dSPACE MAGAZINE

1/2021

Bugatti – Early Simulation Speeds Up Development Process | Page 18

Neusoft Reach – High-Precision Environment Simulation Ensures Safety in Camera-Based Assistance Systems | Page 10

Volkswagen – Completely Virtual Integration Testing Helps Manage the Complexity of Software-Defined Vehicles | Page 24

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> "Our unique end-to-end solution approach covers the entire spectrum of simulation and validation methods in connection with vehicle development, thus accelerating processes and cutting costs for our customers."

Dear Readers,

Mastering complexity: That is the focus in this issue of dSPACE Magazine. By consistently enhancing our solutions for autonomous driving, electromobility, and digitalization, we support our customers as a reliable partner in simulation and validation. In 2020, we added to the ranks of our global dSPACE team, while at the same time significantly expanding our range of solutions for data-driven development and the validation of AI-based functions for autonomous driving and enhancing our competencies in cloud computing and electromobility. At the same time, we are also expanding our global network of partners. And we continue to invest in customer proximity – for example, by founding a regional dSPACE company in Korea and a third Chinese location in Guangzhou.
Our unique end-to-end solution approach covers the entire spectrum of simulation and validation methods in connection with vehicle development, thus accelerating processes and cutting costs for our customers.
The construction of a test factory at Volkswagen shows the amount of effort involved in mastering the complexity of software-defined vehicles. We had to completely rethink the concept of validation in particular. We are proud to have been a strong partner for Volkswagen in this endeavor.
Sensor simulation is another example of how complex the validation process is. A vehicle with sensors and an AD stack has to be tested in a defined environment, for example, at an intersection: possible parameters include fellow road users, speed, weather, etc. This is impossible in the real world because the number of situations to be tested cannot all be reproduced there. Simulation makes this possible.
Our customer Neusoft attests to the fact that using high-precision sensor simulation early on by means of a consistent SIL- and HIL-based method shortens software development cycles while improving the quality of the ADAS/AD control units. The developers agree: This helps reduce costs significantly and makes an important contribution to ensuring a timely market launch of safe vehicle components.
We are constantly improving these simulation solutions, as demonstrated by the new solution for sensor-realistic simulation on page 36. This simulation technique is set to be enhanced with the web-based simulation platform SIMPHERA, which will make it possible to simulate scalable variations of highly complex scenarios also in the cloud.
These examples demonstrate that the focus of all activities at dSPACE is always on the challenges faced by our customers and their success. And as your partner in simulation and validation, we are constantly investing in new technology, solutions, and competencies.

I wish you all the best and stay healthy,

Martin Goetzeler

IMPRINT

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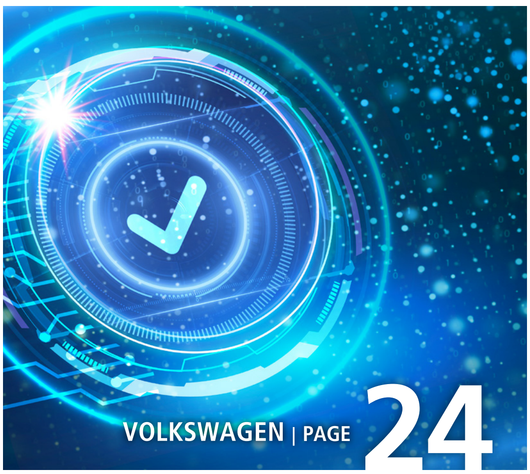

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To automate its mechanical test benches, Toyota relies on a combination of AutomationDesk and SYNECT

Automated Rolling

The recent electrification trend in the automotive industry has created a pressing need to adapt to electrified systems in powertrain development. This adaptation process has become more complex, prompting Toyota to strive for improved efficiency with the advanced dSPACE automation solutions.

To make complex powertrain development more efficient, more adaptation and evaluation tasks have to be frontloaded. Toyota performs these tasks before test track evaluation with actual vehicles by combining various test benches: a vehicle evaluation bench (chassis dynamometer), a powertrain system bench, and various component benches (engine bench, e-motor bench, etc.). However, since test bench manufacturers and system configurations vary according to purpose and application, configuring the test benches can be challenging. Each test bench requires dedicated test preparations and test methods. In the past, two or three preparation cycles were required for each test bench, even if they performed similar evaluations. Even so, data formats and result contents were different, rendering an integrated evaluation difficult.

Test Environments Require Integrated Automation Platforms

There are two main requirements for frontloading adaptation and evaluation tasks as well as improving efficiency and productivity:

- Executing standardized automation methods on test benches for various powertrains
- Using test bench automation platforms that can be flexibly integrated into various test benches

Test Efficiency Challenges

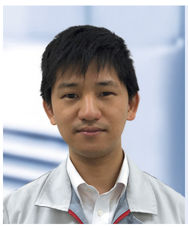
In order to work efficiently with test benches, it must be possible to remote-control them, automate them, and easily and flexibly change the test sequences for test benches from different manufacturers and for various measuring tools. Mr. Taira, a test bench developer, explains, "I wanted to support the test team with a tool that would relieve them of many manual interventions." He adds, "Drive modes in most tests can be categorized into several types, so changes of the base type must be simple and quick on a daily basis." Therefore, Mr. Taira went about implementing a general-purpose operation flow by analyzing, disassembling, and reconstructing test bench operations, and then consolidating them into the following three parts to automate them:

1) ECU operations (writing to and measuring RAM variables in the ECU software, etc.)
2) Driver operations (accelerating, braking, shifting)
3) Test bench operations (roller/dynamometer rotation speed, etc.)

Toyota started looking for a versatile and easily expandable platform that met these three points.

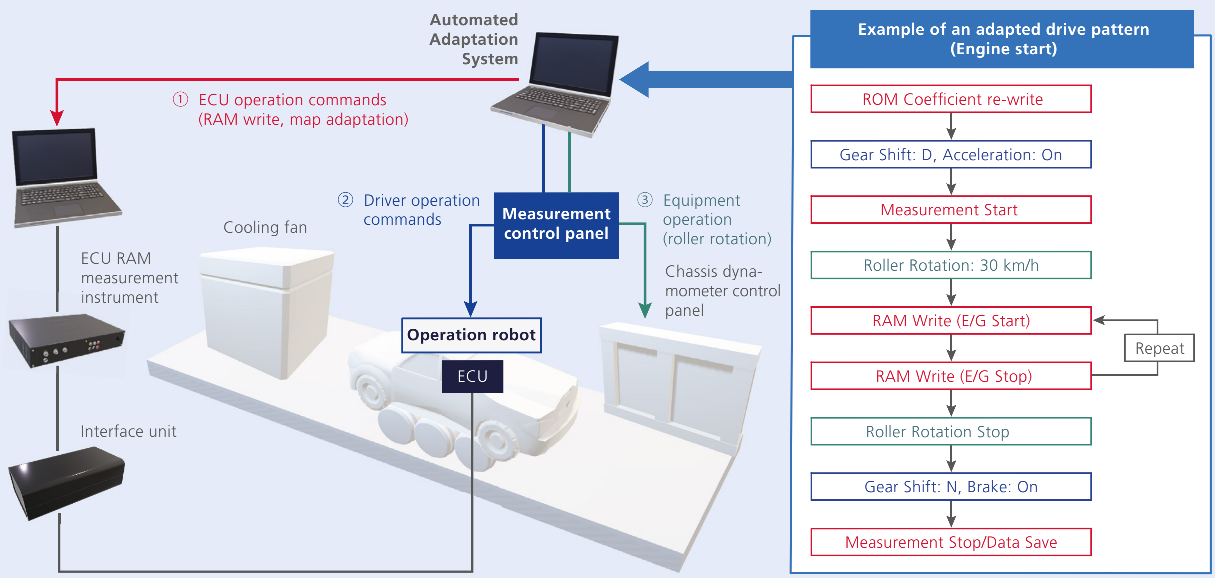
Evaluating a Test Automation Solution

Generally, each company establishes its own test bench automation solutions, the downsides being designs based on proprietary standards, high prices, and poor customizability. The SYNECT and AutomationDesk automation solution tool chain provided by dSPACE eliminates these draw- >>



"The expandability and versatility of AutomationDesk make it easy to automate test bench environments, including the various types of equipment the test benches require."

Tomoki Taira, Toyota



Automation components: access to the control unit, driving robot, roller test bench.

backs. The tool chain offers:

1) Environment integration with standard ASAM-compliant interfaces
2) High versatility in terms of output data formats, etc.
3) Additional automation functions in a reasonable price range
4) High compatibility with versatile general-purpose dSPACE platforms
5) Shareable and reusable client-server test scenarios

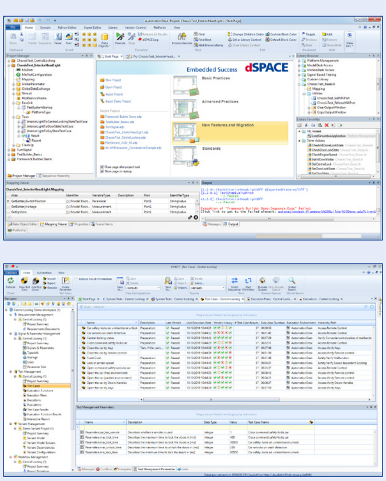
Mr. Sekimoto, the main test bench user at Toyota, comments, "If we succeed in using AutomationDesk and SYNECT as the automation solution for our test benches, we will have the desired flexibility in testing at a fraction of the cost of other solutions."

Implementing the Selected Test Automation Solution

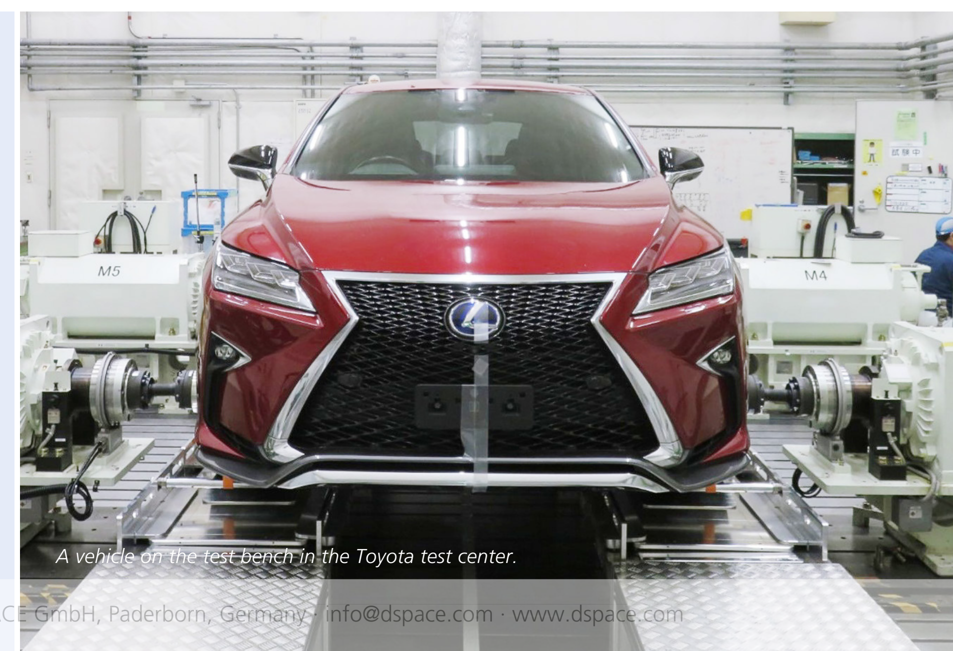
Test bench automation with AutomationDesk was successfully demonstrated in a test setup. The basic ideas:

1) Use the compatibility with ASAM standards that AutomationDesk provides to turn standard interfaces with third-party platforms into libraries and operate them via ASAM standards, such as XCP, ASAP3, XIL MAPort, and ODS.
2) Separate test scenarios from parameters to create reusable and versatile test templates.
3) Learn use cases from human test bench operators, and leverage these cases to separate operations into ECU operations, driver operations, and test bench operations, as well as to create the required and sufficient standard test scenarios.

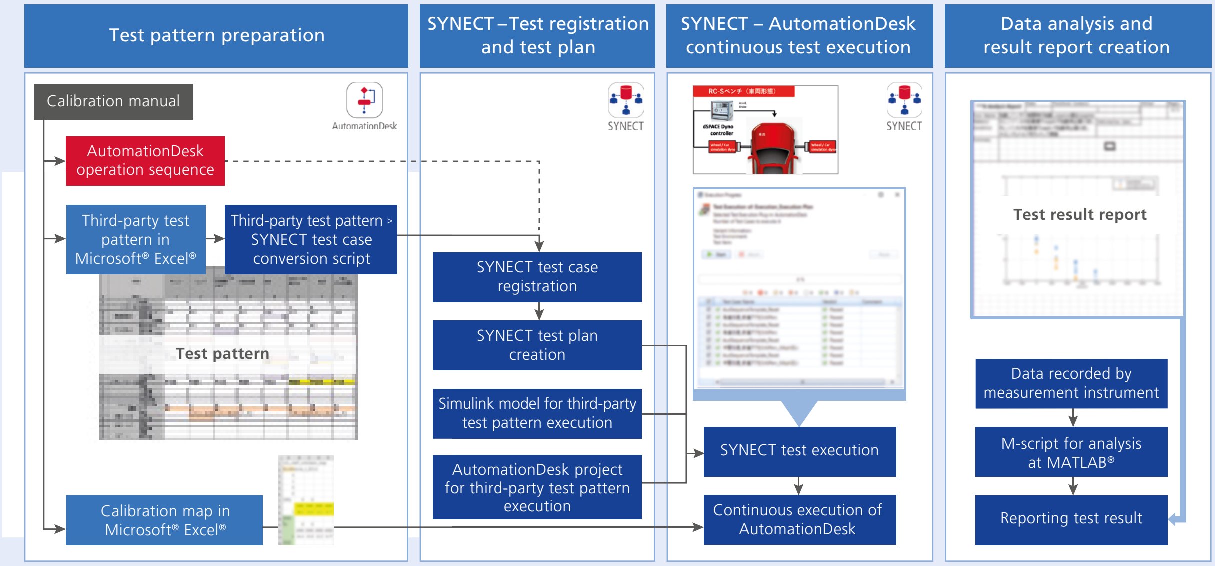
After successful evaluation, this automation solution is now used



Test bench automation mastered by AutomationDesk and SYNECT.



A vehicle on the test bench in the Toyota test center.



Sequence from test definition to analysis.

"SYNECT Test Management not only conducts tests. It also makes the processes before and after tests, and the tasks of test workers, more convenient and productive."

Shun Sekimoto, Toyota

on a number of Toyota test benches, such as powertrain test benches and chassis dynamometers. "Using AutomationDesk on several test benches provides us with powerful and particularly cost-effective test bench automation," Mr. Taira concludes.

Efficient Test Management

Since the goal was not just to automate operations on test benches but to build an integrated development platform, Mr. Taira used dSPACE SYNECT to review development processes on test benches and optimize them.

1) He built a test execution planning and management mechanism using SYNECT Test Management.

2) He extended SYNECT and AutomationDesk using Python scripts to build an interface that can execute the entire process from test registration to test planning to test execution at the end user level.

3) For parallel test preparation and execution and to achieve continuous test execution, he used SYNECT to separate work done in offline environments (test registration/planning) from online work (test execution).

4) He enabled the sharing and reuse of test assets (derived from test scenarios and test plans) with a SYNECT client-server configuration.

"Since the drive sequences of all test benches are similar, sharing them between test benches was not difficult," Mr. Sekimoto finds. He continues, "Separating the processes of stakeholders involved in testing and executing them in parallel with SYNECT Test Management to control automatic test execution centrally in SYNECT made it possible to run tests more efficiently."

Findings and Outlook

With the powerful automation solution based on AutomationDesk and SYNECT, it is easy to define tests and track the test progress and status (pass/fail) during continuous test execution. The convenient graphical user interfaces make it particularly easy to rearrange test sequences, create repetitions and combinations of test sequences, and visualize them clearly. Simple changes of test sequences and test patterns can be made centrally. These quick test modifications facilitate everyday testing and increase the depth of testing. They also greatly improve collaboration with stakeholders involved in the testing process. The dSPACE tools helped Toyota succeed in frontloading adaptation and evaluation tasks and optimizing its processes. In light of these achievements, Toyota is currently adapting and expanding the processes to additional test benches.

Courtesy of Toyota

Validation solution for camera-based driver assistance systems

Virtual Vision Test

How do you succeed in reliably implementing ever new driver assistance systems and functions for automated driving in the vehicle? Neusoft Reach relies on a validation solution that allows for end-to-end testing from the developers workstation to ECU approval.

Picture credits: © Neusoft Reach

Future, intelligently networked, and automated vehicles are highly software-defined. Software and service capabilities are increasingly becoming the decisive competitive factors of the automotive industry. Neusoft Reach already provides an AUTOSAR-compliant software platform for the next generation of vehicles. This software contains a comprehensive advanced driver assistance system/autonomous driving (ADAS/AD) stack supplemented by a driver monitoring system (DMS) for automated driving (Level 2+/Level 4) and a high-precision positioning controller. The goal of Neusoft Reach is to contribute to the safety and efficiency of transportation by providing the world's most intelligent environment detection and identification technology.

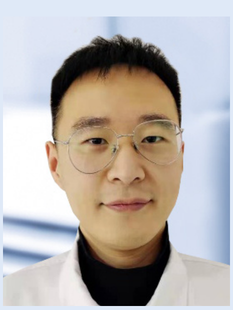
Intelligent Assistance Systems

The ADAS/AD stack is based on multi-sensor technology and has algorithms that have been machine-trained. The stack meets the regulations for commercial vehicles in China and the requirements of the C-NCAP. It also takes into account the requirements of the Euro-NCAP 2025 roadmap. It currently supports the following functionalities:

Traffic Jam Assist (TJA),
Adaptive Cruise Control (ACC),
Automated Emergency Braking (AEB),
Forward Collision Warning (FCW),
Lane Departure Warning (LDW),
Lane Keeping Assistance (LKA),
Advanced Parking Assist (APA),
Around View Monitoring (AVM)

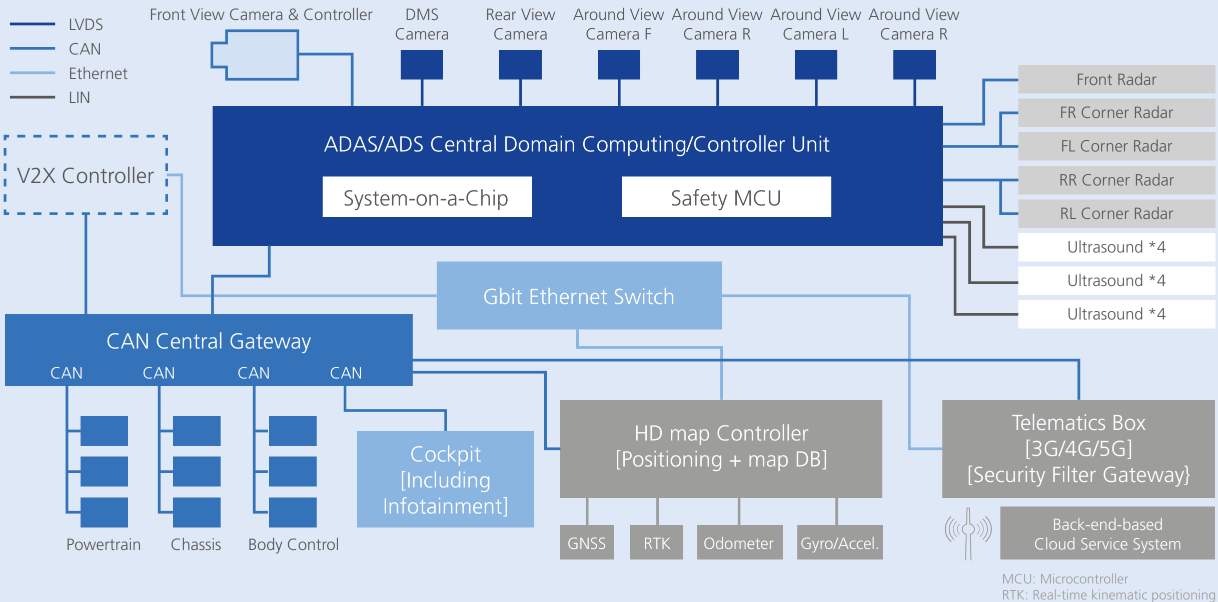
Motivation: Robust and Innovative

The goal of Neusoft Reach is to continuously expand and optimize the ADAS/AD functions. As part of this process, the development team defined performance values for the camera-based functions that can no longer be achieved reliably and efficiently by the development and validation solutions that were previously used. To provide robust functions, early validation of new algorithms for sensor fusion and perception as well as of the overall system must also be easily possible. >>



"The simulation and validation solution from dSPACE meets our requirements for developing and testing ADAS/AD control units. It helps us achieve our project goals and accelerates the market launch. The overall efficiency in developing ADAS/AD control units has been improved by 70%."

Xiao Yu Chen, Neusoft Reach



Setup of the ADAS/AD stack from Neusoft Reach.

SIL

Challenge: Availability of Suitable Test Data

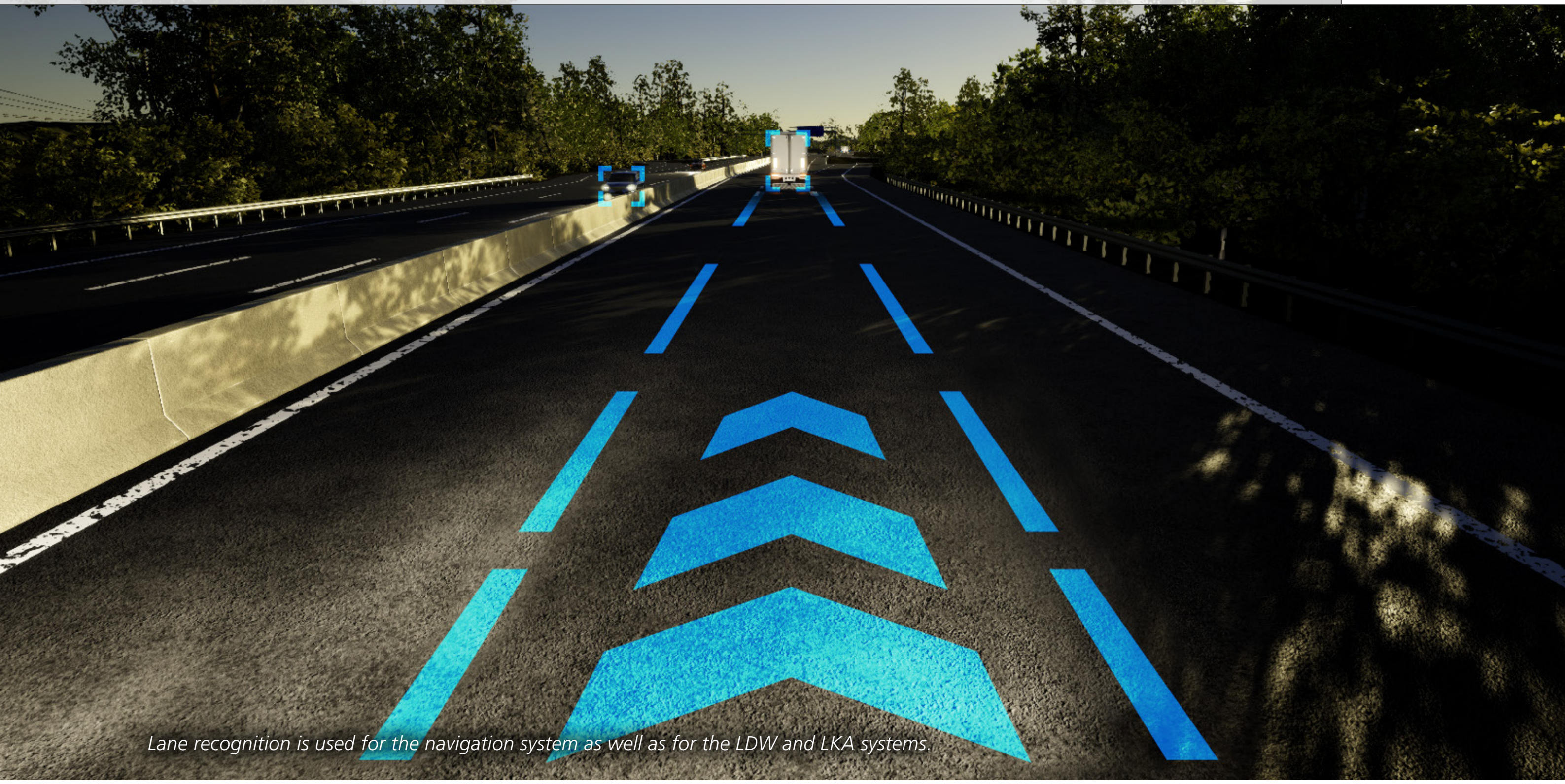
A particular challenge during development is to ensure that the right test data is readily available. One aspect is to use sensor data that is as accurate as possible. Another aspect is to have the option to flexibly use a wide range of corner cases, i.e., particularly critical traffic situations. Exact sensor data can be obtained by logging data during test drives. However, real test drives cover relevant corner cases only insufficiently because critical traffic situations are difficult to perform in reality. Moreover, new test drives are required after a sensor has been changed, which makes the procedure rather uneconomical. Therefore, a simulation-based approach is beneficial because it can simulate arbitrary scenarios, including all corner cases, with a high degree of flexibility. However, the artificially generated data must be based on the physical principles of the respective sensor. A highly realistic sensor model is therefore a decisive criterion for the success of the simulation.

Selecting a Validation Solution

For Neusoft Reach, the first task was to evaluate a suitable development and test solution. In addition to realistic sensor models, the intention was to support developers in the early development phases by means of software-in-the-loop (SIL) simulation. Furthermore, there was a requirement to seamlessly reuse the simulations created to validate the real ECU in hardware-in-the-loop (HIL) simulation. So far, no supplier-independent interface standard has been established for processing raw sensor data. Therefore, a test system for raw sensor data generation must support a wide range of sensor interfaces and protocols. This is the only way for Neusoft Reach to make its control units available to a wide range of customers. Last but not least, this kind of development and test solution must be user-friendly and robust. After evaluating various validation systems, we decided to use a software- and hardware-based solution from dSPACE. Decisive factors were the outstandingly realistic

The forward collision warning (FCW) display is integrated into the navigation system in the vehicle cockpit.

Picture credits: © Neusoft



Lane recognition is used for the navigation system as well as for the LDW and LKA systems.

sensor simulation, the flexibility in handling the systems when feeding in data, and the consistency between SIL and HIL simulation.

Early SIL Simulation Supports Function Development

By using the dSPACE solution chain, a purely software-based validation solution for perception and fusion algorithms and ADAS/AD functions is available at the developer's workstation. It is based on the ground truth simulation models of the Automotive Simulation Models (ASM) tool suite and the sensor-realistic camera model from dSPACE Sensor Simulation. The simulation platform is dSPACE VEOS. ASM simulates the movement trajectories of all road users and the traffic infrastructure. With dSPACE Sensor Simulation, a complete 3-D model of the virtual scene is gener-

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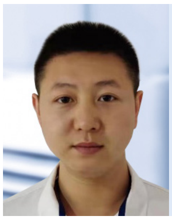
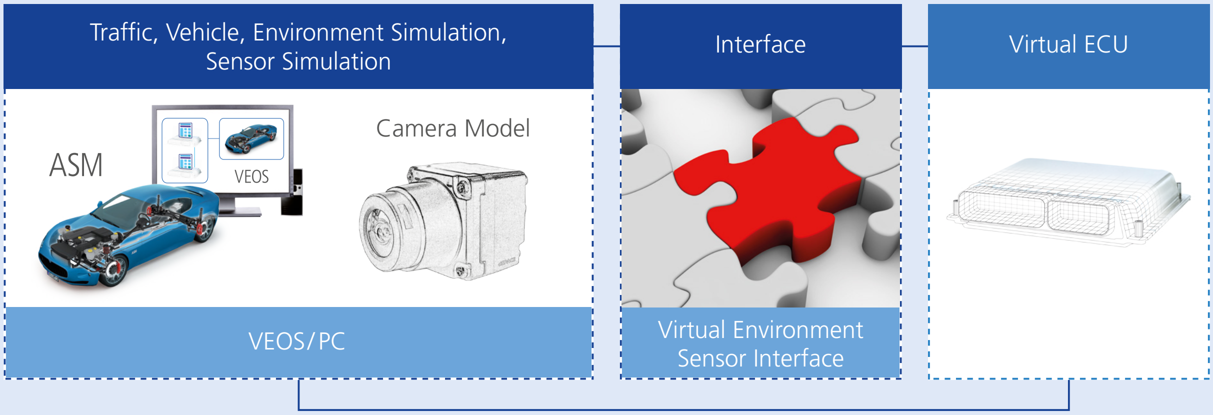
Picture credits: © Neusoft Reach

Examples of different ADAS/AD controllers from Neusoft Reach.



"With the sensor-realistic camera model, we can reliably simulate highly complex test tasks virtually."

Di Wu, Neusoft Reach



In SIL simulation, the vehicle, environment, and sensor models form a control loop with the virtual ECU.

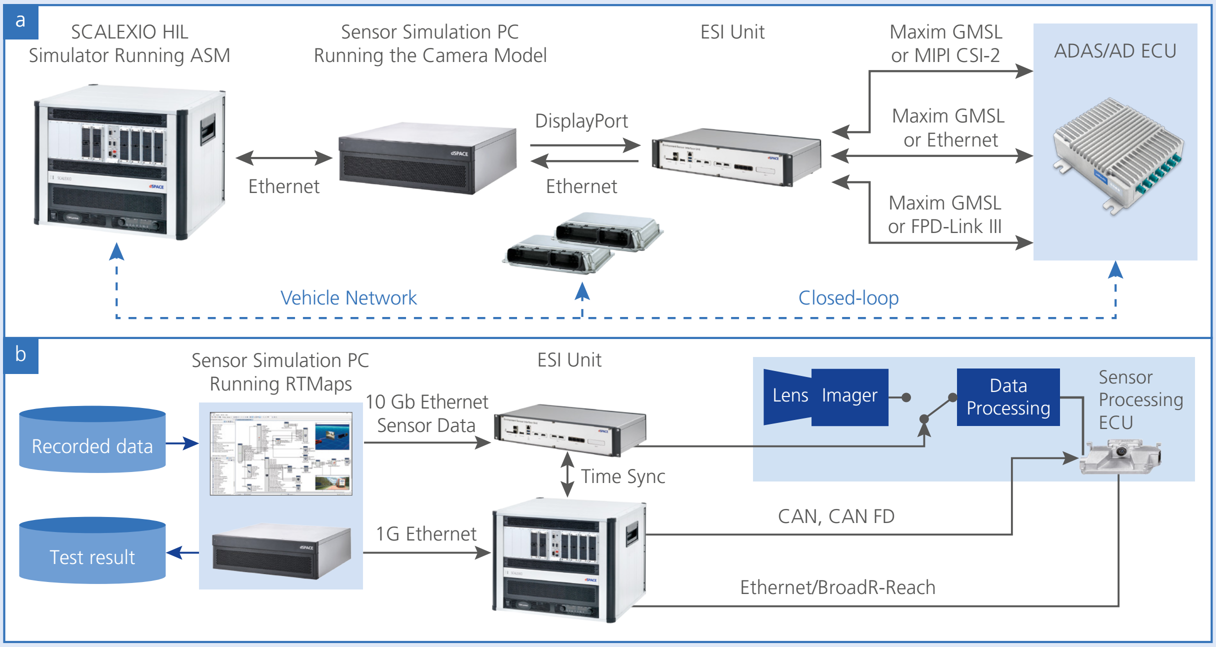
ated to derive a camera image. Via a memory interface, the camera image is subsequently fed into the algorithm to be tested. The algorithm analyzes the image information and provides information that ultimately controls a simulated actuator, for example, a brake simulated in ASM. Naturally, it is possible to use a complete virtual control unit in the simulation which contains, among other things, the developed algorithm. The virtual ECU can be integrated into VEOS parallel to the simulation model, for example, in the form of a Simulink® model, a Functional Mock-up Unit (FMU), or an AUTOSAR-based virtual ECU. To do this, Neusoft Reach uses the V-ECU approach proposed by dSPACE.

Creating Realistic Simulation Scenarios

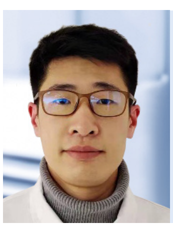
The simulation scenario, i.e., the position and trajectories of all objects of a simulation, is recorded during test drives with real sensors. The data is used to create scenarios, which can now be flexibly modified. For example, the speeds of all road users can be changed individually, distances can be redefined, the sizes of objects can be changed, etc. This enables the developers to determine the performance of an algorithm at an early stage. This also applies to all relevant corner cases. The developers also use manually generated scenarios, such as C-NCAP.

Validating Control Units in HIL Simulation

Whenever a new version of the ADAS/AD software is implemented on the ECU, an ECU test is performed using HIL simulation. To put the control unit into operation, its environment, i.e., the vehicle including the sensor system and the vehicle surroundings, must be fully simulated just like in SIL simulation. In order to fully integrate the ECU hardware and all signal processing stages of the camera into the test, it is necessary to inject the simulated sensor data into the signal chain directly behind the imager chip. For this purpose, the calculated image data must be converted into suitable electrical signals. The Environment Sensor Interface Unit (ESI Unit) is used for this purpose. It is part of a particularly powerful simulation platform: While traffic simulation with ASM is performed on a SCALEXIO system, the model of the camera sensor is run on the Sensor Simulation PC from dSPACE. It is equipped with a graphics card that calculates a 3-D world and sensor characteristics, such as the distortion of the camera lens, in real time based on the ground truth



Setup of the validation system for camera control units: The HIL system and the data replay system use the same components.



"The multisensor software RTMaps enables us to synchronously replay data from different sensors and vehicle buses."

Ding Nan, Neusoft Reach

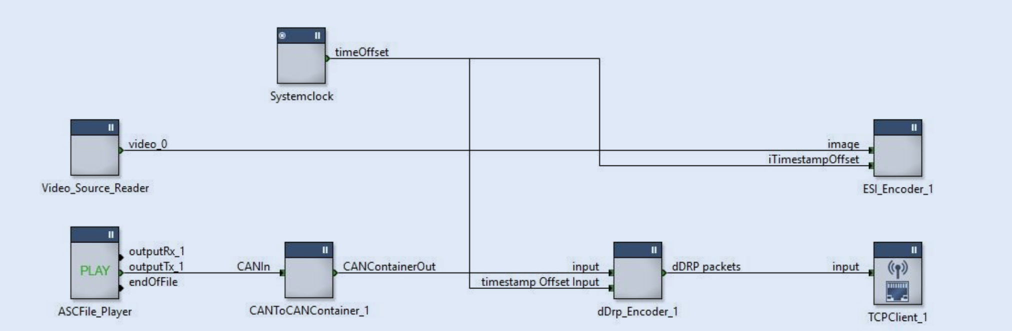
data. The ESI Unit then converts the output of the graphics card into the signals for the control unit and also handles parts of the simulation, such as exposure control. Due to different sensor types involved, the ESI Unit is designed to support a wide range of signal interfaces.

Data Replay Tests

In addition to SIL and HIL tests, we also perform tests with real data. The real data is used, for example, to simulate errors in the laboratory that occurred during test drives. The same test setup is used as in HIL simulation: SCALEXIO, Sensor Simulation PC, and ESI Unit. For data replay, the data is played back from the Sensor Simulation PC with RTMaps. The PC transfers the data both to the ESI unit (camera raw data) and to the SCALEXIO system (bus communication, for example, CAN). There, the data is buffered and then converted time-synchronously to electrical signals for the control unit. The test setup can therefore be used for open-loop and closed-loop tests without any modifications.

Experience from the Development Project

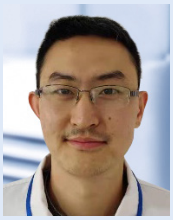
With the simulation and validation solution from dSPACE, Neusoft Reach >>



RTMaps diagram for the data replay.

The robustness of the ADAS/AD algorithms is improved by the targeted injection of errors via test software.

has successfully validated and launched several ADAS/AD ECUs. They are used in passenger cars and commercial vehicles, such as trucks. One of the validated systems was a 360° panoramic view with five cameras, for all of which a data feed via ESI Unit was implemented. The simple reuse of tests for SIL and HIL procedures proved to be particularly useful: On the one hand, tests created at an early stage of function development can also be used for ECU approval, while on the other hand, function developers can take advantage of comprehensive HIL tests for the SIL procedure. The developed tests can be consistently reused between the simulation platforms VEOS and SCALEXIO. The project has also brought about fault injection as a valuable feature that we use to check the reliability of the systems, for example, if pixel- or line-based color errors or noise occur. These errors can be injected automati-



"Without the ESI Unit from dSPACE, it is almost impossible to efficiently test sensors from different manufacturers. It is a valuable component of our validation solution."

Long Ning Zhao, Neusoft Reach

About Neusoft

Neusoft offers a rich portfolio of software-based design services, products, and pre-integrated solutions for industries such as automotive, consumer electronics, mobile devices, IoT, medical, business process outsourcing, finance, security and insurance, information technology outsourcing, and more. Neusoft employs more than 20,000 people worldwide in Asia, Europe, North America, and the Middle East. Neusoft focuses on software technology and covers the areas of navigation, ADAS, HMI, connected car, and infotainment with its products and solutions for the automotive industry. Neusoft serves a large number of automotive OEMs and Tier 1 customers around the world, including North America, Europe, and Asia. Neusoft Reach Automotive Technology Co., Ltd. ('Neusoft Reach' for short) is an innovative enterprise focusing on the application of mobile Internet, artificial intelligence, and new energy technologies in the automotive industry.

cally or manually. The flexibility of the ESI Unit with regard to sensor interfaces and protocols, such as Maxim GMSL1 and GMSL2, TI FPD-Link III and MIPI CSI-2, is excellent. This puts us in a position to meet the requirements of different OEMs with one system and to adapt to special requirements of suppliers. To implement the software on the AUTOSAR-based ECUs, we use the production code generator TargetLink. Its powerful AUTOSAR functions simplify the creation of AUTOSAR-compliant software.

Role and Assessment of the dSPACE Solution

The solution from dSPACE, which consists of powerful, highly realistic simulation software, a HIL simulator, a high-performance PC for sensor simulation, and the ESI Unit, plays a key role in the approval of a new ECU. The early and consistent use of the SIL and HIL methods as well as the replay process make it possible to shorten software development cycles and improve the quality of the software. This adds significantly to reducing costs and makes an important contribution to timely market introduction. Compared to previous projects without the dSPACE solution, the overall efficiency has improved by 70%. This means that the investment costs have already been offset to an above-average extent.

At a Glance

Validation of camera-based driver assistance systems

Challenge
- Testing camera-based control units without stimulation of the imager chip
- Feeding sensor-realistic raw data into the control unit

Solution
- Using an integrated SIL/HIL simulation platform
- Sensor-realistic simulation of camera data with physically correct models

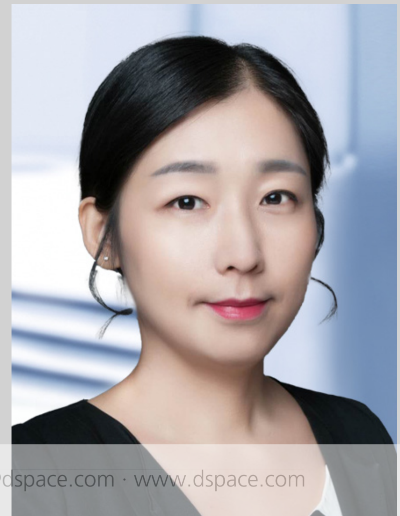
Benefit
- Easily reproducible tests for software and control unit
- 70% increase in test efficiency

Outlook

Neusoft Reach is working on more assistance functions and is further expanding the scope of the systems for automated driving. We work closely with dSPACE to adapt the validation solution to new requirements. In the area of data recording, we are evaluating how the data logging system AUTERA helps us make our workflows more efficient. The latest advancement of sensor-realistic simulation software from dSPACE is also on our agenda as it promises a highly accurate environment sensor simulation with realistic light and weather effects.

Yan Wei, Neusoft Reach

Yan Wei, Neusoft Reach
Yan Wei is responsible for ADAS at Neusoft Reach Automotive Technology (Shenyang) Co., Ltd. in Shenyang, China.



Safe Legends

Developing and testing control systems for high-performance tasks in the ultimate super sports cars

Picture credits: © Bugatti

The performance range of Bugatti vehicles is defined by their integrated, safe electronic systems. A simulator from dSPACE ensures that the systems function extremely reliably.

Bugatti owes its very distinctive character to a family of artists and engineers, and since its beginnings the company has striven to achieve the extraordinary, the very best, the superlative. Each and every element in the new Bugatti Chiron is reminiscent of the marque's history and yet full of innovative technology. The result: creations of enduring value and automotive masterpieces.

At the heart of the Chiron is its quad-turbocharged 8 liter W16 engine. This exceptional masterpiece delivers almost unbelievable power of 1,500 hp and 1,600 Nm torque at a virtually linear performance of between 2,000 and 6,000 rpm. Four high-powered turbochargers running in a configuration with two-stage control define this champion of performance.

The Challenge: The Utmost in Reliability

Making this performance available to the driver reliably and safely under any conditions whatsoever requires numerous electrical systems and highly complex electronic controls. Efficient validation of the electronic control units is a core activity in vehicle development. In particular, tests have to be performed in extreme performance ranges to ensure that the vehicle is completely under control at all times. For optimum efficiency, developers need the ability to test new electronic control units and software versions even when the tested component, or indeed the entire vehicle, is not (or not yet) available.

Solution Approach: Efficient Vehicle Simulation

At Bugatti, hardware-in-the-loop (HIL) simulation is a well-established procedure for ECU testing. With regard to the new Chiron vehicle model, it was imperative to build an optimized testing solution that would reach new performance dimensions and that could also easily be extended for future vehicles. Put more concretely, a detailed simulation of the entire powertrain, including vehicle dynamics, was required in order to connect the engine, transmission, and vehicle dynamics ECUs to the simulator and test them.

Evaluating a Simulation Platform

After evaluating various commercial simulation models and simulators, Bugatti decided to go for a tailor-made simulation solution from dSPACE. The solution consists of a HIL simulator and detailed simulation models that represent the vehicle, including all its components. The mathematical models in the Automotive Simulation Models (ASM) tool suite are used to do this. The developers precisely virtualized the vehicle and the powertrain with the following models:

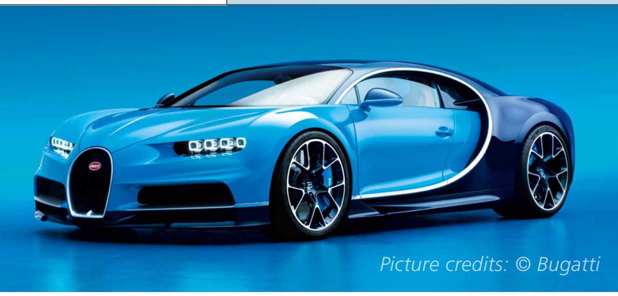
- W16 engine: ASM Gasoline Engine
- 7-stroke dual clutch transmission (DCT): ASM Drivetrain
- Chassis and vehicle dynamics: ASM Vehicle Dynamics

Designing and Parameterizing the Simulator and Models

The planning and design of the simulator, and the creation of the I/O model that would become the interface between the real ECUs and the virtualized vehicle, were based on data on the electrics/electronics system and the ECUs and also on the specifications for the engine and transmission. A model structure was then derived from the design, and requirements for parameterization were defined. The precision of the parameters is a measure of simulation quality; they can be acquired from design data, for example, and also by means of measurements. By making test bench measurements, the team was able to produce finely resolved characteristic maps for parameterization. The parameterization was then validated by means of the soft ECUs from the ASM library. A further validation step, which included the I/O model and the real ECU, followed. This provided the foundation for putting the overall simulator into operation, which included comparing the simulation results with the measured reference values. Experts from Bugatti and dSPACE worked together closely. >>

"Before we ventured to put the vehicle through speed ranges of over 450 km/h, we made comprehensive investigations and tests with the dSPACE Simulator. This meant we were able to find any issues at an early stage."

Dr. Alexander Riedel, Bugatti



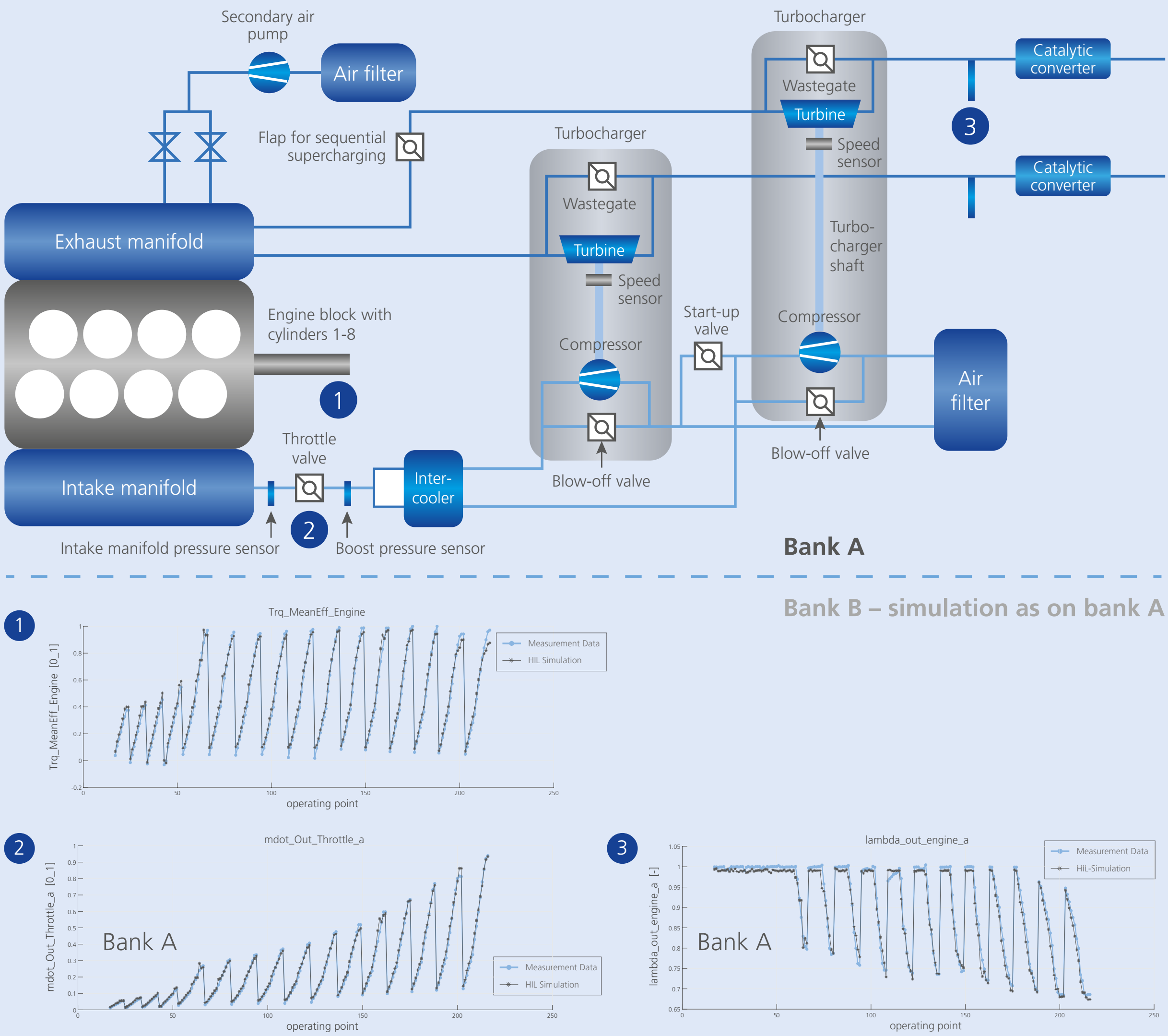
Picture credits: © Bugatti

Picture credits: © Bugatti

Development and Test Tasks on the Simulator

The Bugatti team uses the HIL simulator for a variety of test tasks. Among these are classic release tests for new software versions. The procedure is to first test an ECU with the new software on the HIL simulator and not to transfer the software to the actual production vehicle until the test has been passed. For example, to validate engine and transmission software, onboard diagnostic (OBD) tests are performed with the simulator in specific speed and load ranges. These are manufacturer-independent, standardized tests that are performed continuously while the vehicle is running. They check whether the response to errors is correct and the appropriate responses are produced, and whether the correct error output is made to the ECU's error memory.

While the vehicles then undergo tests



A diagram of a bank of the modeled W16 engine together with the measured and simulated signals. The signals are superimposed to show the high level of simulation accuracy.

Picture credits: © Bugatti

Picture credits: © Bugatti


Picture credits: © Bugatti

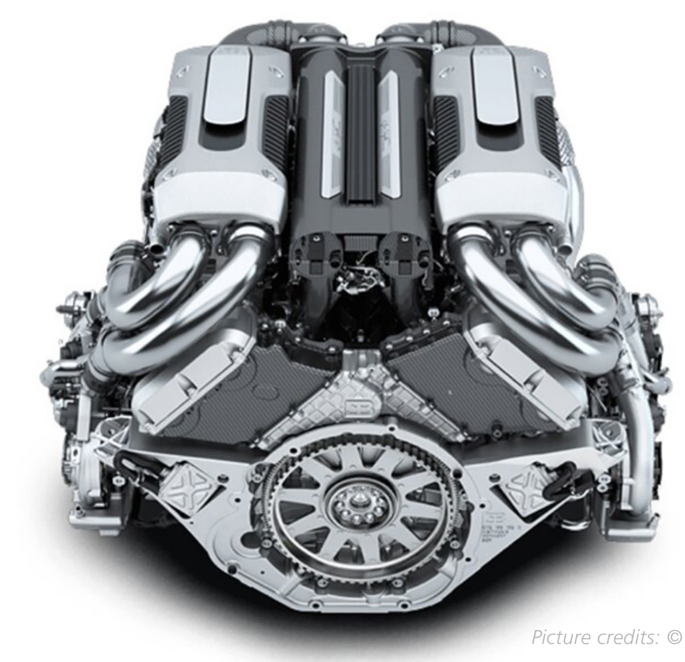
all around the world, the HIL simulator has further test tasks to perform: It is used to replicate errors that were found during test drives. It does this by making a virtual drive along the same route, for example, the Ehra-Lessien test track, which is located near Wolfsburg, Germany. Function tests are also run, and this is where the simulator really shows its special strengths. For example, responses that affect driving behavior can even be tested at speeds of over 400 km/h, risk-free. Other important function tests are in the domain of control strategies for overtemperatures, ignition failures, etc. The simulator can also offer support for development tasks. The diverse electronics systems – such as the ones that control rear spoiler adjustment, active aerodynamics, and level control – can be tested in early phases and optimized while they interact.

Quality Enhancement by Test Automation

To ensure that tests can be performed at any time, even 24 hours a day and 7 days a week, the dSPACE test authoring and automation tool AutomationDesk is used. AutomationDesk has libraries with a selection of predefined test steps, for example, for access to the simulation model, a failure insertion unit (FIU), or the application and diagnostics software. This lets developers automate test execution in order to increase test coverage and enhance the quality of the ECU software, while at the same time saving time and costs.

Evaluating the Test Solution

Because of its reproducible simulations, the dSPACE Simulator played a major role in preparing for the world speed record of the Bugatti Chiron Super Sport 300+. It let the developers investigate the vehicle's behavior at extreme performance ranges in detail and then use the findings to shape the development process, all at an early stage. The relevant components from the domains powertrain, chassis, and body are mapped in real time using the simulation models in ASM. These include the W engine with both banks, including the turbocharger and variable valve timing mechanism, plus the dual clutch transmission (DCT), the Haldex clutch for four-wheel drive, right through to active shock absorbers, differential lock, and adaptive rear spoiler. The position changes for the shift collars, the torque synchronization between all the shafts during gear changes, gear preselection, and position control for transmissions and transmission adaptation can be tested together with the ASM DCT model. The range of tests also includes tests for diagnostic functions and a compre- >>


Picture credits: © Bugatti

The heart of a Bugatti: The legendary W engine with 16 cylinders.

> "The good working relationship we had with our dSPACE counterparts was a major factor in the project's success. We appreciate the dedication that they showed and their flexibility in our project work."
>
> *Dr. Alexander Riedel, Bugatti*

The experiment software ControlDesk sends Bugatti's simulated vehicles on virtual test drives.

hensive results analysis. Moreover, the simulator can be extended flexibly. For example, an ionic current measurement was quickly integrated, helped along by close contact between the responsible developers at dSPACE and Bugatti.

Conclusion

A manufacturer with short production runs like Bugatti cannot simply cover its investments for tools by producing large quantities. Even so, there are two good reasons why using a HIL system is well worth the outlay:

- Bugatti can ensure that its vehicles are up to its quality standards – even in the numerous extreme ranges that vehicles in this performance class can reach.
- Moving some of the development tasks to the HIL simulator to supplement other activities makes complete sense. It helps developers achieve greater efficiency. For example, it reduces the number of tests needed on the actual vehicle and on the test vehicle. ▪

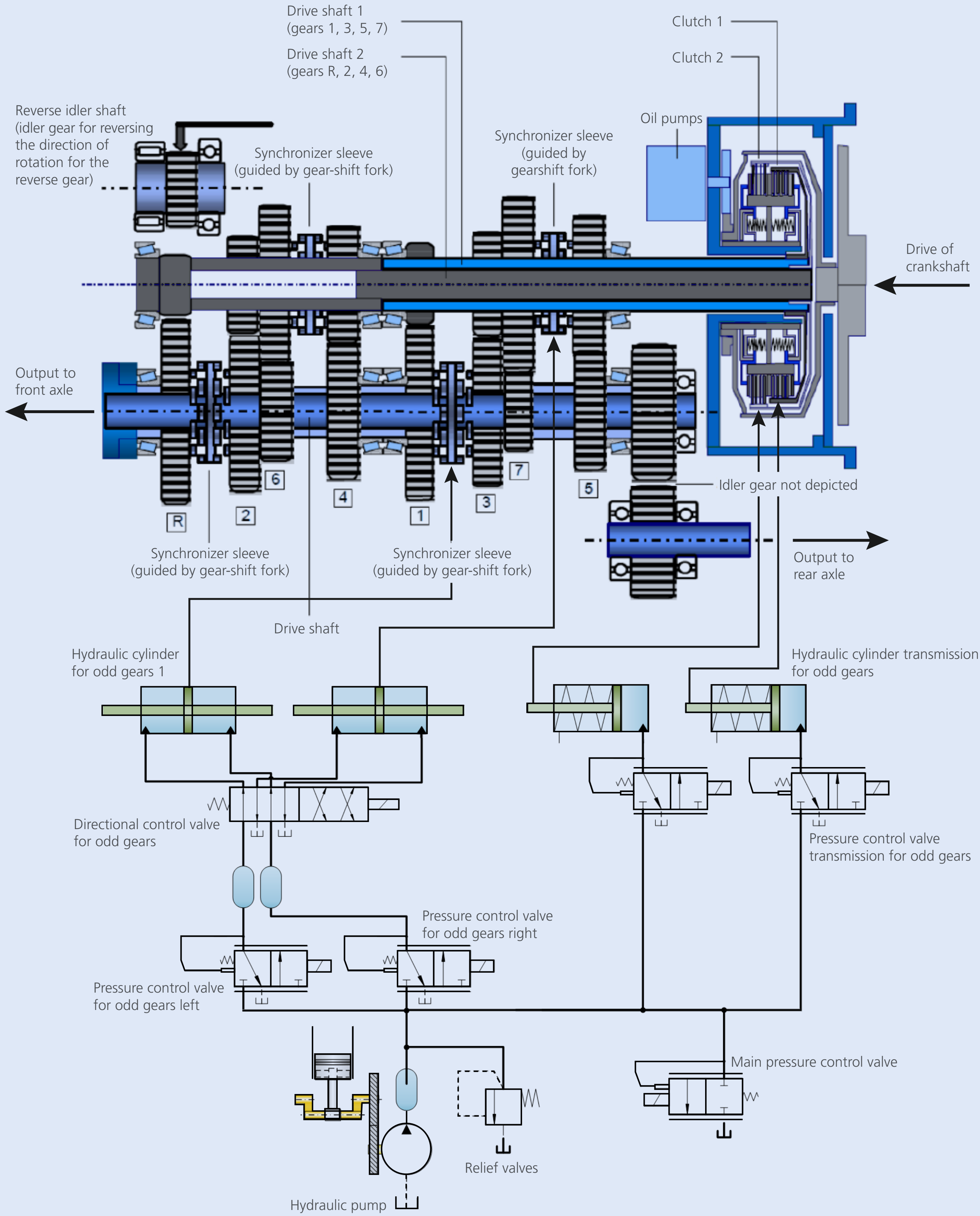
Dr. Alexander Riedel, Bugatti

"We use the ASM simulation models to map all the relevant components of the powertrain."

Dr. Alexander Riedel, Bugatti

A Bugatti vehicle on the virtual test track, visualized with MotionDesk, the 3-D online animation software from dSPACE.

Dr. Alexander Riedel
Dr. Alexander Riedel, Engine Application BG-EA/2, Bugatti



Extract from the detailed model of the dual clutch transmission. The hydraulic control shown here is an extract from the ASM demo model, which was adapted to Bugatti's hydraulics.

Virtualizing ECU integration tests in response to the rapidly increasing complexity in software-defined vehicles

Compound Tests

As the complexity of a system increases, new measures are required to properly validate its functions. This is why Volkswagen is using virtualization more than ever in its validation processes.

When launching a new product on the market, automobile manufacturers assume a great deal of responsibility. For this reason, Volkswagen's corporate mission is to ensure that the end product is free of defects. After all, reliable products are decisive for ensuring customer satisfaction and are an important factor when it comes to brand image.

The Holistic Complexity of Software-Defined Vehicles

New, distinctively software-defined vehicles result in an unprecedented level of complexity: holistic complexity. This entails the complete assessment of the processes inside the vehicle in addition to the infrastructure of its outside environment and the back-end system. The growing number of functions in the vehicle and the increasing communication between those functions add to this complexity.

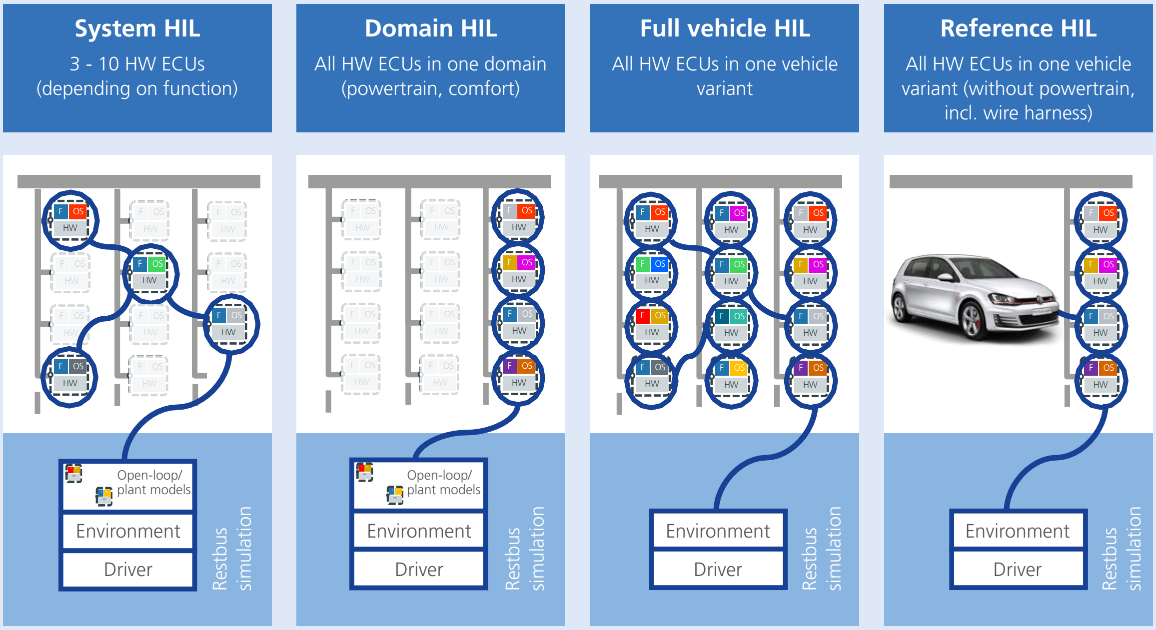
New Challenges for Developers and Tools

Even when developing a relatively small function, the entire system always has to be taken into account for the test in order to provide information about the behavior and the quality of the function, as well as how it affects the system as a whole. The feedback from the overall system regarding the behavior of a function has to be available as soon as possible.

The Dilemma of Early Validation in the Overall System

But how can a function be tested when numerous system components are still being developed? The conventional approach involves testing system components first in order to validate them step by step in combination with other components in increasingly more comprehensive integration tests. While this works well for functions with a basic level of complexity, the method is no longer sufficient for functions that fall under the banner of holistic complexity. Indeed, errors in the components that are only relevant in combination with other components within the overall system are first detected in a much later stage of development. >>

Megatrends such as electromobility, connectivity, automated driving, and mobility-as-a-service give rise to new requirements and functions.



Scaling the validation process, from individual components to the entire vehicle.

A New Approach: Virtualizing the Entire Integration Test

A new approach is required. We could call this virtualizing the entire electronic control unit (ECU) integration test. The complete virtualization – that is to say, the software-in-the-loop (SIL) test – makes it possible to integrate all of the artifacts in a system regardless of their maturity level. Although this early SIL test initially delivers results that are not as realistic for the individual components, it nevertheless provides a comprehensive picture of the overall system behavior straight away. This makes it possible to assess the behavior of a component within the overall system, thus taking into account the holistic complexity throughout the entire development process to the highest degree possible given the respective circumstances.

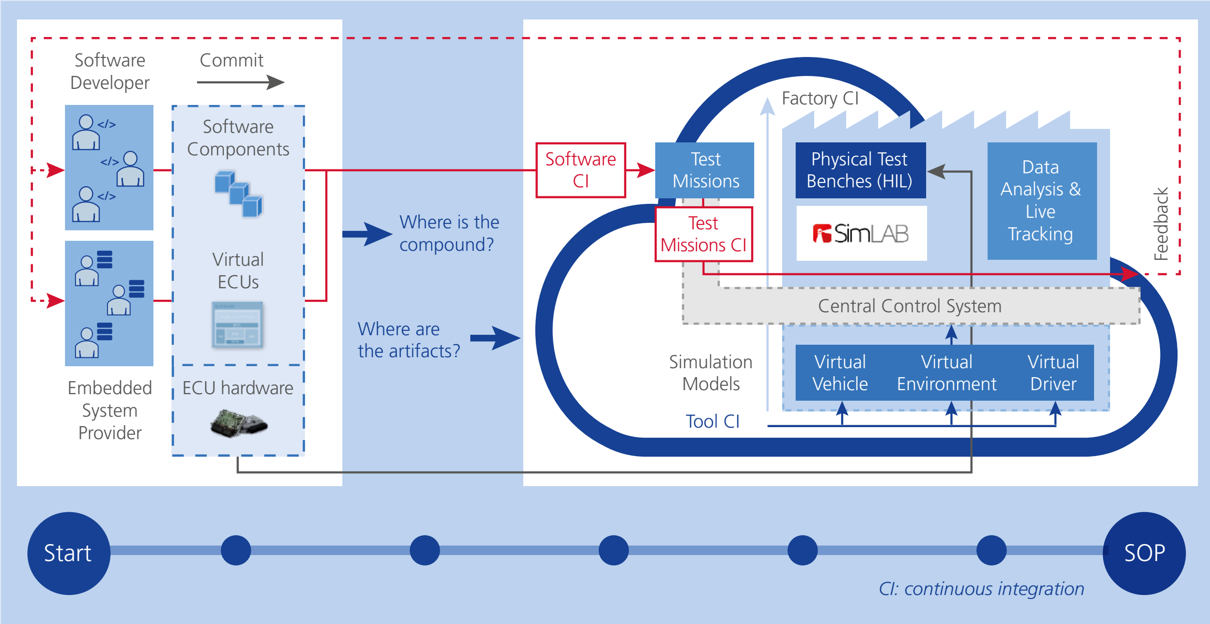
Maximum Complexity Right from the Start Thanks to Virtualization

Especially during early stages, however, the test objects are likely to change as they are being developed. In the hardware-in-the-loop (HIL) test, these objects were the ECUs. The SIL integration test calls for a new way of thinking. Of course, ECU software is required for the validation, and we pack the ECU software in a specific form which we call virtual ECUs (V-ECUs). Preliminary software stages and connecting elements also play an important role in the beginning. This includes all key components, such as specifications, models, and glue code. The comprehensive nature of this integration ensures the necessary representation of the whole system, particularly during the early stages. Of course, rules and standards are needed in order to allocate and integrate artifacts uniformly. For example, the V-ECU approach recommended by dSPACE describes how the software and the other components should be packaged as a virtual delivery artifact in parallel or upstream for ECU provisioning.

Multiplatform Simulations

This gives rise to completely new and exciting simulation possibilities: In addition to the traditional PC-based

> "The agile method helps develop synergetic objectives quickly across departments, divisions, and even companies. The strict division of responsibilities in the past has evolved into cross-functional teams in order to achieve an overarching goal efficiently and by working together on the basis of shared information."
>
> *Dr. Chen Ma, Volkswagen*



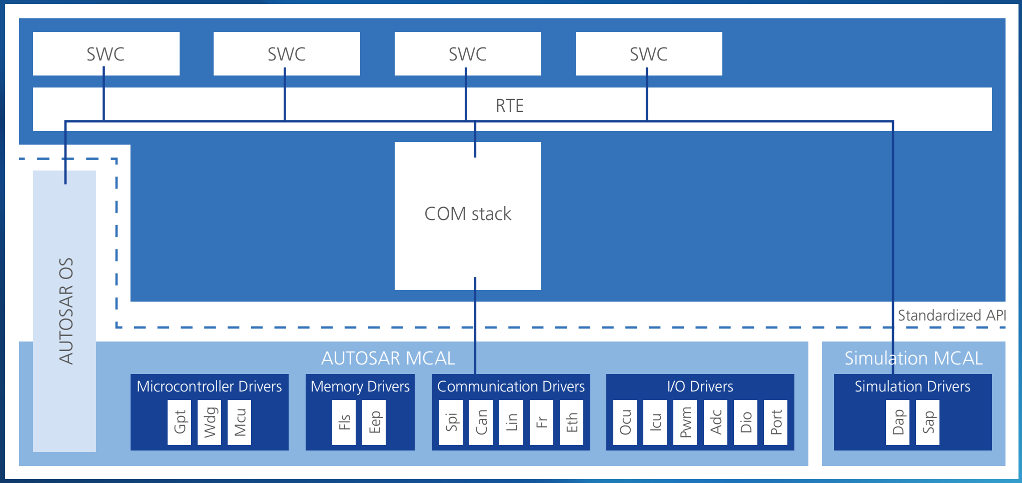
Virtualizing the ECU integration test: an agile journey.

method, container-based options are also available, for example, with dockers for building multiplatform simulations on PCs or even highly scaled simulations in the cloud. In these cases, V-ECUs are executed using software simulation platforms like VEOS.

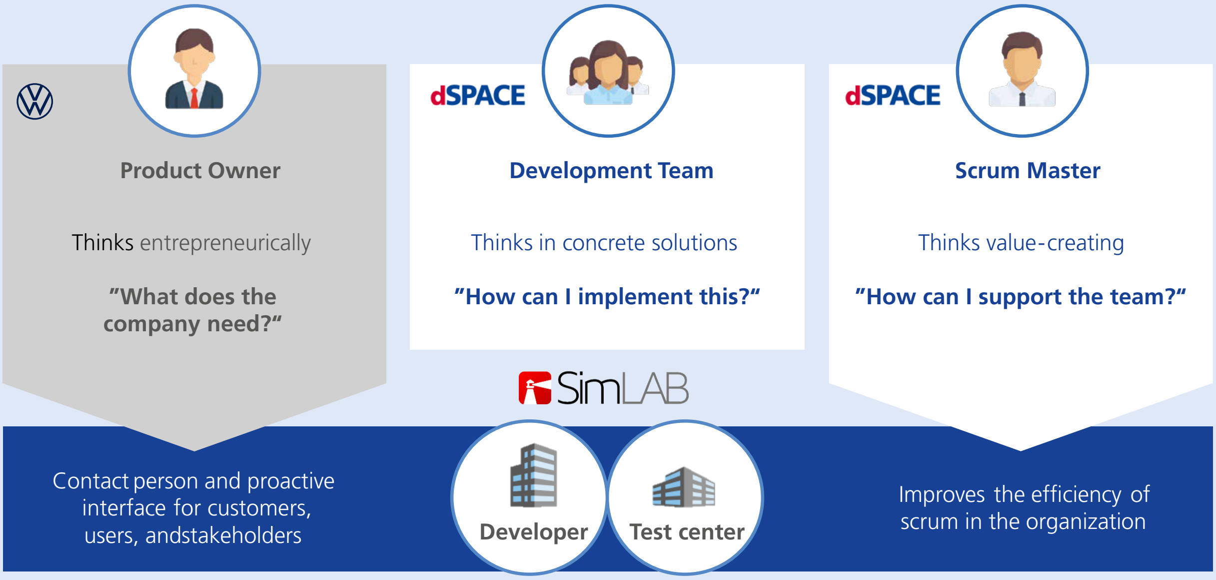
Agile Development Speeds Up the Process

The agile method encourages a new type of collaboration. Synergetic objectives are developed quickly across departments, divisions, and even companies. In this case, it is necessary to share information promptly.

The strict division of responsibilities in the past has evolved into cross-functional teams in order to achieve an overarching goal efficiently and by working together. This agile method requires new roles and responsibilities. For example, product owners represent and analyze the requirements of >>



Industry-wide standards are an important prerequisite for virtualizing tests. This involves defining components according to the dSPACE V-ECU approach and integrating them into the VEOS simulation platform together with controlled system models.



Agile development encourages a new type of collaboration and speeds up the process.

the customers (OEMs). They determine which functions are required and when. Their goal is to maximize the economic value of the operation. Then there are the scrum masters. They coordinate the tasks and optimize the collaboration between all participants. Their goal is to increase the efficiency of the process. The team members are assembled based on their areas of expertise at the participating companies. They include, for example, OEMs, suppliers, tool manufacturers, and engineering service providers.

Reinventing Validation Projects

In a current validation project, an agile team with members from several different companies, including Volkswagen, is working on a vision for a virtual overall network. This vision focuses on validating functions in the overall system with all relevant ECUs at an early stage of the development process. The approach first envisions gradually incorporating a virtual ECU into a model-based network. The team at dSPACE aims to implement this concept by making the project a reality and finding the right solutions. The dSPACE team is acting as the development team in the agile cooperation model. The employees from dSPACE have to use their own tools, and others, in the project as efficiently as possible. This leads to tool updates in accordance with the requirements that arise within the scope of the project.

A Win-Win Situation

Visualizing ECU integration tests and using a collaborative approach offers advantages to all parties involved. Tool manufacturers and suppliers obtain information early on and can adjust their products to customer requirements. Customers (OEMs) benefit from solutions tailored precisely to their requirements with a high level of efficiency and ultimately an increase in the economic efficiency of their enterprises. ■

Dr. Chen Ma, Volkswagen

Dr. Chen Ma
Dr. Chen Ma was the product owner for the project to virtualize comprehensive integration testing and now works as an E/E project manager at Volkswagen AG in Wolfsburg.

Capitalizing on Synergy Effects and Taking Advantage of Virtualization

Interview with Dr. Chen Ma, Volkswagen

You have had a very interesting career. How has it prepared you for the challenges of the automotive industry?
I was born in China, and I have been living in Germany for 20 years now. I live in two distinct cultures. And by culture I mean the way we perceive things and people. How we understand things and people. How we treat things and people. In fact, many of the challenges in the automotive industry are related to culture. Many problems are not actually technical. That is why we need to overcome these cultural barriers.

What does this mean for validating software-defined vehicles?
To a certain extent, software-defined vehicles can be developed and tested virtually. But we always have to ask ourselves whether we have taken the holistic complexity into account. We need a comprehensive approach. And "comprehensive" opposes the traditional, strict division of responsibilities, competencies, and processes. First and foremost, we need a culture change.

How can we achieve that?
We need to work more closely together and keep our eye on an overarching, synergetic goal. In our culture, there is too much competitive thinking. Competition destroys the prospect of all participants winning. That is why progress is so slow. For example, we are not using the full potential of simulation. We are probably just using 10% of that potential.

What is missing?
During the validation process, we generally concentrate on only individual components because we see ourselves as individual development teams from a structural or technical point of view and not as the embodiment of the overall system. In the future, all of the people involved in the development process, regardless of the development stage and the locality (departments, domains), will have to play their part to form an overall network in which the validation can take place.

What is keeping people from participating in synergetic partnerships?
Aside from protecting intellectual property, I see two reasons for this. On the one hand, most people want to see a direct reward for themselves in every activity. And on the other hand, everyone wants to show only perfect final results to maintain their image, and nobody wants to share problems or provisional results with colleagues from other domains. But the truth is that with the current level of product and process complexity, it is only possible to derive a direct individual benefit from a greater, overarching reward, which can only be produced if everyone lends a hand. You can cut off a piece of cake only after the entire cake has finished baking. We all have to take a leap of faith in the end. And the fear of tarnishing our reputation prevents us from taking advantage of these valuable opportunities to detect problems and nip them in the bud, which would be a success for everyone.

Thank you for talking to us.

We use only
10%
of the simulation potential

SIL for Early Validation

Stellantis/FCA accelerates software testing with agile practices and virtualization

The Global Electrical Engineering and Software - Virtual Engineering Team (EE&SW VE Team) of Stellantis – formerly Fiat Chrysler Automobiles (FCA) – is implementing a new and improved software development and test platform that embraces agile technology practices and virtualization capabilities to enable early validation.

Picture credit: © FCA

Virtualization is a key concept when we talk about agility.

By being able to quickly adapt to changes that can arise at any stage of the software development cycle, such as new requirements, code errors, or integration issues, the new test platform will leave the EE&SW VE Team better positioned to secure optimal outcomes. "At FCA, we focus on best software development and testing practices," said Sangeeta Theru, Vehicle Modeling and Integration Lead, EE&SW VE, FCA US LLC. "Virtualization is a key concept when we talk about agility in the controls and software development process." Some of the main benefits that are supported by virtualization include:

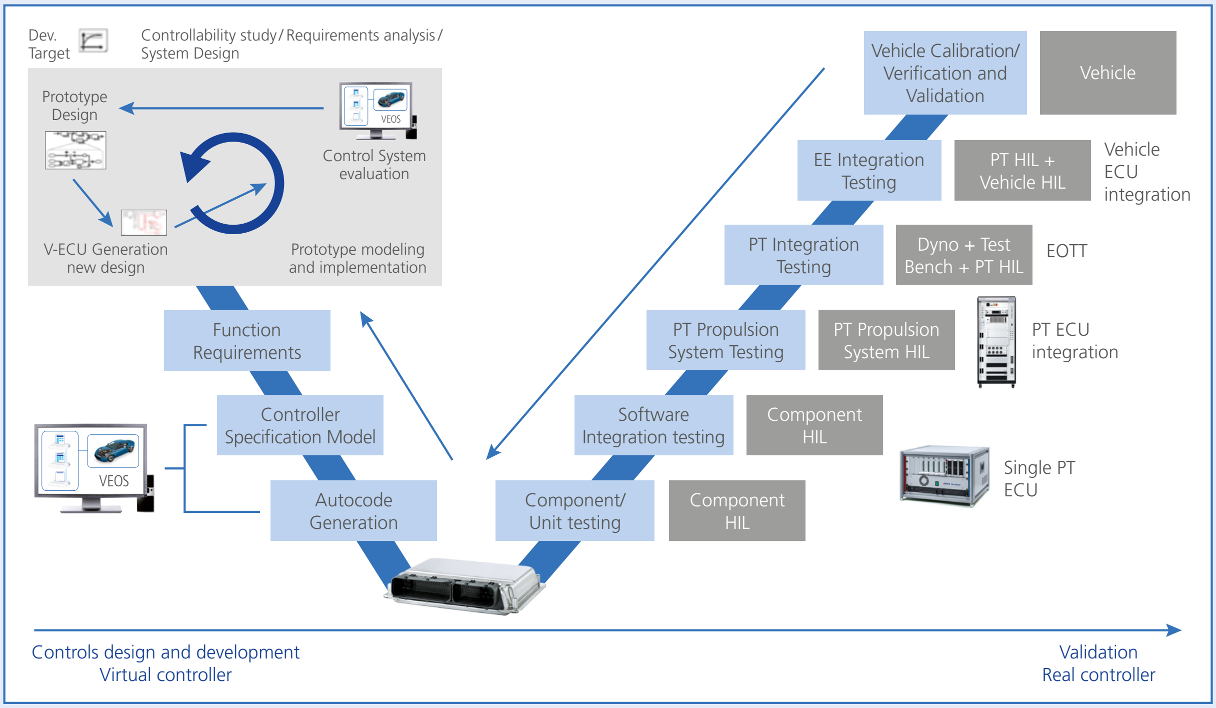
- A reduced number of costly iterations by frontloading tests
- Iterative development of complex new functions at an early stage
- Ability to perform development work on a laptop/computer without requiring the physical controller
- Reuse of plant models and test scenarios across xIL test platforms [model-in-the-loop (MIL), software-in-the-loop (SIL) and hardware-in-the-loop (HIL)]

Valuable Time and Costs Savings

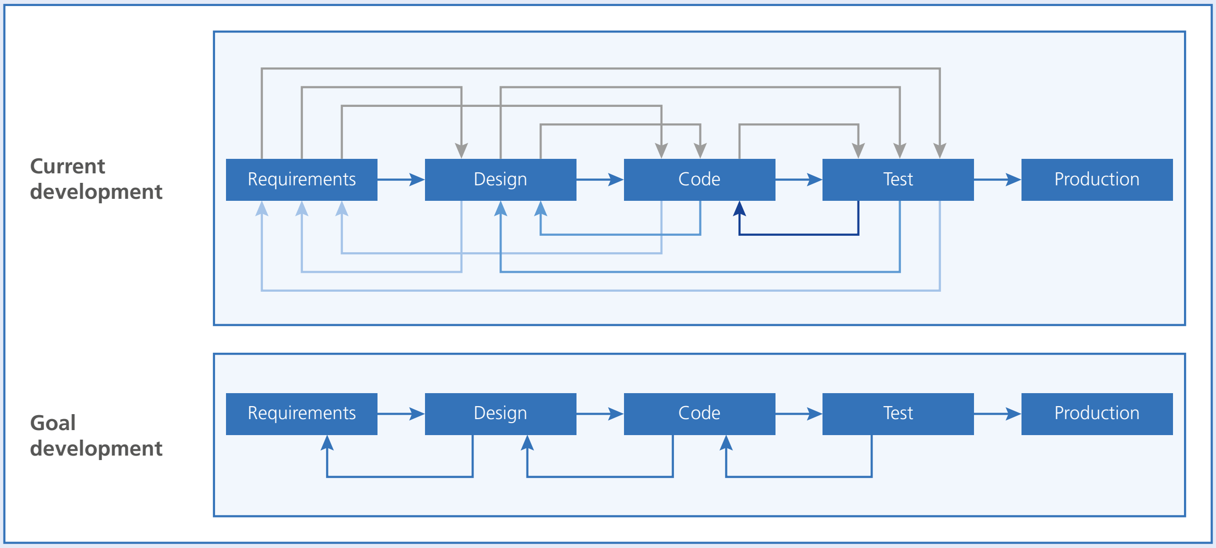
A key incentive of the FCA virtual test platform is the capability to perform early software validation. This is made possible by creating a virtual version of the electronic control unit (ECU) under test. The virtual ECU is a physically equivalent replica of the real ECU. By utilizing virtual ECUs in >>

"Early validation at the software level significantly improves our test efficiency. To use it reliably, we rely on the PC-based simulation platform dSPACE VEOS, which integrates well into our test workflows."

Sangeeta Theru,
Vehicle Modeling and Integration Lead, EE&SW VE, FCA US LLC.



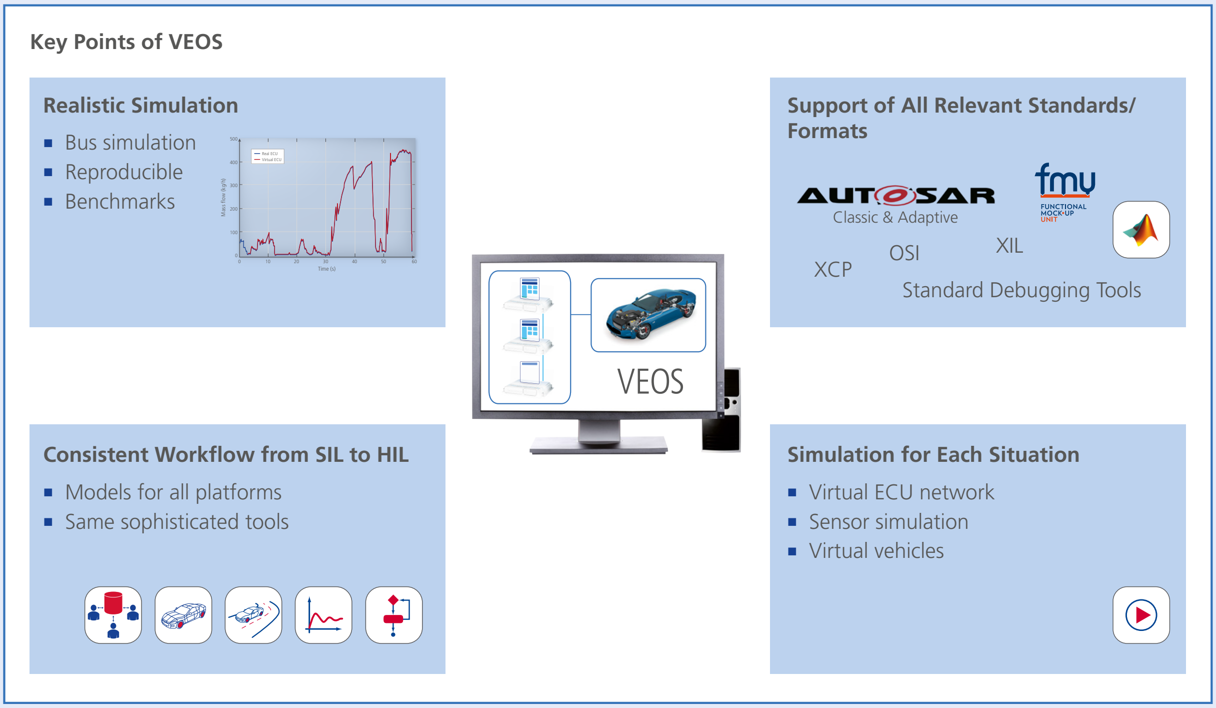
Frontloading software validation and verification through SIL testing.



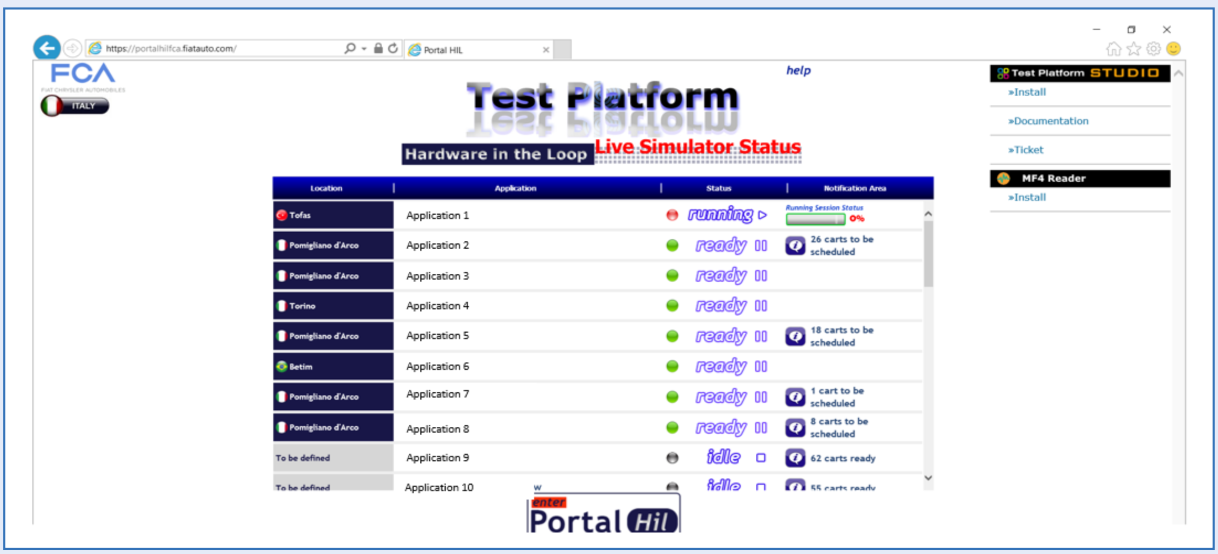
Development process optimization with agile methods.

software-in-the-loop (SIL) testing, early and realistic ECU software validation can be performed – even before the first prototype becomes available. This process allows issues to be identified and debugged much earlier in the development process, saving valuable time and costs.

The EE&SW VE Team began its initiative to develop a virtual test platform in 2016 and has been working closely with dSPACE. Their test platform includes dSPACE VEOS, a PC-based simulation platform that allows for virtual validation. VEOS makes it possible to simulate a wide range of different models, such as function models, Functional Mock-up Units (FMUs), virtual ECUs (V-ECUs), and vehicle models, in early development stages – independent of any specific simulation hardware. The latest version of VEOS supports the AUTOSAR Adaptive Platform for high-performance computing require-



VEOS is a PC-based simulation platform for validating the software of electronic control units (ECUs) in early development stages.



Screenshot of the FCA Virtual Test Platform showing the status of four virtual tests.

ments, such as applications for autonomous driving.

"Early validation reduces costly iterations due to issues or bugs identified very late in the vehicle program development timeline," explains Giancarlo Di Mare, Head of Virtual Engineering, FCA Italy S.p.A.

Mr. Di Mare adds that VEOS and the virtual test platform technology integrate well into the overall model-based development and ECU testing workflow. The integrated workflow consists of database and workflow management to collaborate within different teams across different test phases and xIL environments (MIL, SIL, HIL). FCA currently uses an internal, keyword-driven tool (VST) for test automation and traceability to requirements and test cases in IBM Rational Quality Manager (RQM), which allows for remote global testing in all FCA test facilities. >>

"Early validation reduces costly iterations due to issues or bugs identified very late in the timeline of the vehicle program development. The simulation and validation solution from dSPACE efficiently accelerates their identification."

Giancarlo Di Mare,
Head of Virtual Engineering, FCA Italy S.p.A.

Additionally, FCA is using the dSPACE Test Solution Package (TSP). TSP is a product-bundle solution for performing efficient & automated ECU testing. It includes dSPACE SYNECT (data management and collaboration software), dSPACE AutomationDesk (test authoring and automation tool), and the dSPACE Test Authoring Framework (TAF). "Using TSP, we are able to establish traceability with IBM RQM, handle variants of system tests and parameters, and perform optimized test authoring and synchronization of test steps in the RTC/RQM process," summarizes Sisay Molla, Vehicle modeling and Integration, FCA US LLC.

Improved Test Efficiency

With the virtual testing platform technology in place, the EE&SW VE Team is working toward three significant goals: 1) reducing testing on HIL, 2) frontloading tests to software-in-the-loop (SIL), and 3) synchronizing and managing requirements across the development stages and among various teams and suppliers. To date, the EE&SW VE Team has used this technology to successfully virtualize and implement a hybrid control processor (HCP) in a closed-loop virtual test platform and to virtualize and implement an engine controller in a closed-loop virtual test platform, based on AUTOSAR software architecture with production basic software. The team is also working on the integration of a virtual transmission controller as well as the virtualization of legacy code.

Global Team Effort

The project team from FCA and dSPACE collaborated extensively to develop and implement the virtual test platform. The core group included members of the EE&SW VE Team responsible for virtual ECU generation and integration in the plant models to generate the closed-loop virtual test platform. The user group includes members from the FCA Controls Team Centers of Excellences (COEs) and software teams. This large team had quite an international footprint with various FCA contributors from FCA North America, Italy, Brazil, India, etc., as well as dSPACE team members from the USA and Germany. Together, the FCA and dSPACE teams took on several challenges, including the integration of AUTOSAR basic software from third-party commercial vendors, developing a new ECU with its own software architecture, and the virtualization of complex device drivers. According to FCA, the virtual test platform is currently utilized for control development and software testing and is showing great promise for early validation. ■

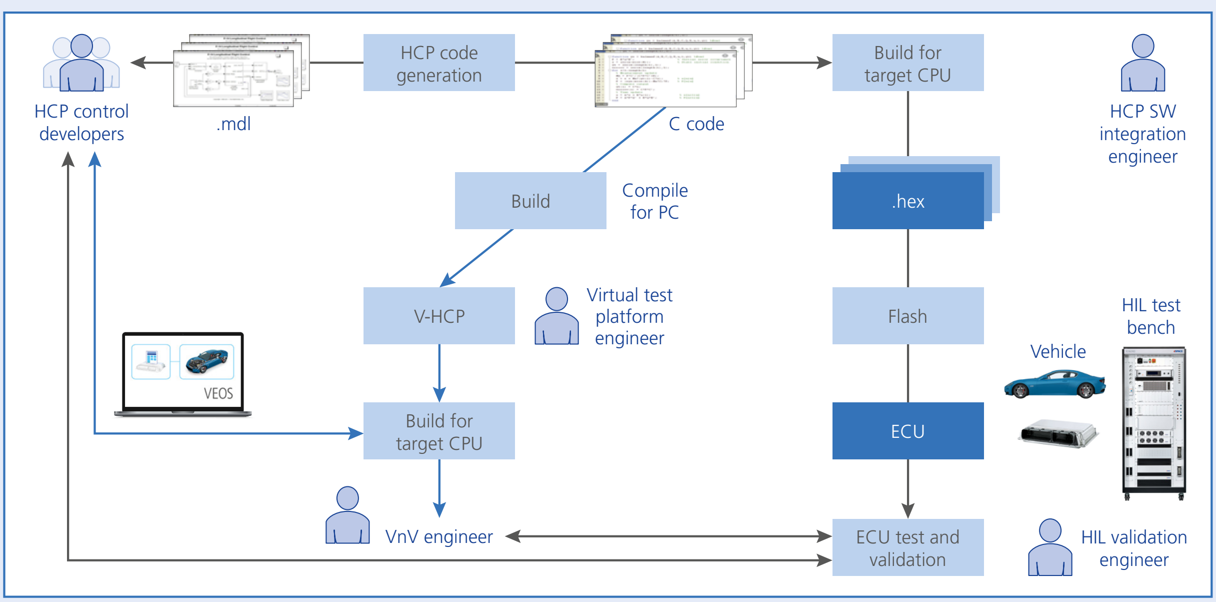
Courtesy of FCA US LLC

"The dSPACE Test Solution Package helps us to optimize tests and the test process."

Sisay Molla,
Vehicle modeling and Integration, FCA US LLC.

Picture credit: © FCA

SIL paves the way to efficiency.



An example of a high-level workflow for hybrid control development. Using virtual ECUs and the HCP Virtual Test Platform, the development team benefits from a more efficient build and time process and can perform tests earlier.

Powerful visualization and physical computation of sensor data for virtual test drives: using the new dSPACE solution for sensor-realistic simulation

Digital Twins

A true-to-life depiction of reality within a simulation, a digital twin, can be used to carry out high-precision virtual test drives. In contrast to gaming applications, in which the human eye can be fooled, the vehicle development process always requires physically correct computations. The new dSPACE solution for sensor-realistic simulation offers next-generation visualization and realistic sensors (camera, radar, lidar), thus making it possible to test and validate driving functions in real time or even faster.

A must-have for the precise generation of synthetic sensor data in virtual test drives with SIL and HIL.

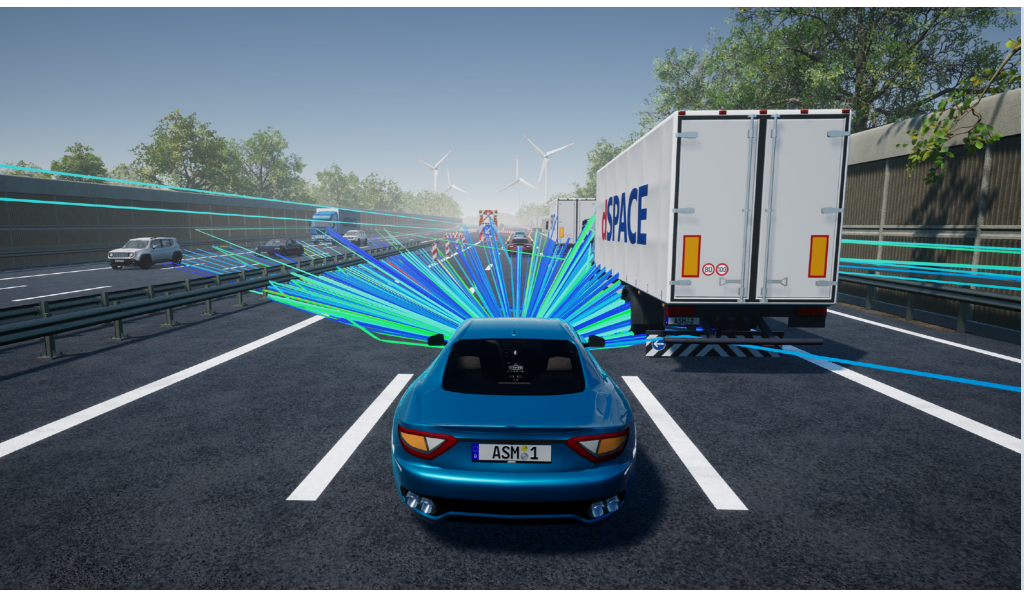
As realistically as possible: Starting in the summer of 2021, a completely new solution by dSPACE will be available to users to integrate top-grade visualization and cutting-edge, realistic sensors into their processes for developing and validating driving functions. This applies to virtually any conceivable use case. The dSPACE solution for sensor-realistic simulation can be used across various stages of the development process, for example, in hardware-in-the-loop (HIL) testing, in software-in-the-loop (SIL) testing, and even for parallel validation in the cloud. In particular, the solution is suited for developing AI-based features and training data, including the training and testing of artificial neural networks. The data for the sensor-realistic simulation >>

On the right: The new solution makes it possible to perform realistic simulations for different regions, such as the driving scene in Japan illustrated here.

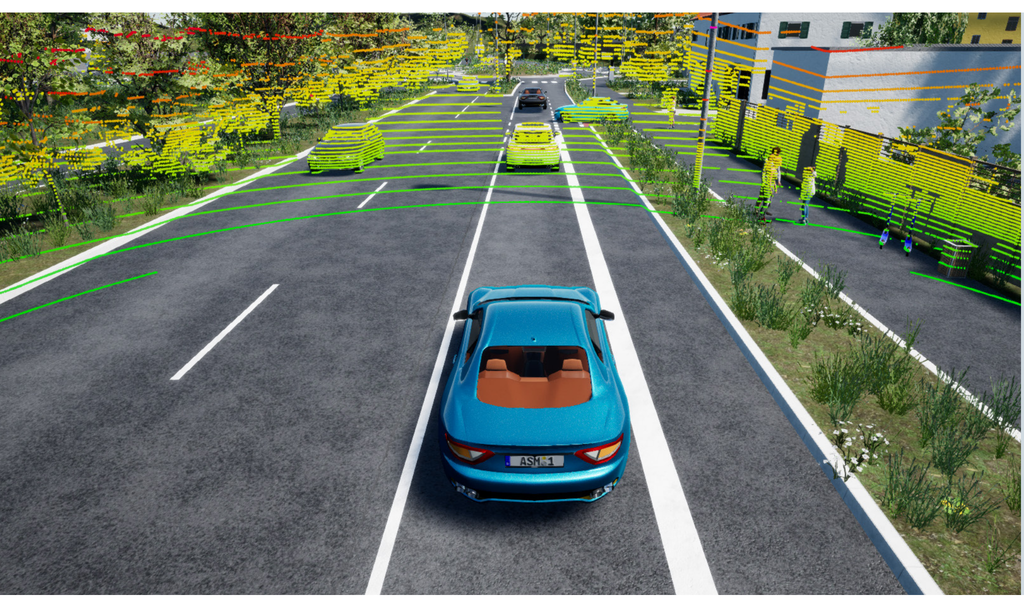
Profile: dSPACE Solution for Sensor-Realistic Simulation

- High-resolution visualization, including realistic lighting and weather effects
- High-quality 3-D assets developed by dSPACE, such as vehicles, e-scooters, and pedestrians
- Realistic camera, lidar, and radar models
- Linux and docker support
- Interfaces for integrating third-party sensor models

Camera sensor model
with high-fidelity graphics and lighting effects, configurable and realistic lens profiles, options for modifying images, and configurable color filters for raw sensor data.



Radar sensor model
with polarimetric calculation of the radar channel, consideration of mirroring reflections and diffuse scattering, multipath propagation, and adaptive ray launching to interact with every object within the detection range of the sensor. The parameterizable models for generating raw radar data and compiling target lists and object lists simulate the real sensors precisely.



Lidar sensor model
with point cloud or raw data output, support for scanning and flash-based sensors, and an ego-motion feature for rotating sensor devices

Interview: Behind the Scenes

Caius Seiger, operative product manager for Sensor Simulation at dSPACE, explains how the new solution for sensor-realistic simulation came about.

Mr. Seiger, this new solution for sensor-realistic simulation is a completely new development. How was it initiated?
Our customers' requirements in terms of sensor simulation have increased substantially. In the past, sensors were largely tested and validated using object lists, especially in the ADAS/AD context. But today that is no longer enough. Even though camera-based tests, for example, were effective with MotionDesk and Sensor Simulation, there were limitations, and the former technology could not be used for realistic, high-resolution graphics without investing a great deal of time and effort.

Where can users really notice the leap in performance of the new solution for sensor-realistic simulation?
The new underlying technology is specifically designed for performance and high-resolution graphics. This enables us to simulate realistic sensors in real time. We are certainly capitalizing on the gaming industry as well. However, while the entertainment industry relies on tricks to create certain visual effects for the human eye, the ECUs used by our customers call for physical correctness. Our aim is to compute the necessary adjustments and expansions so efficiently that we can make them available in real time.

How can you ensure that the computed sensor data delivers the correct results?
We are continuously verifying our models by means of an iterative process. This involves comparisons with values from the literature and comparisons with sensor data that was recorded in real life. It is here that we can see the strengths of our partnerships, for example, with the companies Hella and Velodyne with whom we design, conduct, and analyze experiments. Results flow through an agile development process into the product, thus allowing our customers to reap the benefits straight away.

can be computed both on stationary computers and in the cloud. The solution supports Windows® and Linux, as well as docker containers for Linux systems.

Efficient Inner Workings

The 3-D rendering engine, the high-precision dSPACE simulation models, and the realistic 3-D assets allow for the precise simulation of sensors (camera, radar, lidar), environments, weather conditions, lighting effects (daytime, nighttime), and materials. The new solution represents a significant advancement and will more than replace the current software MotionDesk and Sensor Simulation in the future. It combines a wide range of different features into a single product.

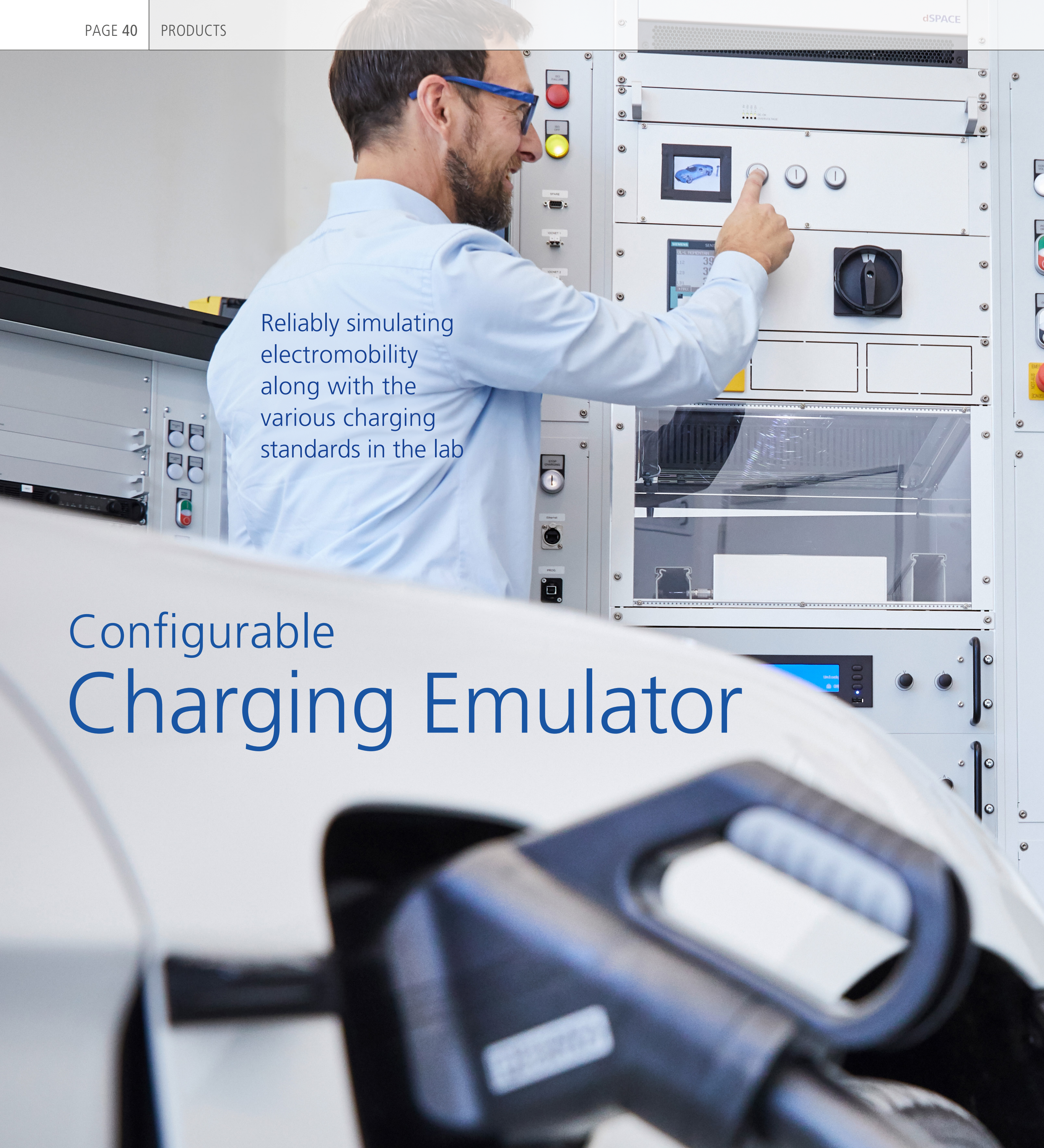
High-Precision Sensor Models

The complex vehicle environment is simulated in great detail to validate different types of sensors with the help of models, with all sensor data being computed in real time. In addition, it is possible to integrate third-party sensor models.

Easy Integration into the Tool Environment

The new dSPACE solution can be integrated seamlessly into many other dSPACE tools, such as ASM simulation models, ModelDesk for parameterization, the VEOS simulation platform, the RTMaps development environment for perception algorithms, the scenario generator, and the Environment Sensor Interface (ESI) Unit. Even the upcoming simulation platform SIMPHERA will be compatible with the solution for sensor-realistic simulation. ■

The new dSPACE solution represents a decisive step forward for our customers in the development and testing of autonomous vehicles.



Reliably simulating electromobility along with the various charging standards in the lab

Configurable Charging Emulator

A key success factor for electromobility is being able to charge batteries quickly and safely. The range of solutions designed by dSPACE helps optimize the vehicles and charging stations.

Generally, a 21st-century electric car is expected to offer the same amenities as those found in vehicles powered by a combustion engine. In addition to the driving experience, charging the high-voltage battery is an essential point for the driver of an electric car. However, the necessary power supply is still limited in many places due to the lack of a charging infrastructure.

Charging vs. Refueling: A Dynamic Competition

To compare the refueling of a gasoline-powered car to the charging of an electric car, take a closer look at the flow of energy: At an average gasoline pump, a delivery rate of 35 l/min can be expected. Due to gasoline's high energy density, this corresponds to an electrical output of approx. 20 MW. Even if a gasoline engine is relatively inefficient, with the efficiency rating normally falling below 30%, this still results in a comparable charge rate of 6,000 kW. Thus, it should come as no surprise that charging an electric vehicle can take a good 40 times longer, even at a fast-charging station (e.g., with a charge rate of 150 kW). This means: While gasoline delivers values of roughly 13 seconds per 100 km, the aforementioned charging station would need approx. 8 minutes for the same distance.

Alternating Current and Direct Current at Your Fingertips

Because it is possible to simply tap into the alternating current (AC) power grid in both the private and public sector, electric vehicles are always outfitted with an AC charging port by default. However, vehicle batteries require direct current (DC) tuned to their specific state of charge, which is why an inverter is needed. In order to ensure that the inverter is designed optimally for the vehicle battery, this inverter is installed directly in the vehicle. That is where the name onboard charger (OBC) comes from. In Germany, home power outlets are generally designed with a 16-amp fuse. Together with the supply voltage of 230 V, this results in a maximum output power of less than 4 kW. Some houses have three-phase plugs, but these are usually outfitted with a 16-amp fuse as well. In this case, the output power is 11 kW. Most OBCs today are limited to this value since larger OBCs would take up too much installation space, generate more waste heat, and needlessly increase the weight of the vehicle. Most home wallboxes are designed precisely for 11 kW. Special charging stations, such as those found at highway charging parks, operate directly with direct current. Since alternating current is converted to direct current outside the vehicle in this case, they can deliver significantly higher charge rates of up to 350 kW.

Refueling:
approx. 13 seconds per 100 km

Charging:
approx. 8 minutes per 100 km

The Voltage Is Rising

From physics, we know that electric power is the product of voltage times current (P = V * I). At the moment, the voltage levels for most electric vehicles are around 400 V. The classic Combined Charging System (CCS) connector is designed for a maximum current of 200 A, meaning it can provide power at up to 80 kW. The cables and connectors must be water-cooled to provide 150 kW of power as otherwise they would overheat due to the high currents. If you were to double the voltage to 800 V, then the high power would also be available with standard connectors and cables. In order to catch up with the charge rates of fossil fuels, it is necessary to break into the megawatt range. Suitable connector systems are already being tested. This power range will probably first be available in the transport sector.

800 V

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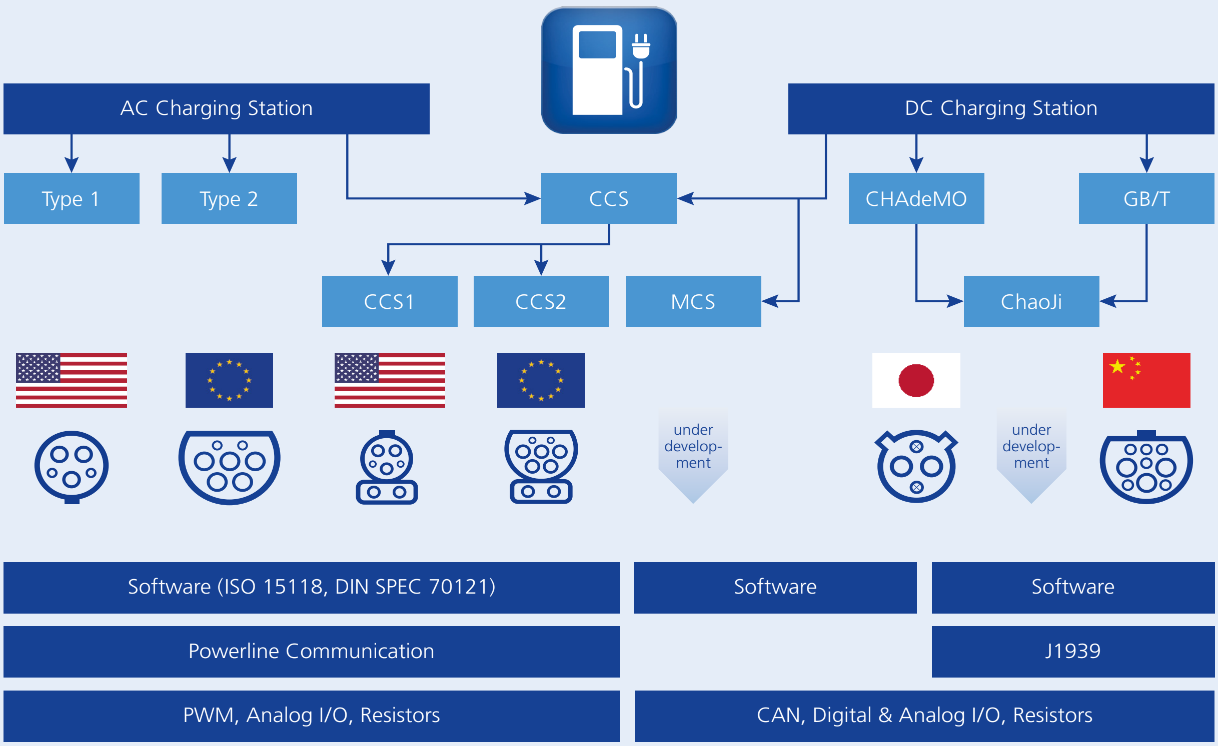


The various communication standards (CHAdeMO, GB/T, CCS) feature completely different connector systems, transmission methods, and transmission protocols.

Ensuring Safety by Means of Communication

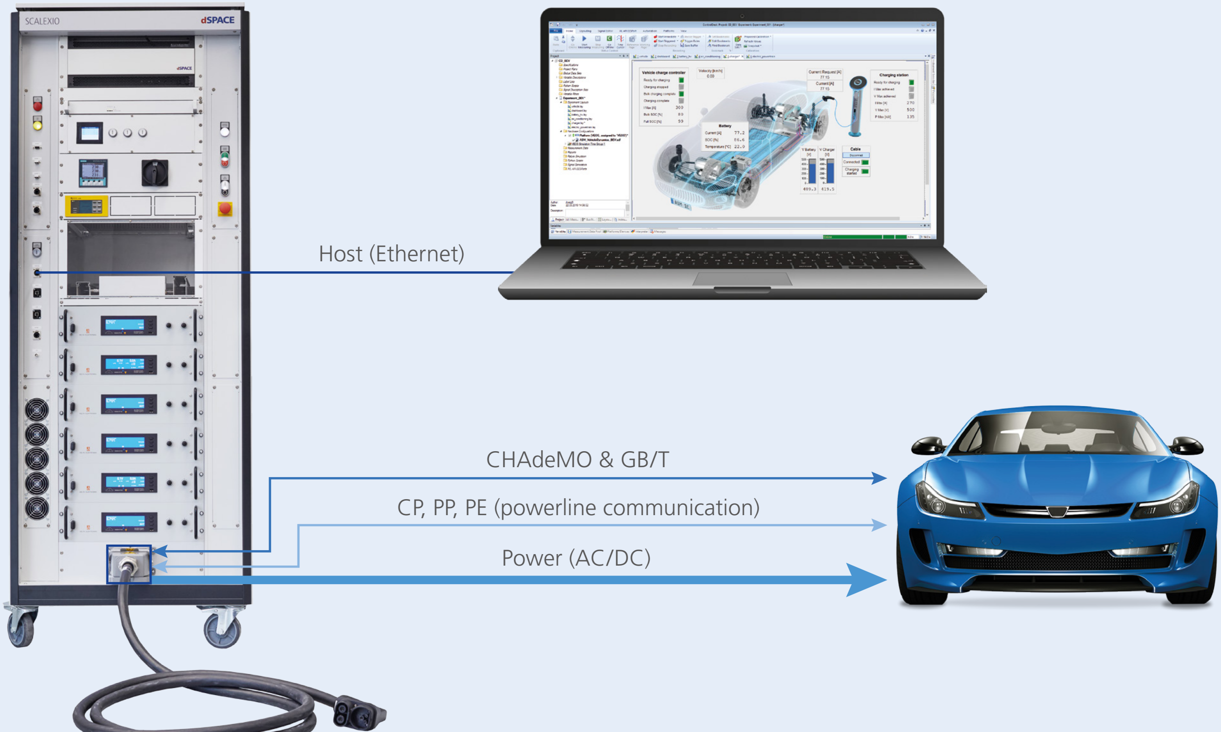
At the charging stations, the vehicle's high-power components come into contact with the charging infrastructure. It is critical that this takes place under optimal conditions to ensure safe charging. Due to the different international standards and provider-specific systems in place, the vehicles and charging stations have to negotiate and monitor the optimal conditions themselves. This requires bidirectional communication via special wires and plug connectors in the charging plug. This is mandatory for DC charging and increasingly important for AC charging. For AC charging, this holds true especially when connecting to smart home systems and supplying potential consumers within a household. In addition, as the share of electric vehicles rises, it will be necessary to coordinate with the network provider to ensure that the power grid remains stable.

International Charging Standards

Around the world, there are currently three different communication standards (CHAdeMO, GB/T, CCS) that were developed in different regions: one for the USA and Europe and one each for China and Japan. Manufacturers developing vehicles for these different markets have to take into account the relevant standards and test accordingly.

Communication Methods

In Asia, they rely on a well-known medium that is tried and tested in the automotive sector: CAN communication. The CAN bus has been an established vehicle component for decades. In China, the familiar SAE J1939 protocol is also used in the commercial vehicle sector, making it possible to transfer large data packets via CAN as well. The USA and Europe are forging ahead with the Combined Charging System (CCS) and have selected a two-tier communication architecture:



The Smart Charging Station Emulator simulates freely configurable charging stations in full and supports charging processes with up to 1,000 V.

- Basic communication by means of pulse width modulation (PWM) based on the duty cycle and voltage level with a frequency of 1 kHz
- High-level communication in the form of powerline communication (PLC) modulated on the PWM signal on the basis of the HomePlug Green physical layer (PHY) specification, which was developed as part of an alliance between the supply industry and automobile manufacturers. A data link allows for TCP/IP communication between the vehicle and the charging station.

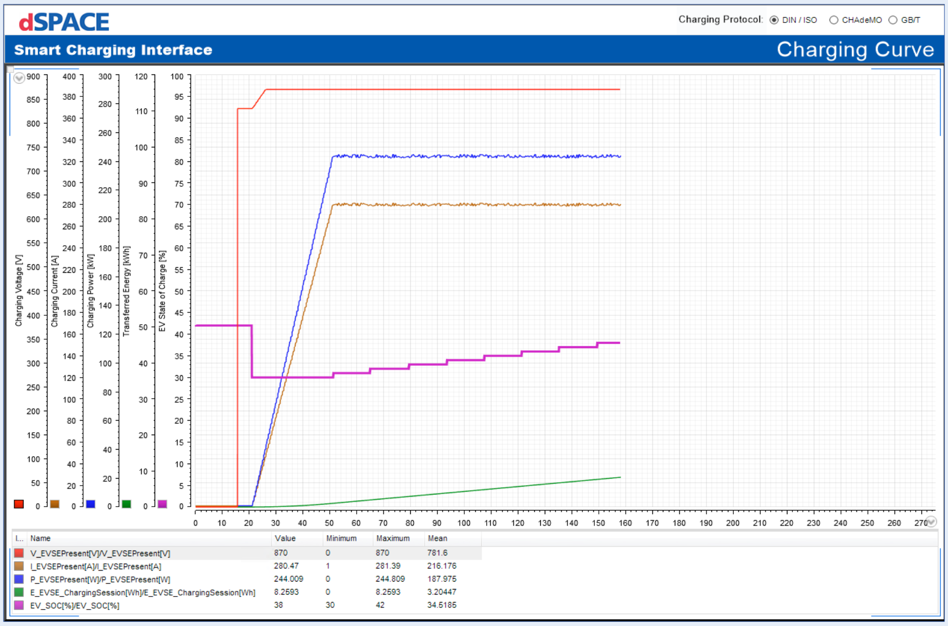
Challenges Posed by CCS Charging

Because the communication wires are housed in the same cable as the power supply and direct current is not always completely uniform, it is essential for the communication to be immune to interference. That is why there are such high requirements for the signal quality of the PLC. It is precisely this PLC that presents new challenges for both vehicle manufacturers and charging station developers in terms of hardware and software. Of course, there are also standards that stipulate quite clearly which parameters must be observed – unfortunately, there is a high probability that the implementation would not be compatible between the vehicle and the charging station. Such errors can be divided into electrical errors and protocol-errors related to the following aspects:

- Electrical: Voltage level, frequencies, slew rates, attenuation, termination resistors, and electromagnetic compatibility
- Protocol: Reaction time to messages, encoding data in the message telegram, parameterization, using optional parameters, protocol versions, etc.

Charging Only in Case of Compatibility

While charging, electric vehicles and the charging infrastructure are tuned to one another, with both taking into account the constraints of the other: a process referred to as smart charg- >>



The charging process can be monitored closely with the Smart Charging Solution, together with the voltage, current, and state of charge.

The Smart Charging Solution can be easily integrated into existing test environments.

ing. If there is any sort of incompatibility, the vehicle generally cannot be charged as a result. This is certainly very frustrating for the driver of the electric vehicle and should be avoided at all costs.

The Range of Smart Charging Solutions at dSPACE

Suppliers and car manufacturers around the world are already using dSPACE systems to develop and test their control applications. These systems often serve as a basis for development and testing in the electromobility sector. The Smart Charging Solution add-on can be used to fully represent the key aspects of the charging process. It offers the following features:

- Easy to integrate into existing test environments
- Comprehensive test options for all relevant standards at the communication and power level
- Easy to automate and parameterize the system
- High transparency for workflows and test library options (white-box testing)

Application Areas of the Smart Charging Solution

Thanks to its great flexibility, the Smart Charging Solution can be used in a wide range of applications, including the simulation of charging stations and the simulation, testing, and development of onboard charging devices. As a result, it supports both electric vehicle manufacturers and charging station manufacturers in developing and testing smart charging technology. It allows for the complete configuration of all timing elements, message contents, and attenuation properties for the transmission. If the communication tests are energized, then the manipulation of voltage and current is added to the equation.

Looking for a freely configurable charging station for laboratory use? Then the Smart Charging Station Emulator from dSPACE is for you.

Smart Charging Station Emulator

As a special configuration, the solution features a system that emulates the electrical and communicative behavior of a charging station. This makes it possible to simulate a freely configurable charging station in the laboratory. It complies with all international standards and is flexibly designed for voltages of up to 1,000 V. Furthermore, the Smart Charging Station Emulator can be equipped with multiple DC power supplies depending on the requirements, thus allowing for a charge rate of 85 kW both at the 400 V and 800 V level. In customer projects, the configuration can be expanded to include more power supplies and reach higher power levels. To test the AC charging process, the dSPACE real-time system offers diverse interfaces for controlling a grid emulator, which makes it possible to simulate the various network types in the target markets or phase distortions, for example.

1,000 V

Standardized Test Libraries

The standardization committees have thought about how to ensure interoperability between the charging station and the vehicle. Test libraries with hundreds of tests were created for this purpose. They provide a good basis but generally are not sufficient for assessing all eventualities. Here, the dSPACE solutions stand out from the rest of the market with their ability to be integrated into any test. All tests are implemented as transparent test scripts to allow for a more in-depth interpretation of the results. The first conformance test is planned for summer 2021. The test libraries will be implemented by the engineering service provider KPIT. Customers can also benefit from KPIT's extensive experience in executing tests.

Automatic Payments

Automatic payments usher in a new chapter in the field of electric charging. Similar to paying with a credit card, encryptions and certificates are used and it must be verified that they are exchanged correctly. dSPACE is working with a back-end provider on this to guarantee a seamless validation chain and quickly roll out solutions on the market. The goal is to support both component and integration testing and vehicle approvals.

Frontloading via Software Simulation

Of course, charging technology can also benefit from early validation by means of software-in-the-loop (SIL) testing. dSPACE tools have been used for years to test virtual ECUs, which are often developed according to the AUTOSAR standard. This test option is currently being tried out for smart charging, too, in order to validate communication and interaction with other software components at an early stage in the development process. As a result, it is possible to perform interoperability tests even without the electric vehicle communication controller (EVCC) hardware. This is especially advantageous since the earlier an error is detected, the easier it is to resolve it. ■

Decisive criteria when testing automotive long-range radars

Precision Means Safety

Self-driving is all about reliability – as is testing the radar sensors and application software involved. Here are some thoughts on why high-precision test equipment is so crucial.

“Our customers confirm time and again that the excellent signal quality and precision of DARTS deliver reliable simulations over the entire operating range of a radar sensor.“

Dr. Andreas Himmler, Senior Product Manager, dSPACE

Automotive long-range radar (LRR) sensors running at 77 GHz are an undisputed key element in the implementation of driver assistance and collision-avoidance functions for upcoming assisted and automated driving. These functions pose rising technological challenges for environment detection with LRR sensors: This requires high spatial resolution and more accurate detection of smaller objects, along with larger fields for view. All of this within a maximum bandwidth of about 1 GHz. Recognition errors and misinterpretations can lead to fatal consequences in scenarios with self-driving vehicles. Therefore, super-accurate and thorough testing is a prerequisite for reliable functions.

Radar Target Simulation – Precise and Versatile

Over-the-air simulation of radar targets and echoes for automotive radar sensors using radar target simulators is a well-established and proven method of ensuring the proper functioning of sensors and developed application software at various stages of the sensor development, production, and release process. Of course, the requirements for radar target simulators include functional requirements, for example, for the radar targets to be simulated precisely in real time. However, they must also meet economic requirements, which include ease of operation and future viability.

Strict Test System Requirements

Testing today’s and especially next generations of 77 GHz LLR radar sensors requires the radar targets to be simulated precisely across the whole detection range, which can span up to 300 m. Comprehensive testing and validation of the new sensors and the functions based on them increases the demand for simulation capabilities with consistent simulation properties and precision over the entire range. Users also demand technology that allows for an uncompromised simulation of multiple, independent radar targets. This needs to be ensured independently of the modulation technique of the radar under test.

High-Precision Digital Radar Target Simulation

dSPACE offers the high-precision digital DARTS 9030-M, which benefits from the expertise of dSPACE development partners ITS and miro•sys. It offers 1.2 GHz of usable bandwidth and covers a frequency range from 75 GHz to 82 GHz. The precision of the device is demonstrated by the fact that the range increments of 6 cm are consistent throughout the simulation range from 5.5 m up to 1,000 m with a simulation accuracy of less than 1 mm. This applies in conjunction with a dynamic range > 60 dB. The advantages of the digital concept are even more evident considering the multi-target simulation capability: Up to four fully independent targets can be simulated without compromising the signal quality. dSPACE is in the process of improving the DARTS 9030-M by means of software updates. These updates will fulfill requirements related to the fast switching of simulation distances. Stay tuned for more details in the near future. ■

Profile:
Radar Target Simulator for Over-the-Air Testing of Automotive Radar Sensors

- Optimized for high-precision 1 GHz radar.
- Simulates distance, speed, width, and elevation.
- Simulates the reflections of up to four freely definable, independent radar targets.
- Range-independent simulation precision.

The high precision and accuracy are, of course, also offered by the DARTS 9040-G, which was voted Product of the Year in the Automotive category by the readers of Elektronik magazine.

Making Sure They're Safe

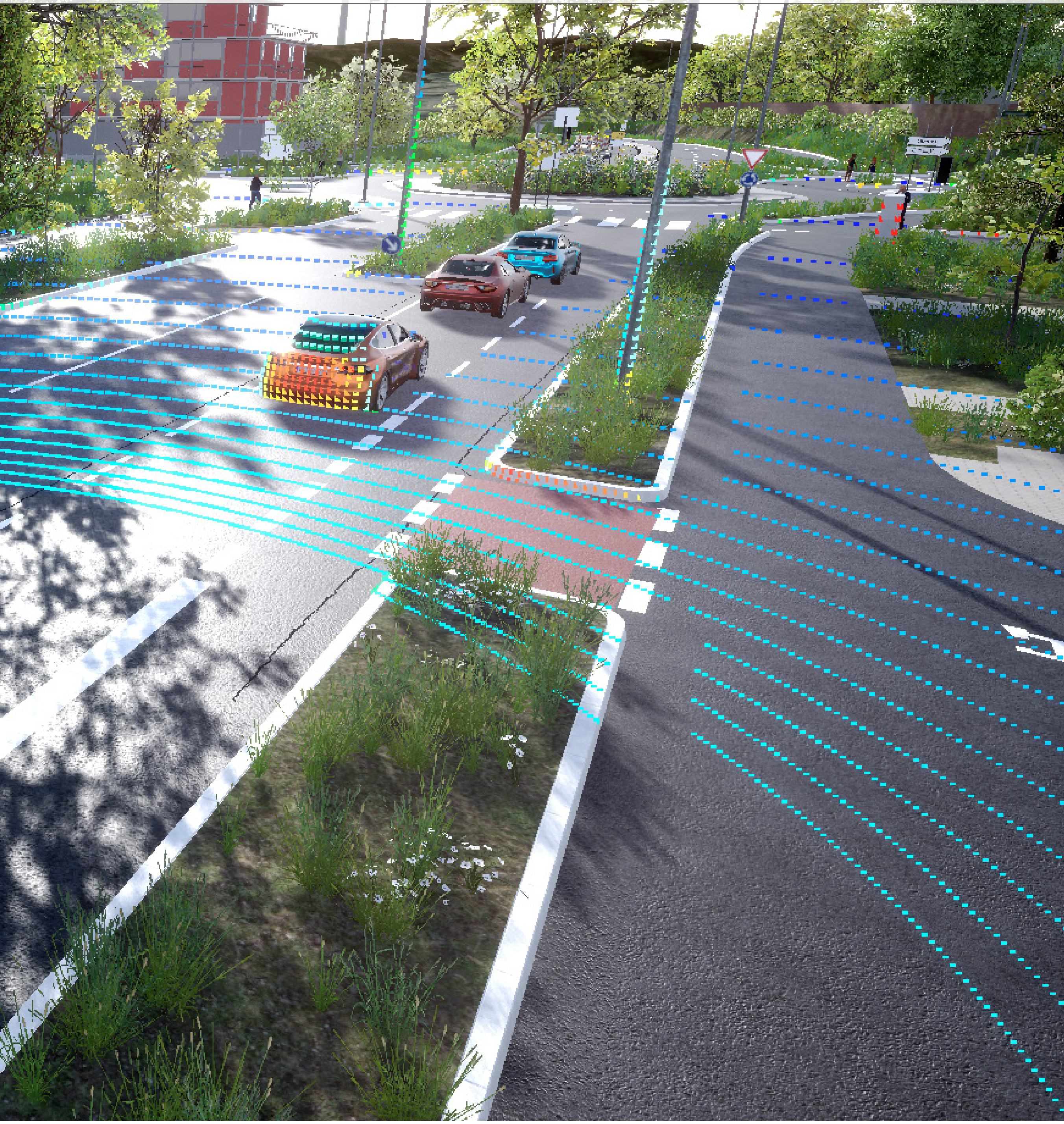
Two research projects aim to provide proof of safety for autonomous driving in urban environments.

dSPACE has joined forces with 25 research and industry partners in two research projects that confront one of the greatest challenges in autonomous driving: the validation of new systems.

The two new projects are building on the results of the PEGASUS project, which was concerned with identifying and describing critical scenarios and turning them into universally applicable test cases for highly automated vehicles, using the Autobahn Pilot as an example. The Verification Validation Methods project, or VVM for short, extends the PEGASUS method to automated driving at levels 4 and 5 in an urban environment, taking a downtown intersection as an example. The second project is called SET Level and aims to advance the simulation-based development and testing of automated driving in urban spaces. The objective here is to provide a vital basis for verifying and validating autonomous cars and for their subsequent release and approval. dSPACE is contributing its expertise on simulation and validation to both of these projects.

VVM: Moving Autonomously Through a Downtown Location

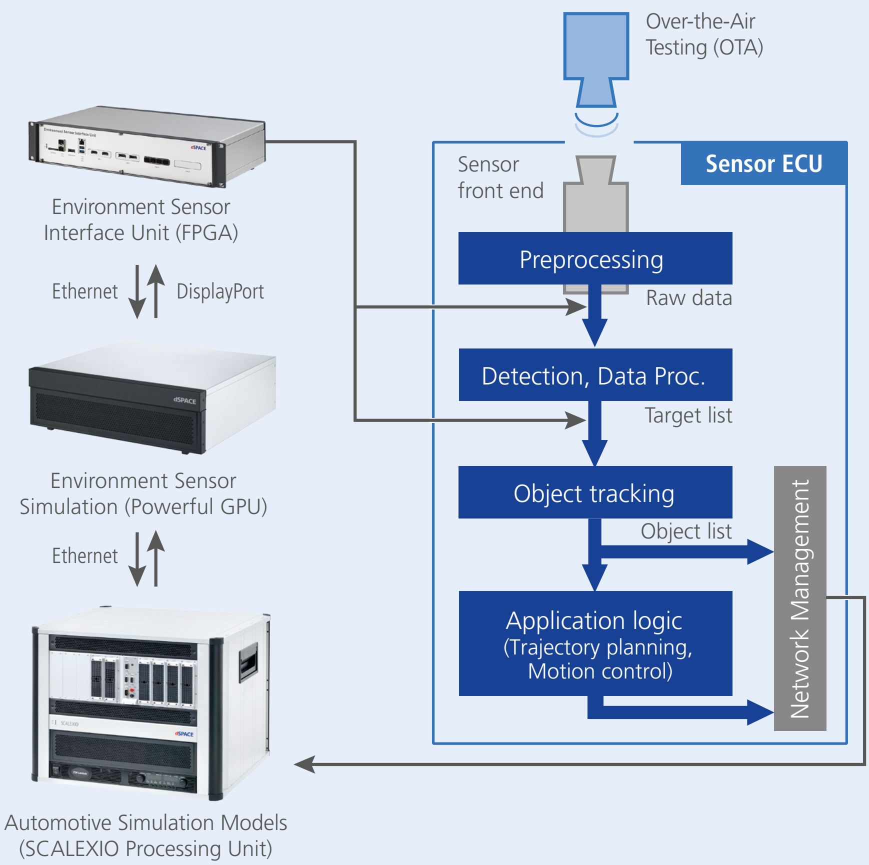
The approach mapped out for the VVM project can be described in three essential steps. Validating an autonomous



vehicle by means of test drives in normal road traffic would require driving several million kilometers in order to cover enough different situations. So VVM's first job is to investigate the combinations of effects that lead to critical situations in urban road traffic. To cover the event space, existing databases and expert knowledge are used, in addition to dedicated simulations that are being developed. As a result, the test space can be reduced to scenarios that are actually relevant, making the amount of effort involved in tests more manageable.

The second step will be to use the findings to develop a safety concept and a functional concept for describing automated systems, which can also be applied to hierarchical subsystems and components. This will make it possible, in the future, to validate new components in independent tests – instead of performing labor-intensive real test drives as is currently the case.

In the final step, an example implementation of the validation framework will be produced as a demonstration. The goal is to produce an >>



Example of a HIL setup with the different input points within the chain of events.

integrated, dynamic test environment in which the various test platforms can be combined flexibly from simulation right through to real drives, while at the same time allowing for an evaluation of the overall safety level. This will mean that tests can be moved systematically from the real world to simulation, resulting in greater time and cost efficiency.

The main focus of dSPACE in the VVM project is on the interface function in the SET Level project and on the example reference implementation. The first step will be to put the SIL tools from SET Level into use; dSPACE will be supporting the other project partners with its comprehensive expertise as a tool producer. To demonstrate the method, dSPACE is working with the FZI research center in Karlsruhe to design a HIL simulator that will fit seamlessly into the integrated framework between the SIL simulation and the real test drives. The main focus is on perception, which makes it possible to map the entire chain of actions, from over-the-air testing of the sensor front end to feeding raw data into the sensor ECU, to inputting object lists to test the functionality of highly automated driving (HAD). Models are connected via open interfaces such as FMI and OSI, their granularity designed to cover the entire range from ground truth to physics-based models.

SET Level: Developing and Testing Based on Simulation

The SET Level partner project plays a major role in VVM because it supplies the basis for SIL simulation, and the two projects are closely interdependent. In SET Level, simulation-based tools or tool chains are produced for the development (including determining and defining requirements) and efficient testing (including verification and validation) of Level 4 and Level 5 vehicle systems. The aim is to develop items for standardizing simulation-based development/test tools, including ones for specifying scenarios (application cases, model descriptions,

Application Case 1: "Testing Sensor Models"

To produce a complete virtual representation of an HAD system in the SIL simulation, it is essential to model the sensors, alongside other components. The sensors include camera, radar, lidar, and ultrasonic sensors. Capturing environment data via the interaction between different sensors is of central importance in an HAD system, so the sensor models used in SIL testing of HAD systems must be of very high quality and map realistic behavior. The development and validation testing of realistic sensor models can therefore be seen as a deliverable for the testing of HAD systems. The particular challenge is also to generate realistic input data for the different sensor technologies by means of ray tracing.

Application Case 2: "Using Simulation to Verify or Validate Vehicle Automation"

This application can be located in various stages of developing an HAD function or an HAD system. It will take different forms depending on the particular V&V tasks in each phase. Typical applications:

- Testing a development version of an HAD function (test object: HAD function)
- (Contributing to) the validation of an HAD system (test object: HAD function including all its components such as HMI, sensors, actuators)

For validation, the simulation has to "drive through" the traffic scenarios that are possible in the application field of the automated vehicle under development (i.e., the operational design domain or ODD). Testing determines whether the automatic system guides the car safely through traffic.

and models, model integration, management of simulation data, etc.). With its MIL/SIL/HIL simulation expertise and active involvement in a wide range of standardization activities such as OpenScenario, FMI, OpenDrive and OSI, dSPACE provides the necessary knowledge on whether the planned application cases can be mapped either to existing standard interfaces or to ones yet to be developed. dSPACE also provides support for gathering requirements and producing methods of distributed simulation and cosimulation on different hardware architectures (HIL, PC clusters, cloud systems) and different operating systems (Windows, Linux). Moreover, dSPACE is an expert project partner on issues of sensor simulation. The goal is to simulate sensors by means of realistic sensor models or in a preliminary stage to enable the development of realistic sensor models (see application case 1 in the text insert).
At system level, dSPACE uses demonstrators to provide proof that the tools and platforms on this level can be coupled (including connection of an AD function) and that the standards the project requires for a tool environment can be supported (see application case 2, text insert). ■

MORE INFORMATION

https://setlevel.de/en

MORE INFORMATION

https://www.vvm-projekt.de/en

FMI: The Functional Mock-up Interface defines a standardized interface for connecting simulation software.
OSI: The Open Simulation Interface is a simple and uncomplicated way to link numerous driving simulation frameworks for developing functions for automated driving.
OpenSCENARIO defines a file format for the description of dynamic traffic maneuvers (scenarios) for use in driving simulators.
OpenDRIVE defines a data model for the highly accurate, logical description of road networks.
ASM is a dSPACE tool suite for simulating combustion engines, vehicle dynamics, electric components, and the traffic environment.

Autonomous driving and AI from an ethical perspective

Weighing the Risks and Opportunities

Before self-driving cars can be released onto the streets, several challenges have to be resolved, and not just of a technical nature. The development of autonomous vehicles also raises ethical questions. In this interview, Prof. Christoph Lütge, holder of the Chair of Business Ethics at the Technical University of Munich, talks about the opportunities and risks inherent in AI and autonomous driving and explains how he teaches his students about ethical behavior.

Ethicists are facing a vast array of questions on this subject. And many times, their responses to everyday questions are surprisingly pragmatic. During the pandemic, you criticized hard lockdowns as a member of the Bavarian Board of Ethics (Bayerischer Ethikrat), explaining that the collateral damage was too high. That sounds a bit harsh at first. How easy is it to weigh the opportunities and the risks as a basis for creating a guide on moral behavior?

Maybe we should start by clarifying what ethics actually are: risk management on multiple fronts. And what ethics are not: namely, complying with principles at all costs. This applies in particular to the field of applied ethics, which covers topics such as artificial intelligence, autonomous driving, and business ethics. As ethicists, our job is to weigh the risks against one another and to look at the big picture. It is not enough to single out just one aspect, as has often been the case in the corona pandemic. Here, the medical aspects have been prioritized. However, there are many other scientific disciplines aside from medicine that deal with the measures, proportionality, and collateral damage, such as social scientists, economists, and ethicists. In theory, this might sound somewhat detached from reality, but it becomes much more straightforward as we get more specific.

You head the Institute for Ethics in

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> "I am convinced that we need uniform directives, which we have been waiting for in vain for years now."
>
> *Prof. Christoph Lütge*

Artificial Intelligence (IEAI). There, researchers from the fields of medicine, science, and engineering work together with sociologists and ethicists in interdisciplinary teams. What are the areas of research at IEAI?
The projects are separated into different research clusters. One of them is devoted to the subject of Artificial Intelligence, Mobility, and Safety, which includes autonomous driving. Another area investigates AI-based decision-making tools for ethical questions in clinical settings. In one major field of investigation, we explore a range of topics related to AI and sustainability: for example, in agriculture, water management, and biodiversity. Currently, we are setting up a focus area to research how we can design AI at the workplace responsibly so that it gains acceptance.

What are the risks associated with AI?
There is a whole host of risks that are stressed time and again in public debates. We consider risks from various perspectives: One perspective looks at the purely technical risks related to safety, data protection, and the robustness of algorithms. Another perspective regards the fairness of algorithms as well as their explainability and transparency since many people see AI as a black box and are worried because they do not comprehend how decisions are made. And some fear they will lose their autonomy. But despite any risks, we must not lose sight of the ethical and economic opportunities of AI.

Let us take a closer look at autonomous driving: From an ethical standpoint, does it make sense to permit driverless cars?
Roughly five years ago, we already underscored one specific point in the first international Ethics Commission on Automated and Connected Driving: The ethical opportunities consist of preventing many accidents and saving human lives. This is a clear ethical advantage that arises even if we are not fully autonomous but are working with highly automated systems.

What is being investigated in the project on the ethics of autonomous driving at IEAI?
In this project, we are collaborating directly with the Chair of Automotive Technology and working on specific tasks such as trajectory planning systems. In this case, we are frequently faced with detailed decisions, for example, the question of how far away a truck should stay from other vehicles or cyclists. In order to calculate exact distances, we carry out studies that can then be used for the purpose of responsible programming.

In 2017, the German Ethics Commission on Automated and Connected Driving set forth several rules: Are there any significant differences in other countries around the world?
Over the last few years, various ethical principles have been defined for AI everywhere in the world. There is not much variance across the abstract principles; I would estimate that 80 to 85 percent of them are the same. Nevertheless, they might differ in the fine print. Let us take a look at the issue of vehicle-to-vehicle distances: I visited Delhi some time ago. The distances between vehicles are much smaller than in Germany. This can affect the programming. It starts to get interesting when we cross a national border: a situation that would never arise in Japan, occurs rather seldomly in China, but happens quite frequently in Europe. This is why I am convinced that we need uniform directives, which we have been waiting for in vain for years now.

In addition to research, you also teach: How can you help students understand ethical behavior? Or to put it another way: How can you teach students to develop ethical algorithms?
Allow me to elaborate on this a little. As the holder of the Chair of Business Ethics, eight years ago I was able to introduce business ethics as a core subject for students of business administration. In my experience, it is not a matter of preaching morality and explaining, "here is a list of ethics and this is how you should apply them." I always point out that you also have to be aware of the difficulties that stand in the way of practicing ethics. In business administration, for example, this

In cooperation, the Governance Lab (The GovLab), the NYU Tandon School of Engineering, the Global AI Ethics Consortium (GAIEC), the Center for Responsible AI @ NYU (R/AI), and the Institute for Ethics in Artificial Intelligence at the Technical University of Munich (TUM) (IEAI) have launched a free online course: AI Ethics: Global Perspectives. Designed for a global audience, it conveys the breadth and depth of the ongoing interdisciplinary debate on AI ethics and seeks to bring together diverse perspectives from the field of ethical AI to raise awareness and help institutions work toward more responsible use.
AI Ethics: Global Perspectives (https://aiethicscourse.org/)

Prof. Christoph Lütge conducts research in the field of economic and business ethics. He advocates the order ethics approach, which investigates ethical action in the context of the underlying economic and social conditions of globalization. His research focuses on the role of competition and that of incentives stemming from orders and assesses the reasonableness of ethical categories. He has held the Peter Löscher Chair of Business Ethics at the Technical University of Munich since 2010.

could be constraints or cost pressure. We do not have any compulsory classes yet on how to deal with digital issues and AI. However, the president of the Technical University of Munich has presented human-centered engineering as his vision, thus laying the foundation for the introduction of ethics in technical disciplines. Human-centered engineering involves incorporating parts of the humanities and social sciences into technical disciplines. One objective is to impart more competency to students by raising awareness for ethical issues. Engineers and computer scientists should be aware of the fact that their actions have an ethical dimension.

When will we see fully autonomous vehicles on the road, and to what extent will they be capable of making good and moral decisions?

If we are talking about self-driving cars according to the current level 4 (high driving automation) or level 5 (full driving automation) specifications, then that may take some time. However, today we already have quite extensive applications for certain purposes that work very well. In response to the question of how such systems could be rolled out broadly onto the streets, I believe that this is more of an ethical and legal issue and less of a technical one since a great deal is already feasible from a technical perspective. Several advances were made in US legislation in the last one or two years. As a result, the first driverless delivery vehicles, for example, are now out and about on the streets. We must not underestimate these advances; unfortunately, they often take place outside of Germany. I think it was a mistake for German car manufacturers to postpone their research on autonomous driving. I think in ten years we will see considerably more automation on our roads. Especially in Germany, we have a tendency to set the bar very high, saying that we cannot possibly permit autonomous driving until we are prepared for every conceivable eventuality. We need to abandon this everything-or-nothing mindset.

Thank you for the interview.

YOUR PARTNER IN SIMULATION AND VALIDATION

dSPACE