the best players alone does not make for a winning team. When we designed the system architecture, we therefore not only used the latest, most powerful technology. We also optimized their interaction. For example, we use a state-of-the-art Intel® Core™ i7 processor. The high processing power enables it to compute even sophisticated and complex applications very fast. But for this to work, the operating system must contribute its part, for example, by reacting promptly and reliably when switching between tasks. Add the I/O, and even the strongest processing power is not enough if the bandwidth is insufficient or if high latencies or considerable temporal fluctuations, called jitter, occur. Since dSPACE has always been a top player in real-time systems and has longstanding experience in the field, we did not settle for the status quo but developed innovative technology like an intelligent I/O network that has already passed the litmus test in HIL applications: IOCNET. In addition to an exceptional latency behavior, its bandwidth allows for an outstanding handling of large data streams, for example, when capturing comprehensive data or connecting to modern vehicle networks. The SCALEXIO system, with all its capabilities, prepares the user for current and future applications. In the automotive industry, this includes the development of

> SCALEXIO systems provide high computing power and bandwidth at low latencies and jitter.



advanced driver assistance systems, highly automated driving, electromobility, and the growing interconnection of vehicles.

What I/O interfaces does SCALEXIO support already?

Since we are no longer at the beginning of development, we already support a high number of I/O boards for processing analog and digital signals as well as buses and Ethernet for many different industries. Several years ago, we introduced the first boards that can be used with SCALEXIO LabBox. At dSPACE, we are continuously developing further boards at full throttle and will continue to do so in the next years.

And what about particular I/O requests?

Here, SCALEXIO gives us the flexibility we need. If we do not already cover the requests with our standard portfolio, SCALEXIO makes it possible to integrate PCIe I/O cards from third-party suppliers in the system in a clean and cost-effective manner. dSPACE offers the relevant support and qualification of the I/O cards. The cards also have to pass compatibility tests so we can ensure consistent system performance and reliability despite the high flexibility. Not all suppliers do this as consistently as we do, and users might learn a "painful" lesson or two when using other products. In everything we do, we want to give our users continuously high real-time performance and system availability. Moreover, SCALEXIO provides additional options for customization with the freely programmable FPGA boards in combination with I/O plug-on modules.

Doesn't new hardware for modular RCP systems also require new software?

Yes and no. The largest part, such as the experiment software ControlDesk, the test automation software AutomationDesk, and the Simulink® application models, is hardware-independent. This is different for the hardware-dependent implementation software. When we introduced SCALEXIO, we also launched dSPACE ConfigurationDesk, which replaces the Real-Time Interface (RTI) software. ConfigurationDesk gives users entirely new ways to display I/O interfaces in a clear overview and configure them quickly at a central location. It also lets them separate an application model, for example, in Simulink, almost completely from I/O-specific settings and modelings. This answers the need for reusabil-

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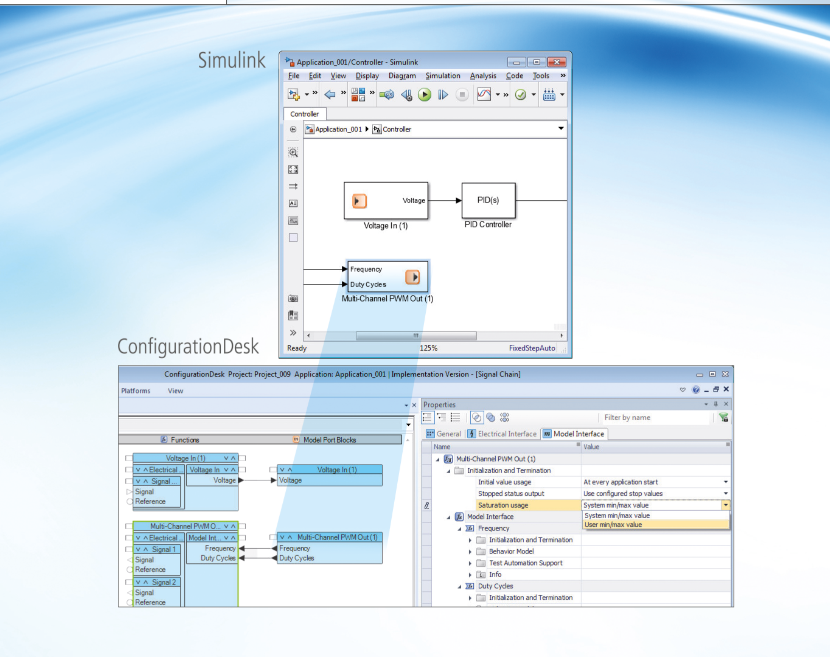


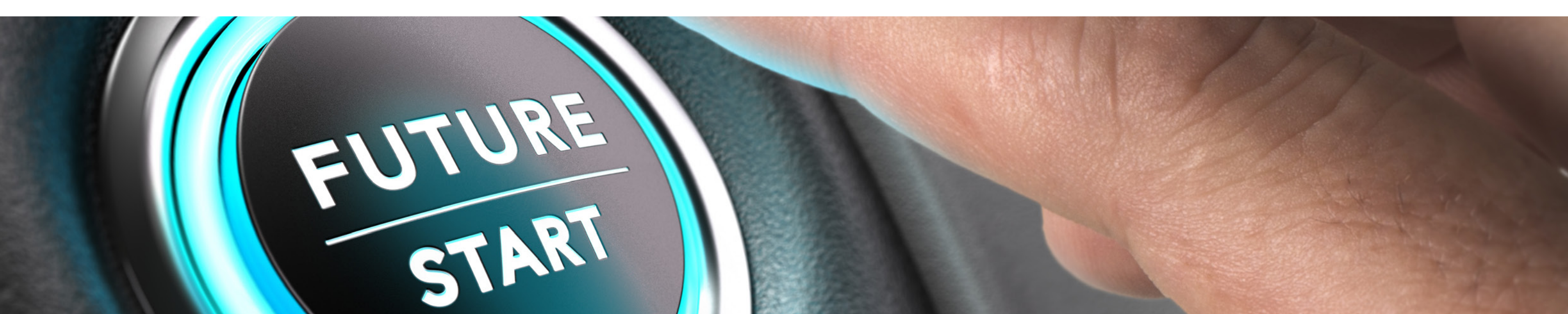
SCALEXIO is based on a state-of-the-art, innovative technology for the optimum setup of modular real-time systems – be it for rapid control prototyping or hardware-in-the-loop applications.

ity, seamless transitions, and the "golden model" approach. The openness of the software due to Functional Mock-up Interface (FMI) support is certainly another plus.

Will SCALEXIO replace today's modular systems, which are based on a peripheral high-speed I/O (PHS) bus, in the long term?
I am sure of it. This will be driven mainly by customer requests, but it will not happen overnight. PHS-based systems have been around for over 25 years. They have set the standard for modular real-time systems. We will therefore continue to offer them in the medium term and service them for a longer period of time. However, in the future the growing and changing demands can be optimally met only by using SCALEXIO with its performance power, flexibility, and openness. One day, we will eventually ship the last PHS-based system. Then, we will have fully entered the SCALEXIO era.

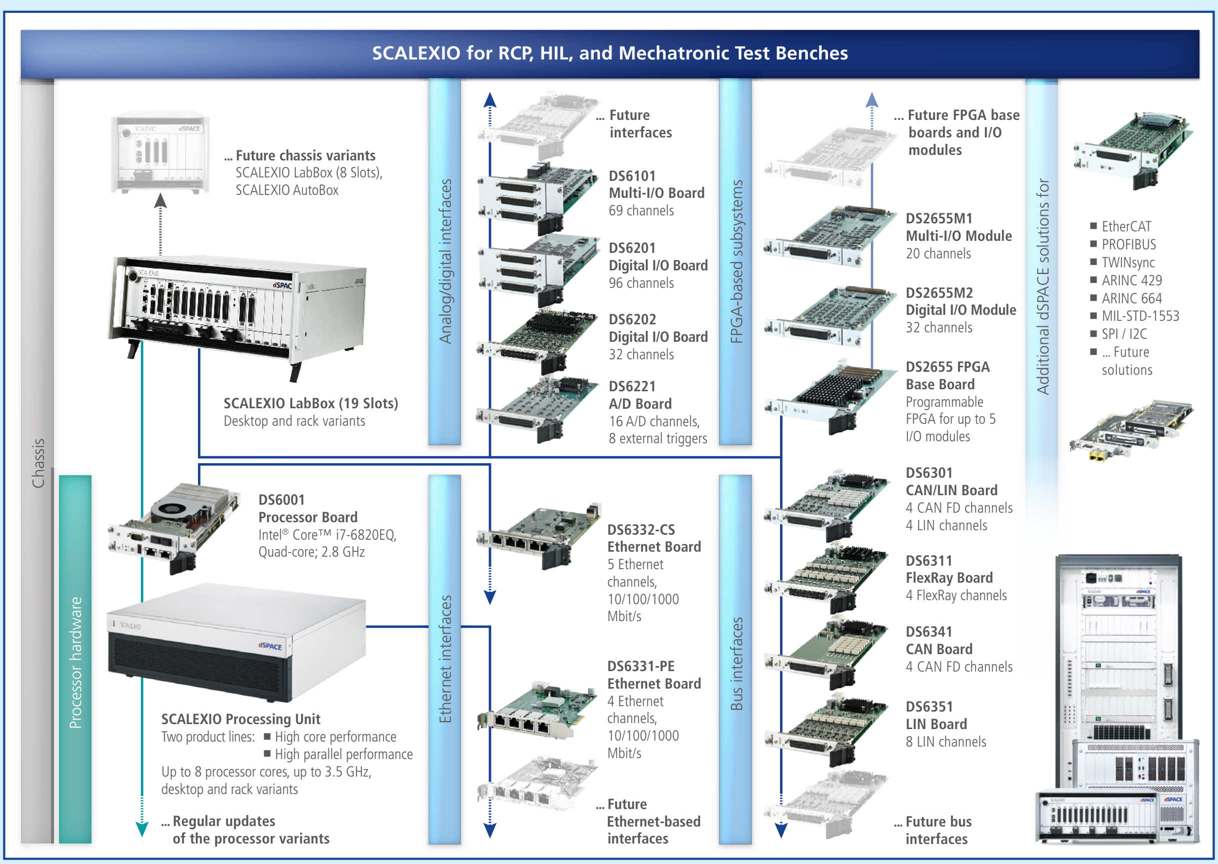
Thank you for talking to us.

As Lead Product Manager Rapid Prototyping Systems, Frank Mertens is responsible for the entire RCP tool chain at dSPACE GmbH, Paderborn, Germany.



The SCALEXIO Product Line – Now also for Rapid Control Prototyping

The SCALEXIO product line is based on a state-of-the-art, innovative technology that was specially developed for modular real-time systems. It is highly scalable and can be flexibly configured. SCALEXIO-based systems provide high computing power and a fast, broadband I/O connection. This makes them ideal for a wide range of applications. The bottom illustration shows some of the SCALEXIO components that are particularly suited for RCP in the lab (function design, execution, and validation), and complement the portfolio by adding new options to the HIL use cases. The system is based on a compact chassis, the SCALEXIO LabBox, which has a slot for a processor board as well as slots for I/O boards, and can be used in a 19'' rack or on a desk. Other benefits of the SCALEXIO LabBox are low noise emissions and an easy board replacement. The real-time processor is either provided by an external SCALEXIO Processing Unit or the new DS6001 Processor Board, which can be integrated in the LabBox. With its four processor cores and a computing power of 2.8 GHz, the DS6001 is ideal for the most complex model calculations. If even this computing power is not sufficient, multiple processor boards or Processing Units can be coupled. The system has a high number of powerful, partly FPGA-based, I/O boards for connecting sensors, actuators, buses, and networks. The boards are connected to the real-time processor with the IOCNET data network developed by dSPACE, which has a high bandwidth but very low latency and jitter. For faster cycle times and large-scale data preprocessing, dSPACE offers the freely programmable SCALEXIO DS2655 FPGA Base Board, which can be extended with additional I/O modules. It is also possible to include dSPACE-qualified PCIe cards of third-party suppliers in the system. Other components, such as a chassis for in-vehicle use (SCALEXIO AutoBox) and more I/O boards are currently being developed and will be available soon.



High-voltage electronic loads for motor and battery emulation

Electrifying Emulations

dSPACE has developed a new high-voltage electronic load for emulating motors and batteries with voltages of up to 700 V. In combination with the required simulation models, this makes for a single-source, ready-to-use test system for all traction applications.

The ideal test system for electronic control units (ECUs) of electric drives is flexible, open for modifications, compact, and powerful. This is where dSPACE's new high-voltage electronic load comes into play. It is the heart of highly dynamic electric motor and battery emulation up to 700 V. Open and flexible dSPACE simulation models and a dSPACE SCALEXIO hardware-in-the-loop (HIL) simulator complement the load. The ECU under test is the only real component needed, making the test setup flexible and cost-effective.

Motor Emulation for HIL Testing

ECUs for electric motors have to use their integrated electronic loads to process the entire drive power of vehicles with electric drives. During HIL tests, this type of ECU therefore has to be subjected to real motor currents. Until now, the ECU was usually operated together with the real drive motor on a mechanical test bench that includes a dynamic load machine. However, this method has some drawbacks. The high mechanical energies of the rotating machines require complex safety measures, and test benches are both expensive and inflexible when it comes to testing different motors. The dynamics that can be achieved are limited by the dynamics of the load machine. The device under test (DUT) cannot always be operated safely and fault simulation is possible only to a certain extent. Emulating the motor and battery circumvents these drawbacks and gives the testers new possibilities. During the emulation, the motor and battery are simulated, and highly dynamic loads are used to subject the DUT to the real currents and voltages – without any mechanical components.

Years of Experience

With its new high-voltage electronic load, dSPACE adds to its range of products and now offers a ready-to-use system for the complete virtualization of vehicles with real energy flows from a single source. Users benefit from dSPACE's years of experience with low-voltage motor emulation. The established concepts have now been transferred to high-voltage motor emulation and have been advanced further. The complete hardware was developed by dSPACE and patent applications have been filed for key technologies. Since users have to contact only a single company, the effort required for coordinating the system setup and operation is reduced considerably.

Dynamic High-Voltage Loads

The high-voltage electronic load (figure 1) can be used to emulate loads, such as motors, and other sources, such as batteries and AC

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> With the new high-voltage load, vehicles can be simulated completely virtually with real energy flows, all ready-to-use and from a single source.

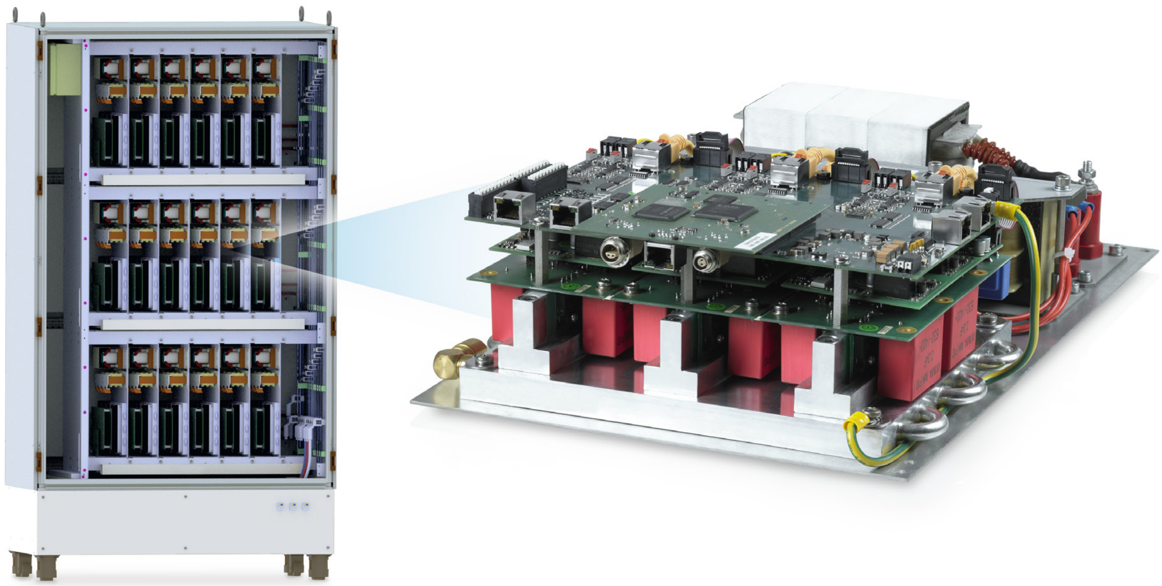


Figure 1: The high-voltage electronic load makes it possible to emulate motors and batteries with voltages of up to 700 V.

power supplies. Using the same hardware for both applications reduces the training effort for using the overall system and makes it easier to change the configuration. Because the hardware provides a highly dynamic rate of current change, a high bandwidth of the emulated inductance values, and a current range of up to 700 V, it meets all requirements for traction applications. By using any loads in parallel, it is possible to achieve up to several hundreds of kilowatts of power. With measurements of 45 cm x 30 cm (approx. 18 in x 12 in), the module is very compact.

Open Simulation Models

The motors and incremental encoders are simulated with open FPGA-based models from the dSPACE XSG Electric Components Library. The models can be used to induce real phase currents that allow for very precise and fast computation. If needed, customers or the dSPACE experts can adjust and extend the models for special requirements. The dSPACE Automotive Simulation Models (ASM) give users various model libraries with open simulation models for the processor, which they can extend themselves for special applications. The libraries include models for different battery types (ASM Electric Components) as well as for complete drivetrains and vehicles (ASM Vehicle Dynamics), etc. The simulation models for testing at the power level are the same as the ones used for simulation at the signal level. Therefore, users have to learn how to use the models only once and can reuse existing configurations.

Powerful Simulator

A SCALEXIO simulator is used as the HIL system. Due to the high number of flexible I/O cards, the system is easy to adjust to a wide range of applications. With the powerful SCALEXIO Processing Unit and FPGA-based motor emulation, there are no limits to simulation and emulation. All operating points of an electric motor can be emulated, in both motor and generator mode. It is also possible to emulate harmonic frequencies, allowing for a highly precise simulation of motor currents. Therefore, SCALEXIO is the ideal HIL environment for load and function tests at the power level.

Wide Range of Applications

The high-voltage electronic load has been optimized for the highly dynamic motor and battery emula-

> The compact, modular setup of the emulation system as well as the open simulation models make it easy to adapt the system to a wide range of applications.

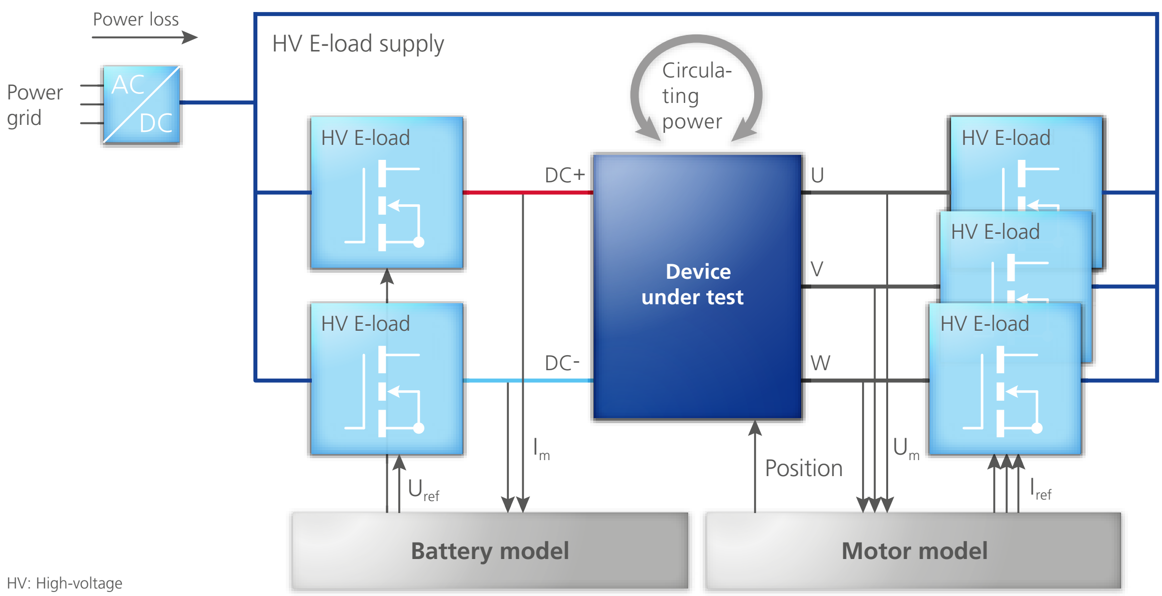


Figure 2: Schematic of a typical test setup.

tion for electric drive systems. Other application areas include tests of industrial inverters, wind and solar power inverters, DC/DC inverters, and the emulation of AC power grids. The flexible configuration covers all common frequency ranges, e.g., two or three phases at 50 Hz or 400 Hz for projects in aerospace engineering. The emulation system can be used in various development phases and test processes:

- Tests of new control algorithms for power electronics systems
- Reliability and fault tests
- Release and approval tests with controlled fault insertion
- Robustness tests, e.g., with different motor parameters
- System tests in which the high-voltage components of a vehicle interact

Because the components are emulated, all of these tests can be performed without risks – even at critical operating points that could put a real motor at risk or even destroy it. The continuous monitoring of currents and voltages ensures that the DUT is protected even when tested under extreme conditions.

The Overall System

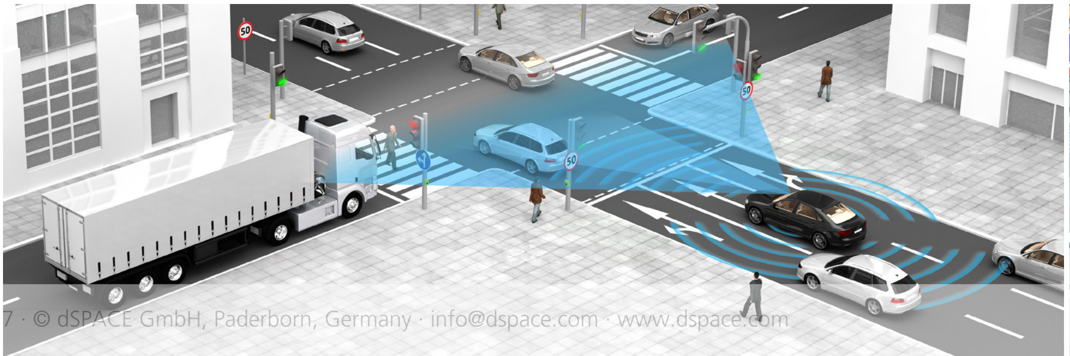
The overall system consists of the emulator cabinet with the high-voltage loads, the HIL simulator for calculating the simulation models, and a cooling device. The SCALEXIO simulator and the emulator cabinet are connected by the dSPACE network technology IOCNET. It allows for fast, low-latency communication with the SCALEXIO real-time processor. Only an affordable standard mains supply is required for installation, because no energy is fed back into the power grid. Due to the internal energy flow between the motor and the battery emulation, the overall system is very efficient and requires only a relatively low connected load of usually 20% of the power rating. A typical test setup for a traction drive includes two electronic loads for emulating the battery currents, three loads for emulating the motor, the ECU to be tested, and a mains adapter for compensating for the dissipating power (figure 2). Due to the compact design, this example configuration requires only one emulator cabinet to emulate a 150 kW motor and the battery.

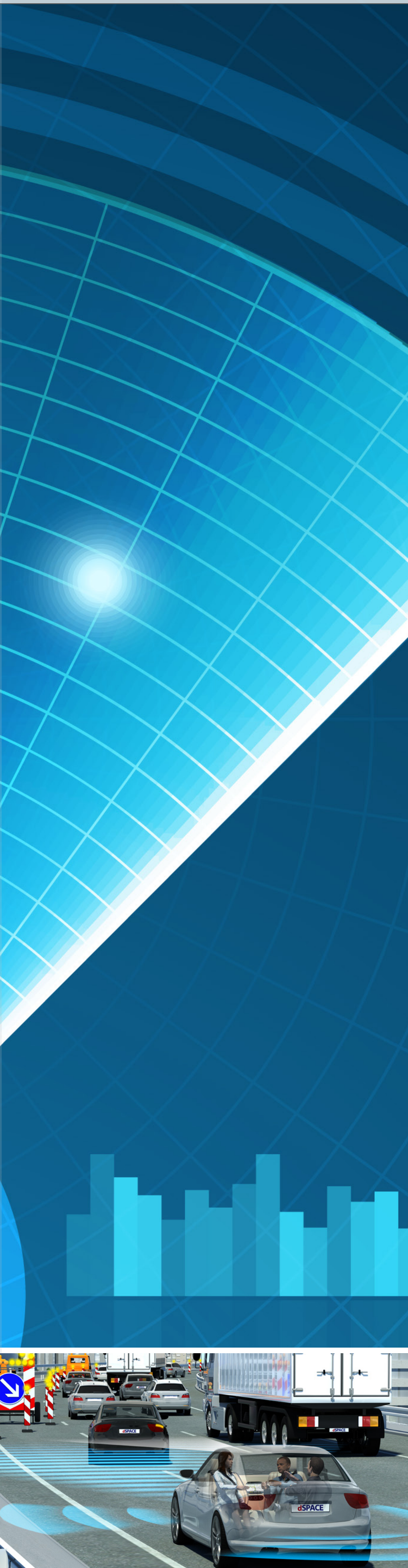
Integration into the Existing Tool Chain

In addition to the simulation models, other dSPACE software can be employed as usual, e.g., ModelDesk for model parameterization, ControlDesk for simulation monitoring, MotionDesk for visualization, and AutomationDesk for test automation. The new high-voltage electronic load becomes available in 2017 as part of engineering projects. ■

Testing radar sensors with real radar echoes

Real Echoes in the Lab





Testing radar sensors in a closed loop is one of the elementary challenges when developing advanced driver assistance systems. By adding enhancements to their HIL simulators, dSPACE now makes this possible in the limited space of a lab – using real radar echoes instead of virtual ones.

Radar sensors supply the advanced driver assistance systems of modern vehicles with the required environment information to avoid accidents or execute functions for autonomous driving. When the assistance systems are validated, the propagation behavior of the radar waves must be considered as realistic as possible. This means that costly and time-consuming road tests are usually inevitable. However, these road tests can be avoided by using radar sensors with real radar waves (over the air) in the lab.

Testing in the Lab and Not on the Road

To test radar sensors in the lab, a range of requirements must be met:

- Radar echoes of traffic participants, which would normally be present on the road at different distances (ranging from a few meters to some hundred meters) and different speeds, must be generated in the limited space of the lab.
- Changes in the direction of origin of the radar echoes (for example, when the vehicles drive around a bend) must also be simulated as well as radar cross sections (a measure for an object's ability to reflect radar waves).
- Undesired radar echoes that occur on the test bench must be filtered out or the test bench must be shielded from these echoes as they would compromise the test results. Therefore, the tests must be performed in a special absorber chamber.

Because it is difficult to meet all these requirements, most tests of radar-based driver assistance algorithms are done via restbus simulation. During these tests, detected radar objects are fed to the bus, for example, a CAN bus. However, this approach lacks test depth, because the tests are performed without real radar sensors. These disadvantages can be avoided by using real radar sensors and echoes. Thanks to the generic work process of the miro•sys Automotive Radar Scenery Generator, no ECU-specific internal information is required, which lets you treat the radar sensor as a black box and test it as such.

Test Bench for Radar-Based Algorithms

The dSPACE over-the-air (OTA) radar test bench for testing radar-based

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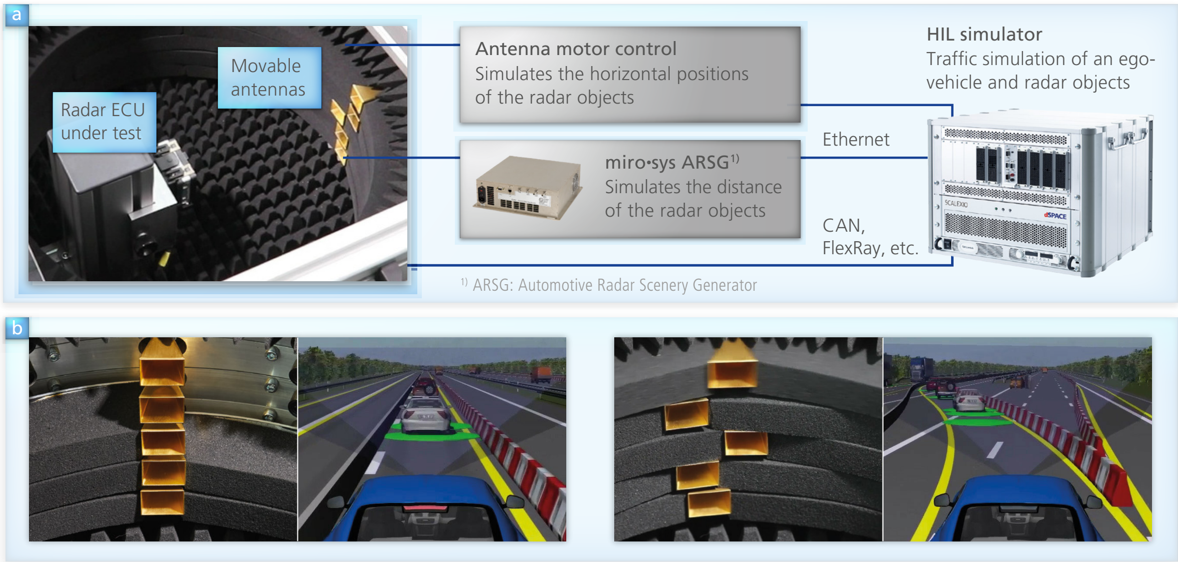
Figure 1: An overview of the radar test bench.

algorithms essentially consists of a mechatronic test bench, a dSPACE SCALEXIO HIL simulator, and the miro•sys Automotive Radar Scenery Generator (figure 2a). The mechatronic test bench includes an absorber chamber (a space with low reflection) in which the radar sensor is located as well as multiple stacked rings that rotate around a common perpendicular axis and are driven by an electric motor. The antennas are attached to these rings.
The rotation of the rings changes the antenna position and in turn the direction of origin of the radar echo (figure 2b). The miro•sys Automotive Radar Scenery Generator receives the radar waves sent by the radar sensor and modifies the original signal on the basis of the driving scenario that is played on the HIL simulator. The elapsed time between the sent and the received signal is varied for this, depending on the distance of the vehicles. As a result, the radar sensor receives radar echoes that match real road traffic. This way, all typical use cases, such as automatic cruise control (ACC), autonomous emer-

Figure 2: (a) The radar measurement device is located in an absorber chamber. The dSPACE simulator calculates the driving scenarios, positions the antennas, and controls the miro•sys Automotive Radar Scenery Generator, which generates the related radar echoes from up to four objects. (b) Two exemplary antenna positions with their respective driving scenarios.



gency braking (AEB), and lane changes can be simulated easily in the lab. The properties (shape, varnish) of the front spoiler into which the radar sensors are usually integrated can be easily taken into account for all tests. The test bench offers enough space to integrate part of the front spoiler and the radar sensor.

The video shows the working radar test bench. www.dspace.com/go/dMag_20172_Radar

Profile: Radar Test Bench

Main Features	Details
Radar objects (number/ properties)	■ Four independent radar objects with the following parameters: ■ Distance ■ Speed ■ Radar cross section ■ Azimuth angle
Refresh rate	■ 1 ms
Distance range/step width	■ 2.0[1)]-1,000 m / 5.6 cm (digital)
Speed range/step width	■ ±700 km/h / 4 mm/s
Azimuth angle range/resolution	■ ±90° / 0.1°
Azimuth angle speed	■ Max. 200°/s
Supported radar frequencies	■ 23-26 GHz, 75-82 GHz

1) Under development. Shorter distances on request.

Michael Rožmann, Managing Director at miro•sys GmbH, explains the challenges of using real radar echoes.

Mr. Rožmann, why is working with radar echoes so demanding?

In contrast to high-resolution images, such as images received from optical cameras, radar signals are harder to interpret. Moreover, the delicate high-frequency technology requires absolute precision with regard to signal quality and coherence. Even the smallest deviations can lead to major mistakes. Short-wave signals are also reflected extremely well, which means that undesired reflections must be managed accordingly.

How did you tackle these challenges?

miro•sys has decades of experience in the area of high-frequency technology and optics, which paid off when we developed the radar signal generator. The device allows for generating precise and coherent radar signals in real time. The tailored absorber chamber fitted with special material removes all undesired reflections so the radar sensor detects only the generated radar echoes.

What are the advantages of real radar echoes? Are there situations that can only be tested this way?

The advantages are obvious: The radar sensor to be tested can be treated as a black box, which means that no manufacturer-specific knowledge about the sensor is necessary. The complete chain of effects, from the radome to the tracking algorithm, can be tested with only this one approach. Moreover, the influence of the surrounding materials, such as the front spoiler, on the electromagnetic signal is taken into account.

What distinguishes your product from those of your competitors?

The properties of the radar echo, i.e., the radar cross section, relative distance, and relative speed can be set each millisecond. Additionally, we have a single compact device that supports up to four completely independent radar objects as well as three conventional radar frequencies, namely 24, 77, and 79 GHz. We can also configure the signal generator according to customer specifications, because it has a modular design.

What type of extensions are you planning for future versions?

We will primarily work on increasing the number of possible radar echoes and reducing the minimum distances of the radar objects.

Mr. Rožmann, thank you for talking to us.

Professor Dressler uses communicating robot cars today to analyze the potentials of cooperating vehicles of tomorrow.

"We might be surprised to see the capabilities that cooperating vehicles will have."

Professor Falko Dressler is researching the future of inter-vehicle communication

The dSPACE-sponsored research group for Distributed Embedded Systems is working on one of the most promising topics at the Department of Computer Sciences at the University of Paderborn. In an interview for dSPACE Magazine, the group´s leader, Prof. Falko Dressler, not only looks back at three exciting years. He also looks ahead to the future challenges for the automotive industry.

Prof. Dressler, you have coordinated the team for Distributed Embedded Systems since 2014. What were the team's most important milestones of the three years?
We were able to reach our first milestone as early as December 2014, in the founding year of our team. We successfully convinced the internationally renowned Vehicular Networking Conference (IEEE VNC) to take place in Germany for the first time, and in a relatively small city at that – after it took place in major cities like Amsterdam, Boston, and Kyoto. It was not just a good start for me, but a great effort that made the entire team proud. Only two years later, we hosted the International Symposium on Mobile ad-hoc Networking and Computing (ACM MobiHoc), an international technical conference with world-class speakers. The conference also brought Paderborn into the focus of many high-level researchers in mobile wireless communication. Last but not least, I also consider our cooperation with dSPACE an important milestone. It has continuously intensified over the last three years.

Distributed Embedded Systems – In the age of the Internet of Things, this sounds like a very broad field of research that already touches on many parts of our everyday lives. What are the focal points of your work?
Our field of research is indeed very broad. We therefore focus on two main areas. The first is driven quite strongly by the Internet of Things, where a growing number of the devices we use every day are interconnected. Here, we are working on miniaturizing the sensor technology for embedded systems. The sensors have to be very compact, be very versatile, and have a low energy consumption. Today, we can equip bats with radio sensors that only weigh 1.8 g, including the battery, and continuously monitor their social interactions in the network for up to two weeks.
The second main part of our work is inter-vehicle communication. In contrast to the Internet of Things, this area focuses mainly on criteria such as reaching ultrashort communication latencies and a high robustness of wireless networks, because human lives might depend on them.

Your inaugural lecture already addressed the challenges of this type of vehicle network. How do you view these challenges now that many automobile manufacturers are plan-

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ning to have their vehicles communicate with each other and the infrastructure?

We are currently focusing specifically on cooperative autonomous driving. This includes much more than today's environment perception of modern vehicles: Vehicles that interact with each other will also be able to detect dangerous situations that are outside of their own sensor perception range, for example, by being able to literally see through obstacles with the help of their partner vehicles. Even though the semi-autonomous cars of today are already impressive, I think it will be intriguing to see what a high number of interacting vehicles will be able to do. However, another great challenge will be to efficiently manage the resources of the required communication channels so that safety-relevant messages are always transferred, even when road traffic is very dense.

And how will it be possible to master these challenges in the future? What can the automotive industry do to prepare the ground for a stronger interconnection of their products? And what can university research do to support the industry?

In my opinion, one key to the solution will be choosing and standardizing a suitable transfer technology for the wireless communication between vehicles and the infrastructure. So far, I have had the impression that each OEM is doing it their own way. For example, some use mobile communications standards of the fourth generation (4G), whose coverage is still insufficient in many countries. Others push for networking via WLAN (IEEE 802.11p) but are facing enormous challenges in reaching a minimum penetration rate. Here, the longer-term research of universities can support the industry's research, which often runs for only a few years and aims at a quick return on investment. The support

Adaptive wireless communication is one of Professor Dressler's main research areas.

can be a type of "technology radar", for example. However, what I find most important is that companies consider the cooperation with universities a double win.

What does your cooperation with dSPACE look like, the company that sponsored your research group by means of a foundation? And in what areas do you cooperate?
To my mind, our cooperation with dSPACE is a good example for such a double win. One reason, of course, is that the professorship would not have been possible without the foundation. I think the company has also clearly recognized the long-term benefits of university research. dSPACE not only benefits from our work. It also openly shares the results with us, which is not a given in industry-financed research projects at universities. The many liberties we have in using our insights lay the foundation for more exciting topics and questions of the future. Our cooperation is also successful in terms of bachelor's and master's theses, and in terms of the hardware that the company provides us. We benefit from the cooperation because it lets us offer practical seminars. In turn, our students start working with dSPACE products very early on. It is not surprising that many of our graduates start their professional career in this company.

> "It is particularly important for me that companies consider the cooperation with universities a double win situation. In my opinion, dSPACE has a clear understanding of this."
>
> *Professor Falko Dressler*

For your HY-NETS project, you also work closely with dSPACE and other partners with the aim of simulating complex traffic flows and making hybrid drives even more efficient with assistance systems. How is this project coming along?
HY-NETS not only gives us a vivid example for our good cooperation with dSPACE and partners from the industry. It also presents a very interesting use case for vehicles that communicate with each other and the infrastructure, in this case even from an ecological point of view. The traffic flows we simulate for the project, as well as the simulated communication among the vehicles and the infrastructure, can already be combined with the dSPACE models for the immediate traffic environment of the hybrid vehicle to be optimized. This makes it possible to create complex cooperative driving scenarios, which our partners use to test a real hybrid drive on a test bench. The great potential for future improvements in efficiency and fuel consumption is visible even today.

In 2016, you were named Fellow of the Institute of Electrical and Electronics Engineers (IEEE). What does this mean for you personally and for your research?
Personally, the IEEE fellowship is a great honor, but it is not likely to have a direct effect on my research today. In the long term, however, I think it can open up new possibilities and networks for the Distributed Embedded Systems team. First, it improves the image of the professorship, which might be of help when acquiring exciting new research projects. Second, this recognition will also transfer to our graduates. Graduating under an IEEE Fellow can tip the scale for a graduate to be successful on the IT job market.

Professor Dressler, thank you for speaking with us.

Prof. Dr.-Ing. habil. Falko Dressler, born in 1971, has been with the Department of Computer Sciences at the University of Paderborn since April 1, 2014 and heads the research group for Distributed Embedded Systems.

Developing an autonomous racing vehicle for Formula Student Driverless

Track Record

Precise, reproducible, adaptive – these are the prominent characteristics of virtual drivers. The Formula Student team of Augsburg University of Applied Sciences is focusing its efforts on precisely this to achieve the best possible lap times. It uses a MicroAutoBox and RTMaps, a multisensor development environment, for developing the autonomous driving control.

Formula Student is always up to date, even for the latest developments in the automotive industry. Since 2017, teams have been competing in Formula Student Driverless with autonomous racing cars. The aim is to race a vehicle around a track marked by traffic cones - as fast as possible and fully autonomously. Team Starkstrom of the Augsburg University of Applied Sciences is one of the participants. The team introduced automated testing with a virtual, GPS-based driver as early as 2015. Chairman Julian Stähler says: “This way, we were able to optimally tune the torque vectoring of our electric vehicle, because no real driver can offer this precise reproducibility.”

Driving by Maps

The team now has an autonomous racing vehicle that complies with regulations and features two lidar sensors and a camera. Thanks to these features, the vehicle can independently capture it and then use GPS to drive around the track at high velocity. Because of the properties of the sensors used, the vehicle start is intentionally slow. For example, the lidar sensor only returns reliable measurement data for speeds up to 20 km/h. At this speed, the racing vehicle first becomes familiar with the track and enters all detected traffic cones and their GPS positions into a map. During this, the camera is responsible for the basic detection and the lidar sensors return the exact distances to the vehicle. During the next lap, the speed is increased and the vehicle is controlled by fused sensor data along the nominal path. The map receives more and more details with each lap. After ten completed laps, the vehicle must stop at the finish line, which the camera must detect on the basis of traffic cones with a different color.

Central Computation Unit

To centrally control the vehicle, the

> “RTMaps and MicroAutoBox help us develop new functions very quickly and implement them in the autonomous vehicle in a short amount of time.”
>
> *Julian Stähler, Team Starkstrom*

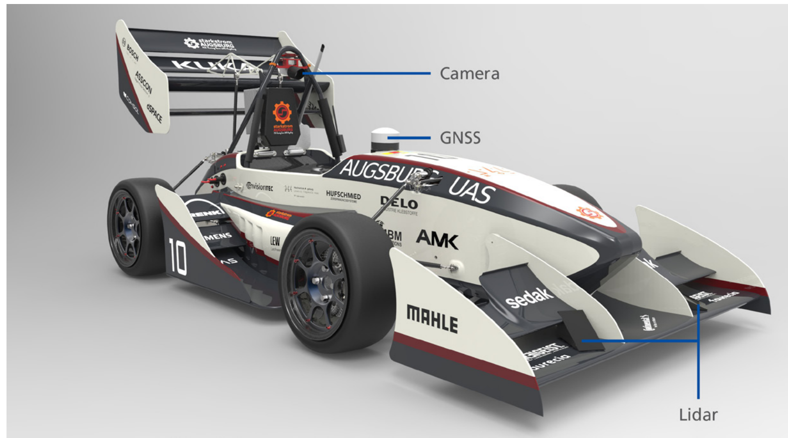
team uses a combination of MicroAutoBox and MicroAutoBox Embedded PC. While MicroAutoBox calculates the steering angle and brake commands, which control the actuators, Embedded PC receives the signals of all image sensors. To process and merge these, the team uses the RTMaps development environment from Intempora.

Developing Algorithms

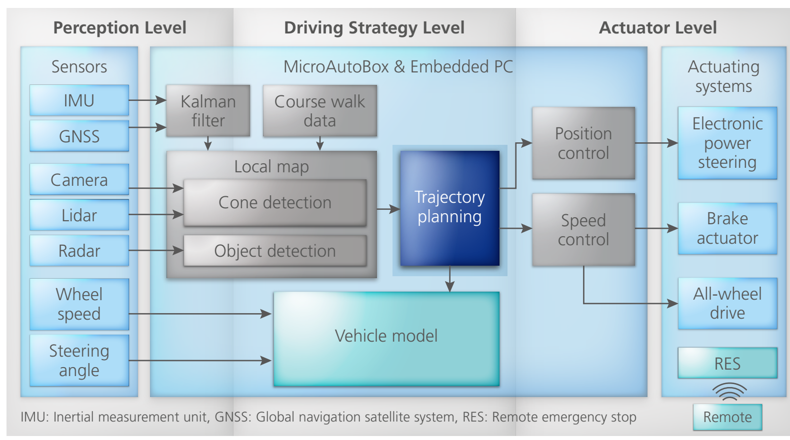
Software developer Mathias Pechinger explains: "We created the algorithms used to detect the traffic cones ourselves using Python and open-source libraries. We then integrated them in RTMaps with the Python block." Afterwards, the camera and lidar signals were fused in RTMaps and the movement trajectories were calculated. After the function development, a simulation was performed, and subsequently it was possible to execute the software immediately on the Embedded PC together with an RTMaps runtime environment. When the vehicle drives autonomously at high speeds, a sensor fusion of GPS reference signal data, lidar data, acceleration and wheel speed is performed. If the GPS signal is disrupted, a Kalman filter supports driving at 50 km/h for another 7 seconds approximately until the vehicle is slowed down and the imaging systems control the vehicle.

Reaching High Performance

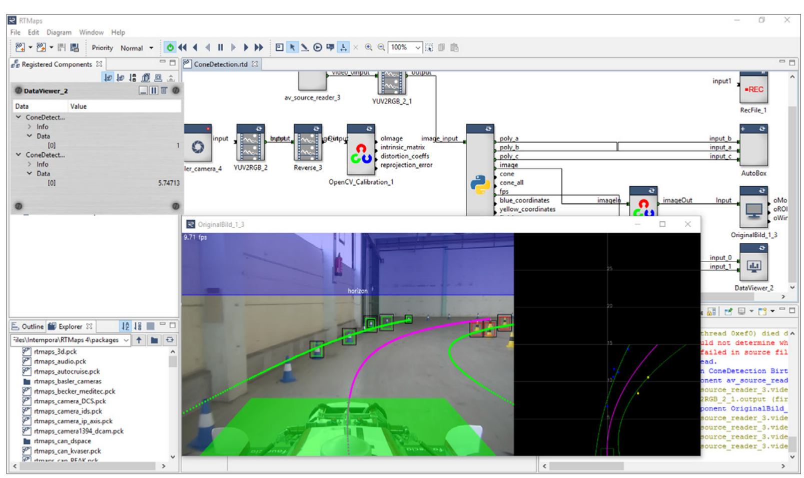
The student developers are extremely content with the functioning and the workflows of RTMaps. Mathias Pechinger says: "RTMaps works really well. Especially the simple linking to the algorithms developed in Simulink® on the MicroAutoBox allows us to implement new functions very quickly." Replacing the initially USB-based camera with an Ethernet-connected model was done just as quickly. The student developers only had to select the relevant RTMaps block for the camera to start working. The flexible and powerful tool chain enabled the team to drastically increase the performance of the vehicle. It can now follow the track safely at 90 km/h, which is a great basis for future competitions. ■



The autonomous vehicle by the Augsburg University of Applied Sciences is equipped with a global navigation satellite system (GNSS) and captures its environment by using a camera and two lidar sensors.



Schematic setup of the vehicle control.



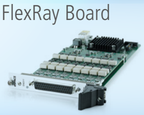
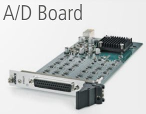
RTMaps evaluates the captured environment and determines the movement trajectories.

New Hardware for SCALEXIO Systems

dSPACE offers a large number of hardware boards for SCALEXIO. They are used in different systems, for example, SCALEXIO LabBox and the SCALEXIO rack system. The new boards are suitable for both function development and ECU testing.

The compact SCALEXIO LabBox can be used with up to 18 boards.

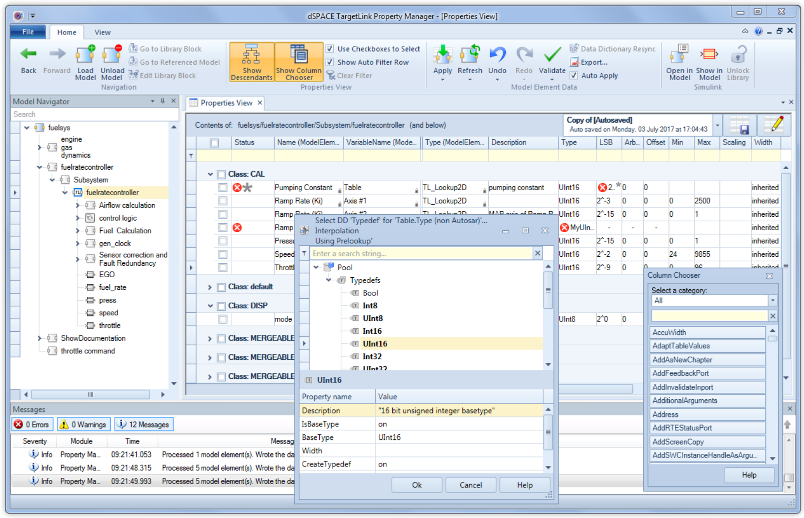
The SCALEXIO rack system has up to 12 height units and can be used with up to 20 boards.

Product	Description	SCALEXIO System
DS6001 Processor Board[1)] 	■ Processor board with Intel® Core™ i7-6820EQ, quad-core, 2.8 GHz ■ Ideal for fast closed-loop applications ■ High bandwidth and fast access to SCALEXIO I/O boards ■ Easily scalable processor performance when coupled with additional processor hardware	■ SCALEXIO LabBox
DS6331-PE Ethernet Board[1)] 	■ Expands the SCALEXIO Processing Unit by 4 Ethernet interfaces ■ Supports the transfer rates 10/100/1000 Mbit/s ■ 4 integrated Ethernet controllers	■ SCALEXIO rack system
DS6332-CS Ethernet Board[1)] 	■ Adds 5 Ethernet interfaces to the DS6001 Processor Boards ■ Supports the transfer rates 10/100/1000 Mbit/s ■ Integrated network switch	■ SCALEXIO LabBox
DS6311 FlexRay Board 	■ 4 independent FlexRay controllers ■ Channels A and B of each controller can be used in parallel ■ Software-controlled termination resistor as well as feed-through operation ■ Wake-up support	■ SCALEXIO LabBox ■ SCALEXIO rack system
DS6341 CAN Board 	■ 4 CAN/CAN FD channels ■ All channels are independent of each other ■ CAN FD data transfer rate 40 kBd ... 8 MBd ■ Software-controlled termination resistor as well as feed-through operation	■ SCALEXIO LabBox ■ SCALEXIO rack system
DS6351 LIN Board 	■ 8 LIN channels ■ All channels are independent of each other ■ Software-controlled termination resistor	■ SCALEXIO LabBox ■ SCALEXIO rack system
DS6221 A/D Board 	■ 16 fast A/D channels ■ Conversion time of 250 ns (4 Msps) and 16-bit resolution ■ Versatile trigger options ■ Streaming interface	■ SCALEXIO LabBox ■ SCALEXIO rack system
DS6202 Digital I/O Board 	■ 32 bidirectional channels ■ Voltage supply for sensors with 5 V and 12 V ■ Expandable digital I/O functionalities	■ SCALEXIO LabBox ■ SCALEXIO rack system
SCALEXIO Serial Interface Solution 	■ Serial Peripheral Interface (SPI) for up to 4 channels ■ Inter Integrated Circuit (I^2C) interface for up to 5 channels	■ SCALEXIO LabBox ■ SCALEXIO rack system ■ External enclosure for connecting to a SCALEXIO rack system

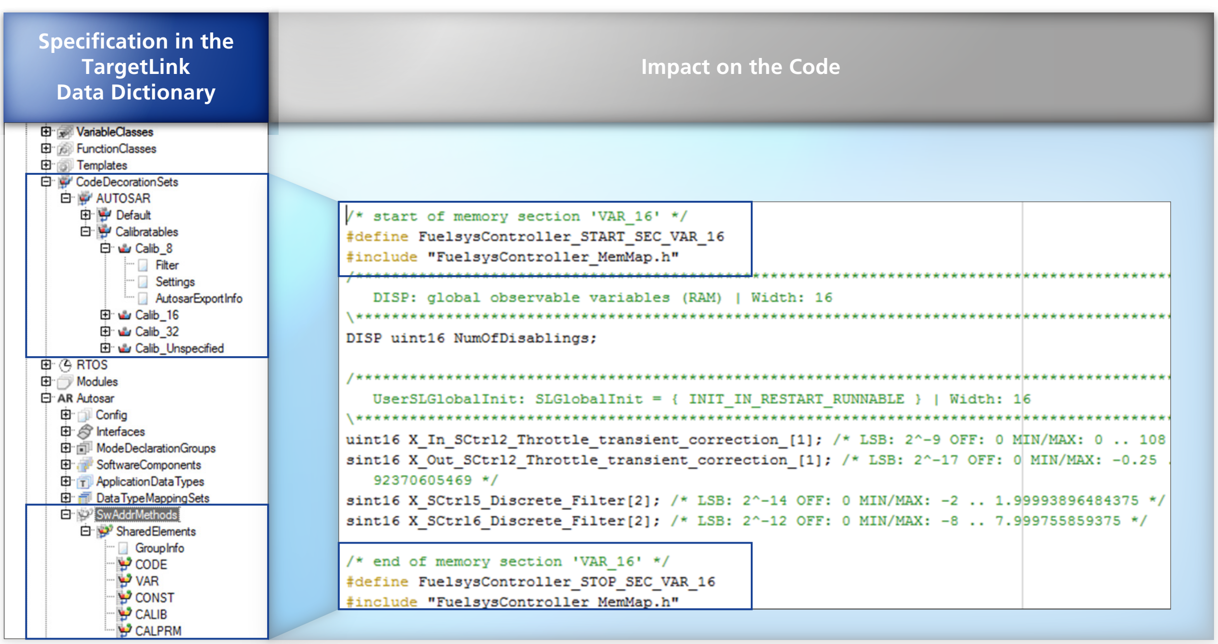
[1)] For this board, slot dependencies apply. For more information, contact dSPACE Sales at info@dspace.de.

TargetLink 4.3: Large Models Under Control

The completely revised Property Manager of TargetLink 4.3 gives production code developers an even better overview of their models as well as their block and object properties. Some new features include detailed filter options, automatic validation, and error indication. This particularly makes working with large models much easier and improves usability. The modular development for creating, integrating, and reusing individual components becomes simpler with optimized workflows and more flexible organization of the created artifacts. TargetLink 4.3 also supports AUTOSAR 4.3 and offers new, powerful mechanisms for partitioning data and code into individual memory segments. This is particularly helpful for safety-critical projects, as is the fact that TargetLink 4.3 complies with all autocoding rules in the Mandatory and Required categories of MISRA C:2012. This significantly reduces the work involved in documenting deviations. In addition, TargetLink 4.3 will provide comprehensive extensions for the modeling of algorithms, which will make the work of function and software developers much easier.



TargetLink 4.3 with its completely revised Property Manager.



New possibilities for code partitioning using the TargetLink Data Dictionary ensure that all functions and variables are instantiated in the desired memory segments.

Results of the dSPACE Magazine Survey

The latest reader survey about dSPACE Magazine has had very positive feedback. dSPACE would like to thank all participants for an informative overview of our readers' opinions that contains much praise but also reveals room for improvement in some areas, which we want to address in the future. dSPACE will also gladly keep its promise of donating for each filled-in questionnaire to a good cause. As the participants selected the cause they want to make a donation to at the end of the survey, 1,100 euros will be donated to the World Wide Fund for Nature (WWF), 1,400 euros to the organization Engineers without Borders, and 2,500 euros to the United Nations Children's Fund (UNICEF). The donations will be used to support current and urgent projects. Again, we would like to thank all participants! ■

Online version and archive of dSPACE Magazine:

www.dspace.com/magazine


Source: © WWF/Steven Morello


Source: © Engineers without Borders

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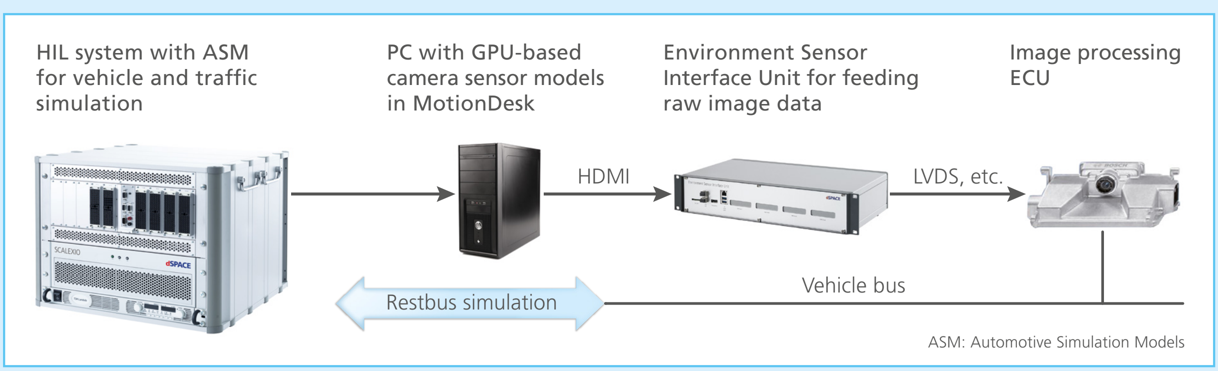
Synchronized Feeding of Sensor Data to Camera ECUs

Systems for autonomous driving use multiple environment sensors. To simulate the sensors in a HIL setup for sensor fusion and function testing, it is essential to accurately synchronize the stimulation of the individual sensors. The new dSPACE Environment Sensor Interface Unit supports the time-correlated feeding of raw sensor data to one or more camera ECUs.

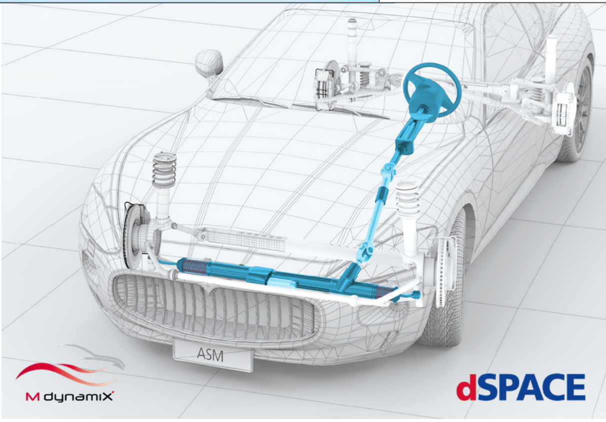
The Environment Sensor Interface Unit is the ideal solution to help you overcome typical problems that occur when testing camera-based systems[1)] "over the air", such as:

- Limited monitor contrast (e.g., insufficient light at night, sun glare)
- Distortion caused by lenses (e.g., fish-eye effect)
- Complex setup with stereo cameras or multiple cameras
- Dirt on the optical path
- Pixel errors



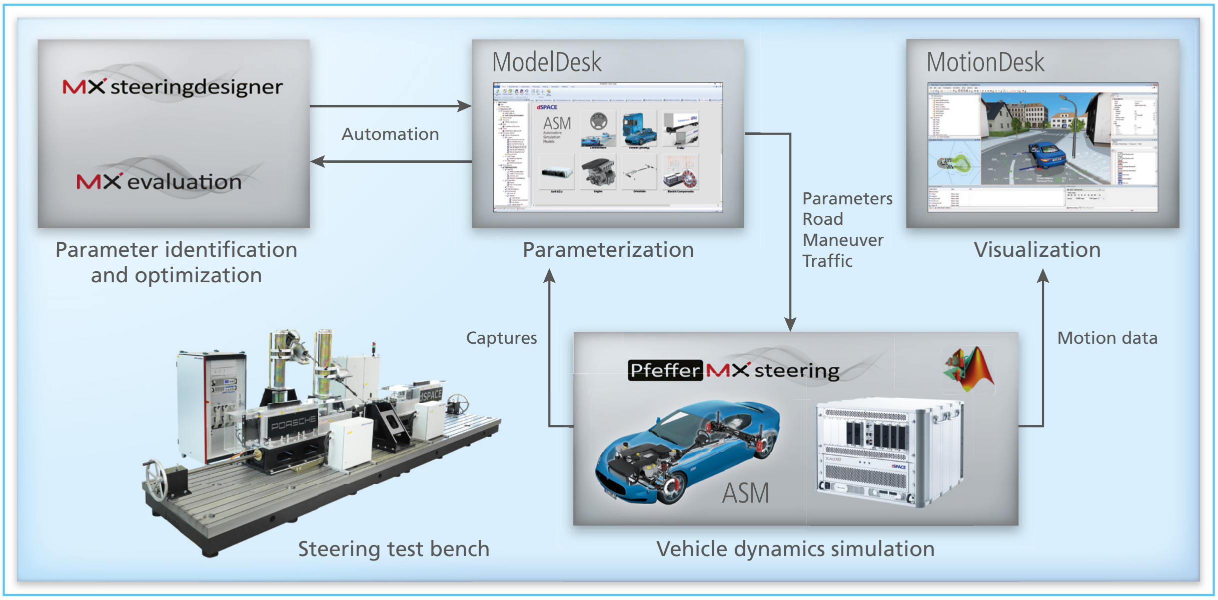
1) An expansion for radar and lidar raw data is under development.

Cooperation of dSPACE and MdynamiX Broadens Range of Solutions for Vehicle Dynamics Systems



The companies MdynamiX and dSPACE have entered a cooperation that intensifies their already constructive collaboration in developing and testing electric steering systems. To this end, the renowned steering system model of Prof. Peter E. Pfeffer, CEO of MdynamiX, was integrated into the dSPACE Automotive Simulation Models (ASM) tool suite. Vehicle developers thus benefit from a powerful tool chain for the application of vehicle dynamics and steering behavior.

The dSPACE platforms now provide the established tools MXsteeringdesigner and MXevaluation as well as the expertise of MdynamiX for crucial work steps, such as steering system characterization and identifying steering model parameters. Integrating the steering system model makes it possible to use MXsteeringdesigner to automate the parameter identification for ModelDesk by using measurements at a dSPACE steering test bench. With MXevaluation, objective parameters can be determined from vehicle measurements and simulations and thus used for the application of electronic control units or the optimization of the steering feel. In development projects, MdynamiX provides particularly strong support for solving complex problems in the fields of vehicle dynamics and steering calibration. Because the ASM simulation tool suite is also used on MdynamiX test benches at the Munich University of Applied Sciences, developments and services can be provided continuously on all involved test systems. The seamless integration makes the new tool chain ideal for a continuous development process, starting with model-based design (MBD), to software-in-the-loop (SIL) simulation, up to hardware-in-the-loop (HIL) simulation with a real ECU. The aim of the partnership between MdynamiX and dSPACE is to offer customers the complete package from hardware, to software, to application knowledge in the fields of vehicle dynamics and steering systems.



In dSPACE ModelDesk, identified and optimized parameters of a steering system can be imported and then be used to parameterize the ASM models together with other data. The real-time simulation, e.g., on dSPACE SCALEXIO, is then visualized by a 3-D animation in dSPACE MotionDesk.

MicroAutoBox Embedded PC with Even More Power for Computation-Intensive Applications

In addition to the existing variants with Intel® Core™ i7 processors of the third generation, dSPACE will soon offer a more powerful variant of MicroAutoBox Embedded PC. With a quad-core Intel® Core™ i7 processor of the sixth generation, 16 GB RAM and 128 GB flash memory, it provides even more power for demanding and computation-intensive Windows® and Linux prototyping applications in the vehicle, e.g., applications needed for developing advanced driver assistance systems (ADAS) and functions for automated driving. The new variant of Embedded PC can still be used together with MicroAutoBox in a compact and robust housing.
Moreover, it is now possible to use Embedded PC as a stand-alone system without a MicroAutoBox. For example, it can be used as a dedicated platform for the multisensor software development environment RTMaps. Another new feature is the optional addition of up to three mPCIe plug-in cards, which allow the system to be equipped with dSPACE-qualified extensions for WLAN, CAN, CAN FD, and BroadR-Reach Ethernet, for example. To record large volumes of data, e.g., from cameras as well as radar and lidar sensors, the new Embedded PC also has an external SATA interface (4 x SATA 3.0). The interface lets you capture data with a very high bandwidth. For this use case, dSPACE is planning on offering a MicroAutoBox Embedded Data Storage Unit (DSU) with up to four SSDs and several terabytes of storage capacity that can be used together with Embedded PC. ■

The new variant of MicroAutoBox Embedded PC (front/rear sides) can also be used as a stand-alone system without the standard MicroAutoBox.

The new variant of MicroAutoBox Embedded PC used together with MicroAutoBox in a compact and robust housing.

dSPACE on Board

Discover intriguing and innovative applications, achieved with dSPACE development tools

Euro 6 Retrofit Solution

For the development of an exhaust aftertreatment system that can be used as a retrofit solution for older diesel vehicles, Twintec Technologie GmbH uses tools from dSPACE. During test drives with MicroAutoBox and ControlDesk on board, the system shows a significant reduction in nitrogen emissions.

The exhaust gas aftertreatment system from Twintec is designed as a retrofit solution for diesel vehicles.

With ControlDesk, the developers monitor the pollutant emissions during the test drive.
www.dSPACE.com/go/dMag_20172_TwinTec

Docking System for Space Ships

The International Docking Adapter (IDA) is a new spacecraft docking system for the International Space Station (ISS) to dock the next generation of spacecraft. The company uses hardware and software products from the dSPACE tool portfolio to carry out feasibility testing and develop the safety-critical algorithms that control the docking process.

The new adapter allows for exchanging crew, cargo, power, and data between spaceships and the space station.
www.dspace.com/go/dMag_20172_SpaceX

MOOG also uses the dSPACE Simulator for complex evaluations and controller development.
www.dspace.com/go/dMag_20172_MOOG

Research on Intelligent Hybrid Vehicles

The Ostfalia University of Applied Sciences in Wolfenbüttel is researching intelligent electronics systems for autonomous and energy-efficient hybrid vehicles. Extensive simulations of vehicle dynamics and traffic are performed to evaluate the systems. The tool chain used for testing consists of a driving simulator from Cruden, the real-time platform dSPACE SCALEXIO, and the ASM simulation tool suite.

A driver-in-the-loop simulator recreates the influences of the environment as well as the vehicle dynamics that occur in real test drives.
www.dspace.com/go/dMag_20172_Cruden

The vehicle behavior, the traffic, and the environment are calculated in real time by the ASM tool suite.
www.dspace.com/go/dMag_20172_Ostfalia

Learn more about these applications online, via videos, photos, and reports:
www.dspace.com/go/dMag_20172_REF_E