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dSPACE
MAGAZINE

1/2019

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Sensor Optimization at Fiat Chrysler Automobiles (FCA)
Two are better than one. When it comes to automotive components, one is usually better than two. Therefore, FCA US has begun consolidating the cameras and radar sensors that enable its automatic emergency braking (AEB) systems. In the redesigned 2019 Jeep Wrangler SUV and the all-new 2019 Ram 1500 pickup truck, both technologies are housed in a single component adjacent to the rear-view mirrors.

"Consolidating cameras and radars will help us proliferate AEB, which benefits our customers. dSPACE tools were used to accelerate the technology's launch."

Phil Jansen, Head of Product Development – FCA North America

Picture credits: © 2019 Fiat Chrysler Automobiles

"Accelerating your success."

Dear Readers,

In March 2018 I joined the dSPACE executive management team and it has been an exciting time so far. Our industry is experiencing a period of remarkably dynamic change. This has been confirmed not only in my conversations with employees and company founder Herbert Hanselmann, but particularly in the dialogue with you, our customers. I value this personal, direct exchange with you, now and in the future.

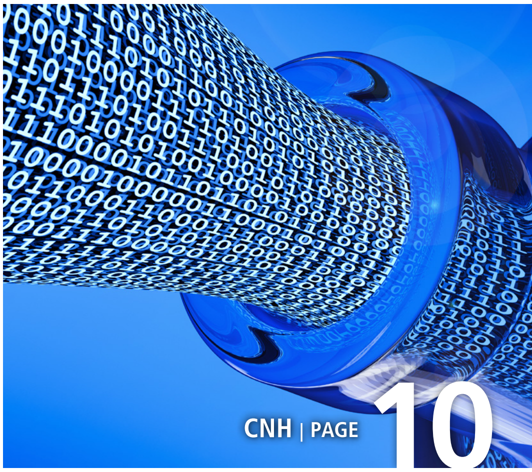
In many discussions with customers in recent months, I was able to get a good impression of what has been driving the success of dSPACE for so many years. It seems that almost all customers were able to successfully launch new product generations thanks to the collaboration with dSPACE. I would like to intensify these customer partnerships.

I also understood that you genuinely appreciate our reliability and high quality – of our software and hardware products as well as in joint projects. These strengths will continue to be our yardstick for measuring our mutual success.

It is now important to move forward. New business models for overall mobility as well as increasingly complex applications in electromobility and autonomous driving are fundamentally changing the requirements for structures and processes. The complexity of the systems you are currently developing increases at a rapid pace, as does the volume of data that must be processed. All of this has a direct impact on development and testing, and thus on customer expectations. One dSPACE customer put it this way: "After the HIL revolution 20 years ago, I would now like to see another revolution in virtual validation." As you will see in this issue of dSPACE Magazine, we are already working on and investing in these developments. Volkswagen and Case New Holland Industrial describe how dSPACE virtual validation tools have contributed to their success. On page 38, you will learn more about our new simulation solutions that drive the validation of autonomous vehicles.

Dear Readers, in order to provide you with the latest innovations in due time, dSPACE is constantly increasing its future investments and R&D expenses. For example, we continuously and intensively work on new test methods as well as cloud solutions and artificial intelligence. Our goal is to support you most efficiently in optimizing your current simulation and validation development projects. The close cooperation with you is key to making your complex projects manageable while reducing project development time. It is our top priority to accelerate your success.

Martin Goetzeler



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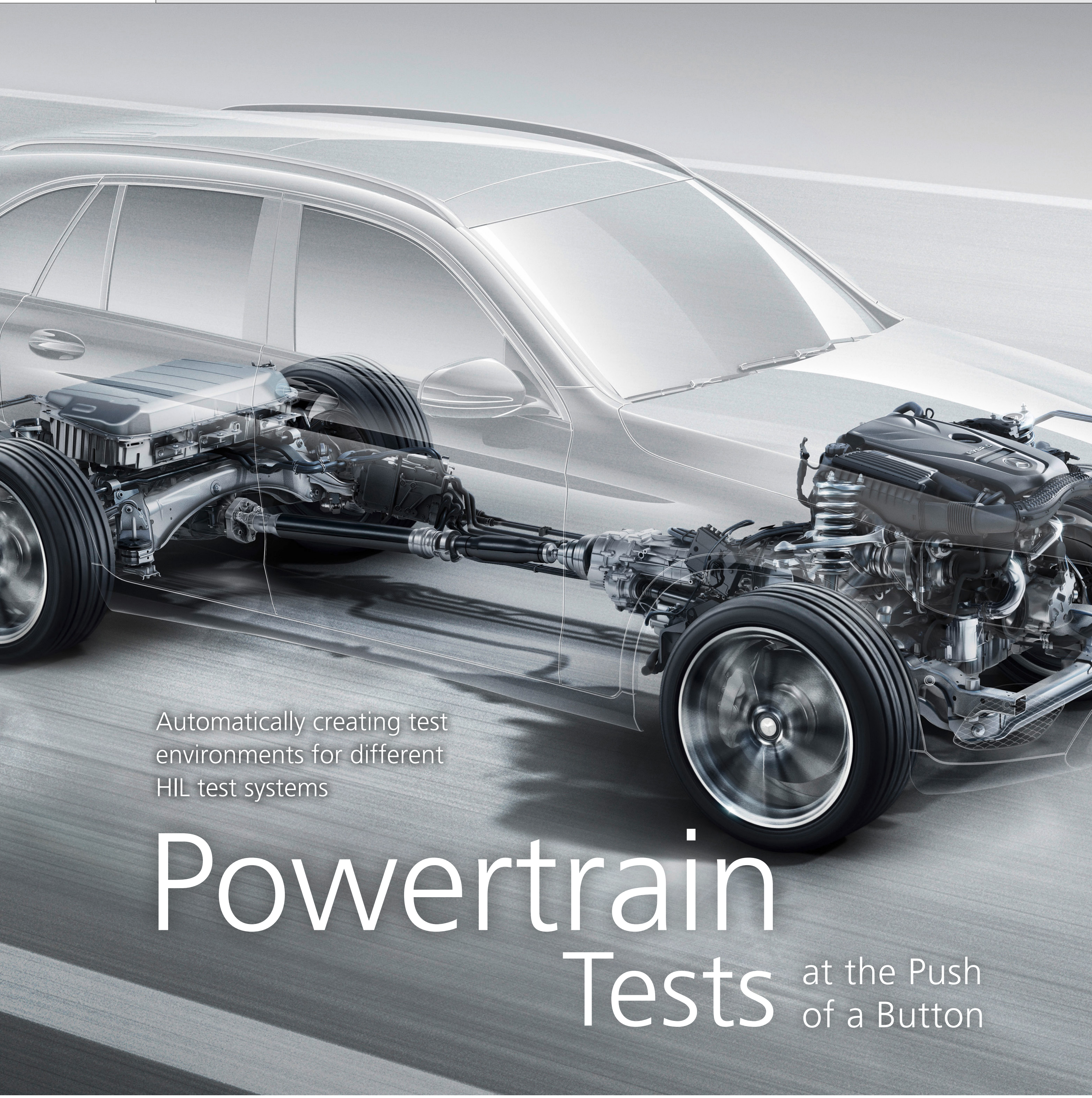
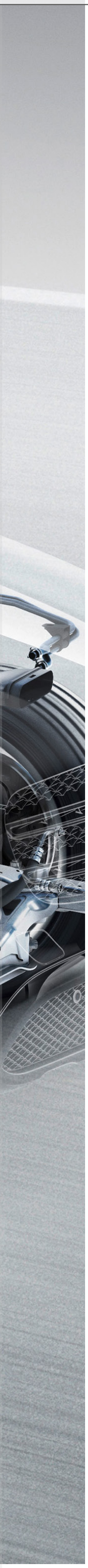


Automatically creating test environments for different HIL test systems

Powertrain Tests at the Push of a Button

To quickly and safely create model integration versions, for example, for testing new powertrains, HIL simulator farms can be equipped with workflow automation that is based on the dSPACE data management software SYNECT.



New architectural approaches in powertrain design, for example, for advanced combustion engines and hybrid drives, as well as the simultaneous increase in variants are a substantial challenge for developers and tool chain managers. To ensure high-quality powertrain systems, Daimler AG has been conducting hardware-in-the-loop (HIL) tests for system verification for some time. To be able to sufficiently reproduce and test the complex and extremely varied interaction between powertrain, complete vehicle, dynamic environment, and network architecture, extensive and highly flexible simulation environments are necessary. For this, various types of HIL simulators are used, which are all universally set up and equipped with I/O that is required for all projects. This helps to quickly adjust the specific configurations to the individual project requirements. The user team simultaneously applies dSPACE HIL systems based on peripheral high-speed (PHS) buses and dSPACE SCALEXIO HIL systems. Several engine and transmission HIL simulators are used in combination for the powertrain development in the various international locations, such as Germany, India, and China. One central data repository in a German location is accessed when developers are creating simulation models and during the build process for all simulators of the HIL farm. Because new integration versions of the environment and I/O models used in HIL tests must continuously be created in a safe and efficient manner during development and because they must take the various HIL test system configurations into account, an automated approach is indispensable. Therefore, the required builds are conveniently created in the Workflow Management (WFM) solution, which is based on the dSPACE data management software SYNECT.

Why Use Central Workflow Management?

The models used for HIL simulation are a combination of different components, which are developed as modules by various employees. For testing, the relevant components must be suitably combined. This is done by automating the build workflow. Typically, the following roles must work together:

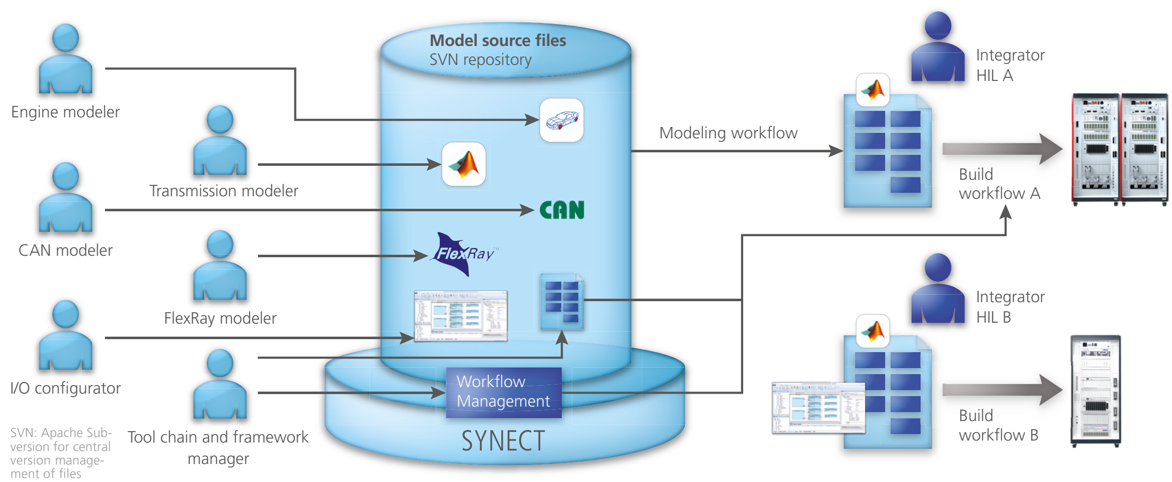
- Engine modeler
- Transmission modeler
- CAN modeler
- FlexRay modeler
- I/O configurator
- Tool chain and framework manager
- Integrator

All listed roles can work with different models, model components, and model versions, while the model sources are stored in a central data repository (in this case, Apache Subversion). To create a new integration version, the individual components must be combined to a case-dependent complete model. And the best thing about it: The SYNECT-based Workflow Management combines all data required for the build process with the help of version control files and direct data access. This, for example, includes the correct versions, parameters, and HIL simulators required for the HIL tests. WFM supports integrators in their tasks so they can quickly and automatically perform the integration using the tool – with a minimum of user interaction or without any interaction at all. There are also other benefits. Not only do all persons involved benefit from the single-source access to the models, it is also possible to automatically handle I/O and buses for PHS and SCALEXIO simulators together. Moreover, multi-builds can be implemented. These are used for automatically creating multiple executables in sequence for various HIL configurations.

Efficient Workflow

By using the SYNECT-based Workflow Management, the developers do not have to manually perform complex model combinations. >>

> The SYNECT-based Workflow Management helps users automatically model test environments for vehicle variants and supply them to dSPACE HIL systems all around the world.



The SYNECT-based workflow automation enables integrators to quickly create new integration versions of models used for HIL testing.

WFM contains workflows in which user interactions are explicitly excluded to ensure data consistency. These workflows create what is called release executables, which are used for HIL tests. They can be reproduced at any time and they let you trace the version of the underlying model source repository. This is a necessary prerequisite to directly understand how the test results were obtained. This kind of traceability is necessary to fulfill the ISO 26262 requirements for functional safety. In WFM by dSPACE, the individual workflows consist of steps. These steps are small automation steps in a specific configuration environment for MATLAB M, Python, and binary files, or for the version control system. The software provides a number of preconfigured steps. However, the users can also create them themselves. Sequencing the steps results in the specific workflow. After the steps have been defined, they can be used in multiple workflows. The execution sequence can be specified via drag & drop. Steps can result in successful completion or errors. These are then included in the results check for the entire workflow. If the execution was not successful, error routines can be run. The company defined the workflows for various roles and use cases in a WFM-based HIL project. For example, workflows for modelers are available that open the modeling environment. There are also workflows that provide the entire integration environment to integrators so that the functionality of the release executables can be analyzed and improved, if necessary. Other workflows load the model, perform the analysis, and create the build fully automatically without any user interaction – if required also including activated steps for synchronizing the work copy with the version control system (release builds). All workflows

Loïc Brouillard (left) is the project leader for transmission electronic control units on HIL simulators. Patrick Pfeil (center) is the project leader for modeling and integrating engine electronic control units on HIL simulators. Both are employed at Daimler AG in Stuttgart. Christian Schmidt (right) is a HIL group manager at the Project Center Stuttgart of dSPACE GmbH.

are available for SCALEXIO- and PHS-based simulators and they include the tool automation specific to the relevant HIL technology. The workflows are started with the help of WFM Starter. With WFM Starter, users can select the predefined elements, such as projects and variant configurations, and the workflow that is to be executed. The execution and the execution success is displayed graphically. Another important element when creating HIL executables is multi-builds. These are generated by jobs, which are centrally defined in SYNECT. These jobs can be configured with the help of a scheduler, and their execution on a client can be started by a Remote Job Starter. This way, clients can be efficiently used for remote jobs when no manual operation takes place. In addition, jobs can also be started by events. Furthermore, dedicated build machines can be used that regularly or continuously create builds from the files that are checked into the version control system.

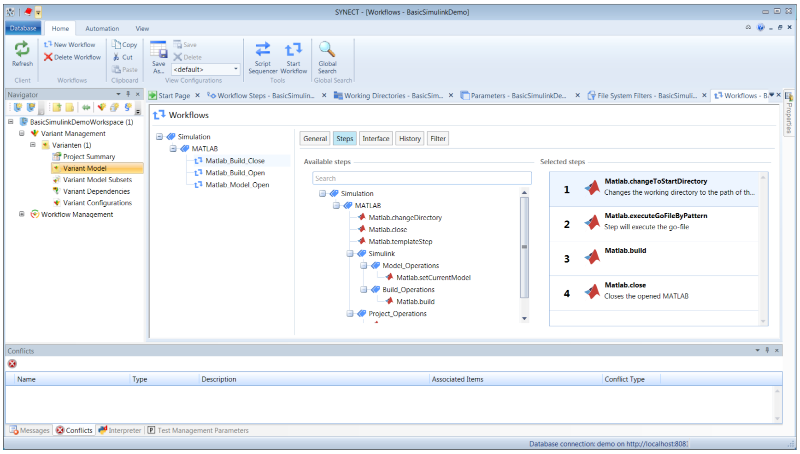
Conclusion and Outlook

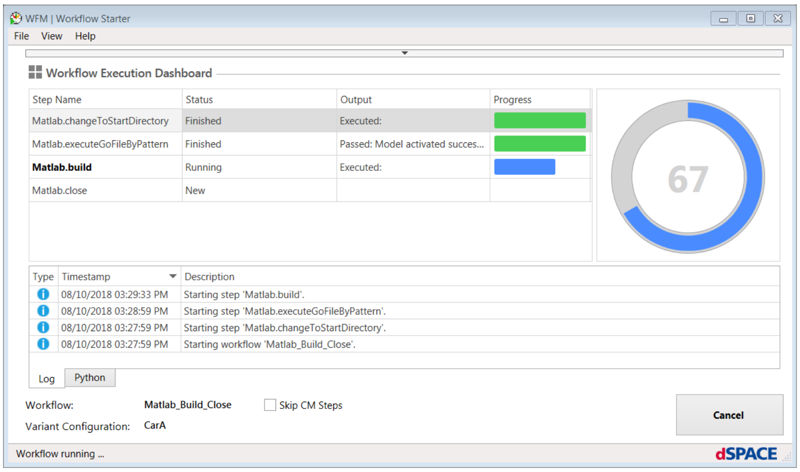
The SYNECT-based workflow automation ensures that the simulation models for the HIL-based tests in the area of powertrain development can be created automatically.

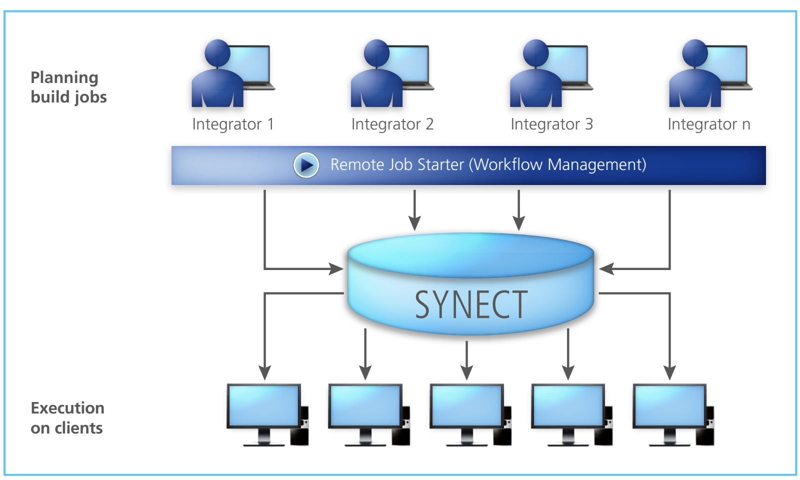
WFM makes complex tasks in model creation and build processes possible. A manual procedure would not be feasible due to the high and steadily increasing complexity.

The tool-supported versioning and the traceability during model creation help meet the requirements of ISO 26262. The plan for the future is to further optimize automation as well as the validation and verification process in combination with using new SYNECT features. The user team was and will continue to be supported by experienced dSPACE engineers.

Loïc Brouillard, Patrick Pfeil, Daimler; Christian Schmidt, dSPACE







Top: Convenient selection of workflow automation steps.
Center: Keeping an eye on things with the Workflow Execution Dashboard.
Bottom: With remote jobs defined in SYNECT, the build clients can be used without manual operation.

Overcoming bottlenecks in the test process by means of virtual validation

Bottleneck Relief

CNH Industrial has set itself the goal of optimizing the processes for testing the ECU software of its commercial vehicles and machines. This was achieved by implementing a combination of HIL tests and virtual validation. For this, CNH Industrial relies on the SCALEXIO and VEOS platforms from dSPACE.

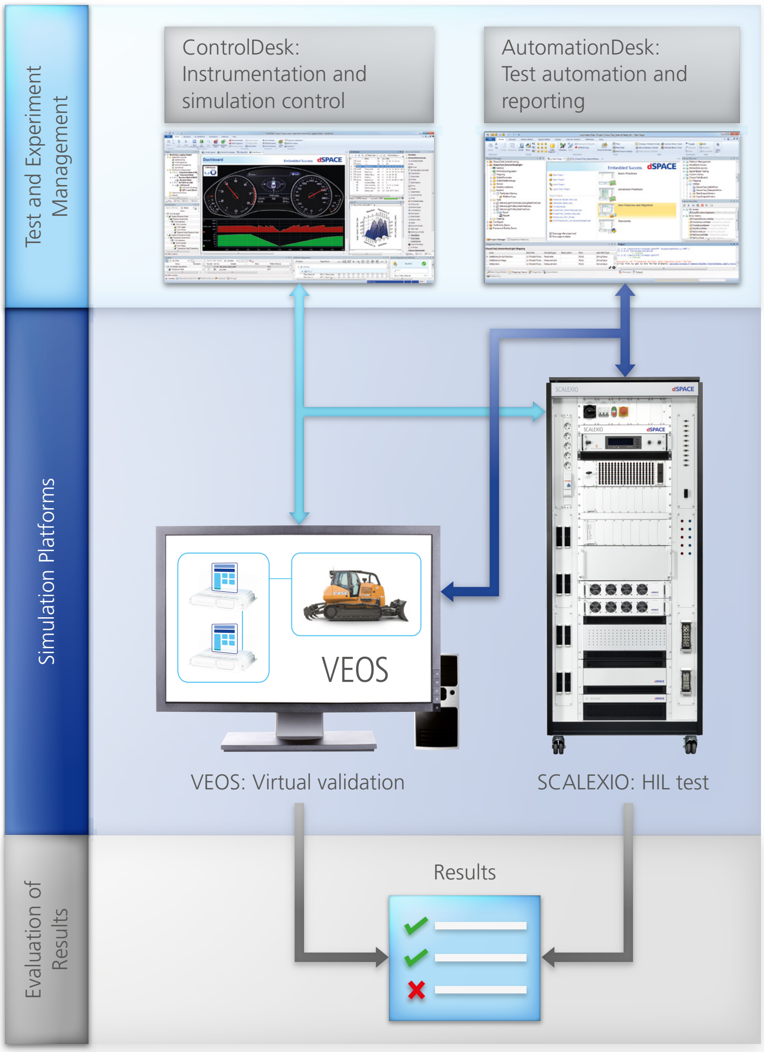
The ability to perform software tests faster and more efficiently is of utmost importance to CNH Industrial. As a designer, manufacturer, and seller of agricultural and construction equipment, trucks, commercial vehicles, buses, and specialty vehicles, precisely timing all development steps in many parallel projects is crucial for this multifaceted company. The sooner new software updates can be tested, the sooner new functions and systems can be implemented in the production line. CNH Industrial is therefore specifically focused on increasing the efficiency of its test environment. One method is to frontload selected tests to early stages of development. The Hardware-in-the-Loop (HIL) Group at CNH Industrial relies on virtual validation with software-in-the-loop (SIL) tests to implement a faster and more efficient process for testing electronic control unit (ECU) software.

Challenge: Test Efficiency

The HIL Group is responsible for testing ECU software and releasing ECUs used in tractors, combines, agricultural implements, and construction vehicles. It uses five PHS-bus-based HIL simulators and four SCALEXIO simulators from dSPACE. According to HIL System Design Engineer Pedro De La Torre, the focus of the search for an optimized test solution was to eliminate several bottlenecks that occurred during the test design and test phase. “When creating a new test project, we were not able to verify and validate the tests until we had the devices, such as the HIL simulator and physical harnesses, on site,” explains De La Torre. The tests for a particular ECU were delayed by this setup time. Another aspect concerned all tests: “If a new software version for a different vehicle came out and needed testing, we would have to wait until the current test was finished before moving on to the next one,” says De La Torre. “These restrictions posed a constant challenge to project management, highlighting the need for a more efficient process.”

Solution: Virtual Validation

To conquer these challenges, the HIL Group has found a way to optimize the entire process of software and application development: Team members accelerate the test process by performing more tests during the development phase with the help of virtual validation. This results in faster and more frequent software releases. Moreover, the HIL Group relies on the PC-based simulation platform dSPACE VEOS. The benefit: The existing HIL tests can also be reused relatively easily in VEOS. Conversely, it is also possible to reuse new tests created with VEOS on a HIL simulator. De La Torre explains the benefits: “With VEOS we can develop, debug, and verify a new test project before the HIL simulation equipment arrives. This means we can begin testing software earlier in the design process.” He adds that virtual validation also allows them to perform several tasks in parallel: By using VEOS, it is possible to work on several software releases simultaneously, instead of just one release as was the case in the past. For example, tests can be performed for the software release of one >>



Design of the tool chain for the validation of control unit software. The test platform VEOS and the HIL simulator can be used in parallel with identical test environments.

vehicle while updating and preparing tests for the software release of another vehicle. "Since virtual validation with VEOS is executed by only using software that is running on PCs, we can achieve more in a shorter time frame because tests can run in parallel," continues De La Torre. In addition, virtual validation helps reduce the test duration by testing different software features in parallel with SIL and HIL simulations.
This leaves more time for debugging the current software release and testing the next release.

Setting up Virtual Validation

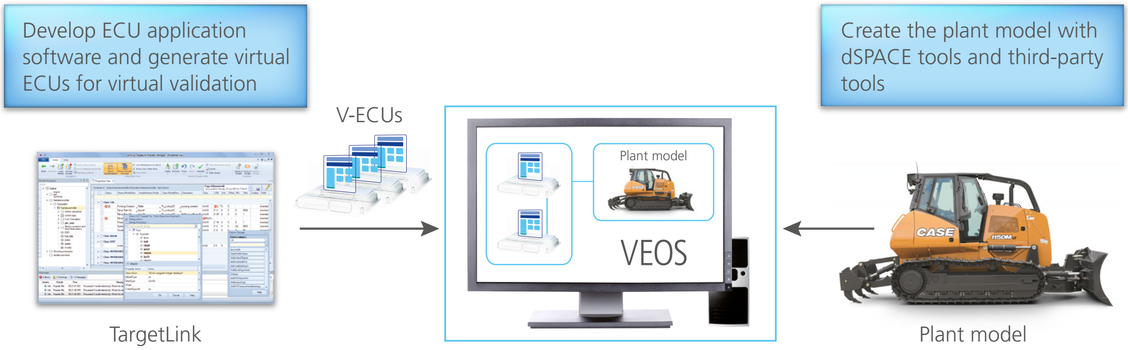
It took the HIL Group approximately seven months to use VEOS productively. During this time, four months were invested in evaluating VEOS and learning its capabilities and functions. The remaining three months were necessary to adapt the interfaces of the HIL plant models and to develop a procedure for generating virtual ECUs so that controller and plant models could be used both with the HIL simulators and with VEOS. With dSPACE ControlDesk and AutomationDesk, the HIL Group was able to make minor changes to the tests so that they work with both virtual and HIL platforms. With additional minor modifications, it was possible to reuse important workflows and working techniques from the HIL test with VEOS.

Creating Virtual ECUs

An important prerequisite for comprehensive virtual validation is the use of virtual ECUs (V-ECUs). They contain all software components and functions of the final control unit. To create the V-ECUs, CNH Industrial uses the TargetLink production code generator. "TargetLink plays a major role in our software development process. With VEOS simulation testing, TargetLink has the added role of generating the V-ECUs used in virtual validation. This provides us with seamless integration with VEOS and a consistent build process. This also minimizes the amount of changes needed to be done to software on the part of the HIL team," explains De La Torre. To solve possible software problems, the HIL Group works closely with the software developers. This ensures that the V-ECUs generated for VEOS contain all functionalities that can also be found in the ECU software. Part of the collaboration is also a comparison of the test results of the V-ECUs and the HIL simulation tests to determine whether their behavior matches.

Listing and Comparing Results

Virtual validation is being used in a current project for testing the CASE Wheel Loader series. From this, typical application scenarios for the different platforms can be derived: While pure function tests run largely in VEOS, tests of time-dependent functions and physical and electrical properties as well as stress tests are performed on an HIL system. Finally, a complete test of the software is performed with the HIL simulator



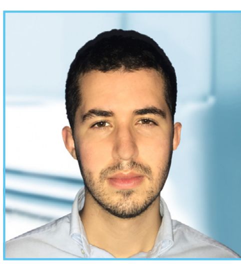
The TargetLink production code generator supports generating virtual ECUs for virtual validation with VEOS.

and then compared with the test results from VEOS. This makes it possible to determine whether the VEOS tests can be further expanded and refined, thus maximizing the test coverage with VEOS. De La Torre summarizes the results as follows: "This helps us make better use of our HIL time, because it reduces a major testing bottleneck, giving us flexibility on how we approach testing and speeding up the testing process. The less software functionalities exclusively covered by HIL simulation the better, since we will then be able to run more tests in parallel with VEOS. In an initial project, VEOS reduced our test execution time by 22% when compared to normal HIL execution."

Conclusion

The earlier errors are found, the more cost-effective it is to correct them. And the more tests run in parallel, the shorter the test phases. The frontloading and parallelization of tests can be integrated in the development process with the help of VEOS. "In the future, we will develop our ECU software faster, because VEOS will make our software development process more efficient in every respect," De La Torre concluded. ■

Courtesy of CNH Industrial.



"In the future, we will develop our ECU software faster, because VEOS will make our software development process more efficient in every respect."

Pedro De La Torre, CNH Industrial

Examples of agricultural machines from CNH Industrial in action.

Real Virtuality

Automatically creating test tracks and realistic traffic scenarios based on vehicle measurements

How do you test vehicles on tracks that no test driver has ever driven before? The ZF technology group uses a virtual process based on map data and vehicle measurements to test vehicle functions during development. The resulting virtual world is realistically simulated using the ASM tool suite.

To meet the mobility requirements of the future, vehicles must act predictively and be networked with their environment. Assistance functions support the driver while driving, and autonomous functions are set to assume all driving tasks in the future. This is why the real road, along with its multitude of variables, is the perfect place to conduct customer-relevant functional testing. However, the random influences that occur in reality make it almost impossible to perform two road tests under exactly the same conditions. To reproduce the variety of real influences for testing the active powertrains, ZF transfers relevant in-vehicle measurements to virtual scenarios. This makes it possible to generate driving profiles from reference routes. However, if, for example, driving behavior on a certain route is to be analyzed, the actual route would first have to be measured with the right measuring equipment. This can involve a great deal of time and expense, especially if the route is not in the immediate vicinity. As a result, the process also has to generate scenarios using data from digital maps. These scenarios must include not only the actual road with the corresponding altitude information, but also the surrounding traffic, other road users such as pedestrians or cyclists, as well as obstacles, signs, traffic lights, etc.

The Virtual Track

Routes can be generated using high-precision vehicle measurements or smartphone recordings. It is also possible to define the test track by setting only a few waypoints on a map or simply by entering the start and end points. These days, positioning is usually performed with the Global Navigation Satellite System (GNSS). Since GNSS measurements are often noisy (shading, attenuation), it is necessary to subsequently optimize the geographical coordinates. The recorded coordinates are compared with the data on a detailed map by means of map matching, and the suitable road is selected from the map. ZF uses tools of the Virtual Measurement Campaign (VMC®) developed by the Fraunhofer Institute for Industrial Mathematics. VMC makes it possible to perform map matching and directly define a route. The map data is imported using a dSPACE converter, which transforms the data into road segments for the Automotive Simulation Model (ASM) tool suite from dSPACE. More detailed information on legal speed limits and the positions of traffic lights, etc. can be automatically added to the route on the basis of data imported from OpenStreetMaps (OSM), for example. Subsequently, reference data, such as the transverse gradient of the road, can be used to further optimize vehicle measurements. Different driver types can be used to generate different driving modes. It is also possible to differentiate between open roads as well as medium and high traffic density. This makes it easy to influence the driving behavior.

Various Test Scenarios

The generated scenarios are the basis for vehicle dynamics simulation with ASM. The scenarios for the virtual test drives are created from variations to the specifications of the virtual environment and the other road users. The influences and variations become transparent, making it possible to look closely at each individual effect separately. The virtual road or virtual road network is available in ModelDesk, which is the parameterization soft-

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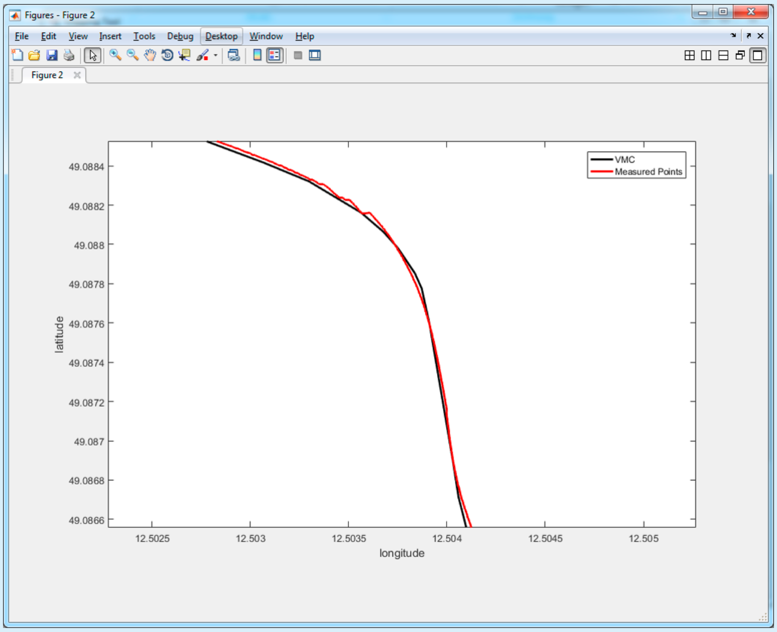


Left: The exact coordinates (blue) of a test track are determined from the noisy measured values (orange) by means of map matching. Center: For comparison, the route as displayed in OpenStreetMap. (Contains information from OpenStreetMap (openstreetmap.de), which is available here under the Open Database License (ODbL) opendatacommons.org/licenses/odbl/.)

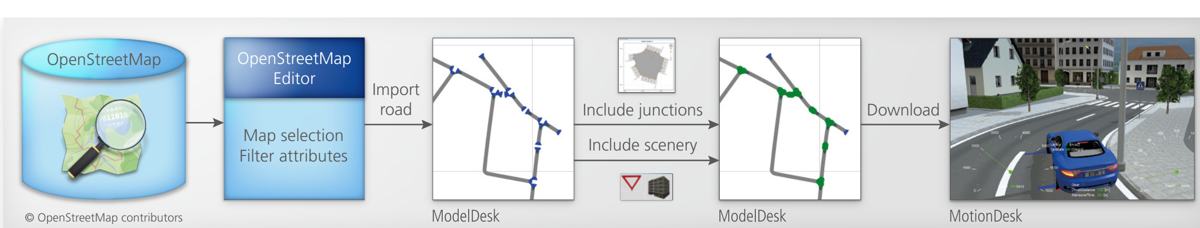
> "We rely on the ASM tool suite to conduct highly accurate experiment- and simulation-based analyses and evaluations of the shifting behavior and efficiency of transmissions."
>
> *Oliver Maschmann, ZF*

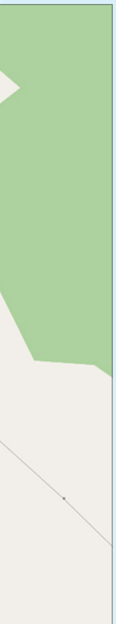
ware for ASM, and can be previewed there. ModelDesk provides the Scenario Editor for defining the driving maneuvers for the vehicle under test and, optionally, the surrounding traffic. For driving on a reference route, it is sufficient to define the reference speed for the route. This can be done directly in ModelDesk. If the surrounding traffic also has to be factored in, the start and end points of the vehicle under test (ego-vehicle) have to be defined as well as trajectories for the fellow vehicles that also perform defined maneuvers in the ego-vehicle's environment.

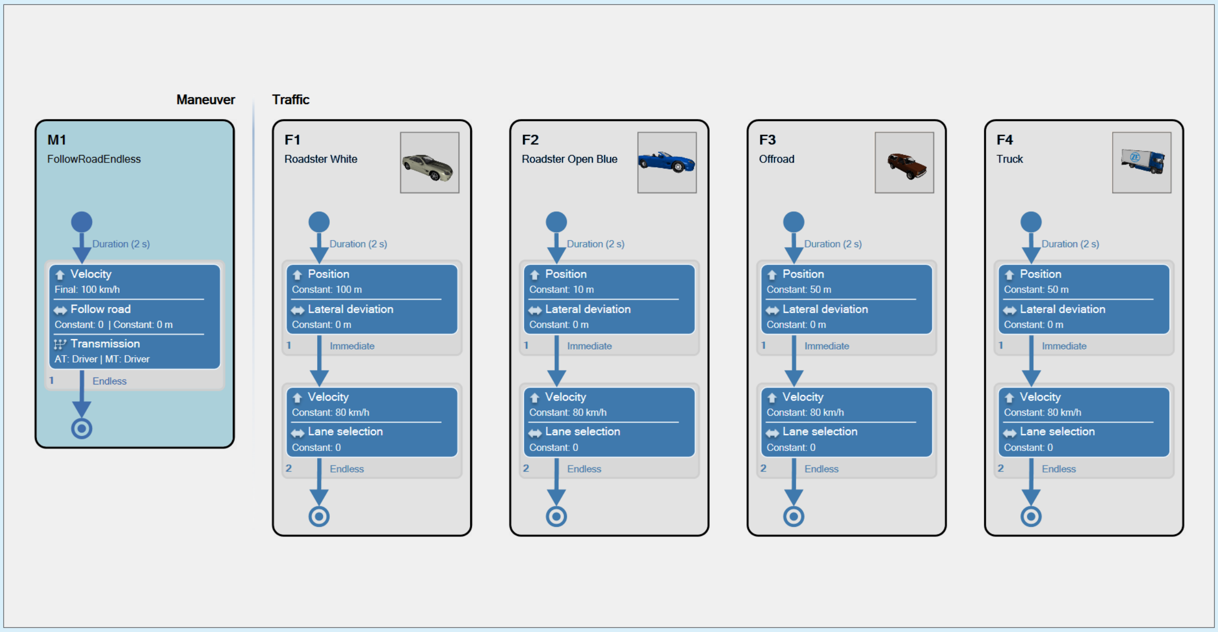
On the Test Bench

The article "Virtual Torque" (dSPACE Magazine 1/2018, page 36) previously described how ModelDesk can be used to integrate ZF-internal models into the simulation of the complete vehicle. Combining highly accurate models for the powertrain and versatile scenarios for the environment with the vehicle dynamics simulation enables realistic analyses and evaluations so that engineers can examine the effects that have occurred during the test drives. In addition, tests on the test bench can be performed using more complex measurement data, which achieves more meaningful and reliable results. It therefore makes sense to work with virtual driving

Workflow for generating the road from OpenStreetMap data.







The Scenario Editor can be used to define the trajectories of the vehicle under test and, optionally, of the surrounding traffic.

> "Performing a comprehensive, realistic simulation of the powertrain is easy because ASM lets us use both vehicle measurements and synthetically generated surrounding traffic."
>
> *Oliver Maschmann, ZF*

scenarios as early as possible in the development process.

Evaluation and Next Steps

The process and the tool chain offer sufficient flexibility to process GNSS coordinates recorded by either a tracking app on a smartphone or high-precision GNSS data loggers. Tracking apps, in particular, are an efficient method for quickly analyzing and verifying problem reports from the field test. This opens up new, faster, and cheaper methods for analyzing and correcting potential errors. These analyses can also be performed on the PC-based simulation platform VEOS. Other dSPACE tools, such as ControlDesk and AutomationDesk, are used to perform the tests and evaluate the data. Virtual tests and analysis tools make PC-based simulation the tool of choice when it comes to analyzing effects and optimizing algorithms. This requires highly accurate data and models. Both can be achieved with map matching and the ASM tool suite. Compared to driving tests, this has decisive advantages: Virtual tests are reproducible, fast, and cost-effective. It is also very easy to include other variables in an analysis, which in road tests would only be possible with additional measuring equipment. In addition, the simulation can also be used as a basis for load tests on mechatronic test benches. These test benches are already in operation at ZF. A new generation of test benches is currently being set up. It will be able to fully exploit the potential of the described tool chain. By replacing the VEOS simulation platform with a dSPACE SCALEXIO system, data, models and tools can be easily reused on the test bench. Tool chain validation is advanced jointly by ZF and dSPACE. This will open up new possibilities for further development, e.g., driver behavior on roads where the driver has limited visibility due to bends in the road, for example. ■

Oliver Maschmann, ZF

Oliver Maschmann
Oliver Maschmann is responsible for setting up highly dynamic test benches at ZF in Friedrichshafen, Germany.

Highly flexible HIL simulators can fulfil the demands of testing a variety of agricultural vehicles

Testing On Demand

Electronics and software have become core contributors to innovations for today's agricultural vehicles. With the growing scope and amount of testing, developers nowadays face great challenges when developing software. Japanese agricultural machinery manufacturer YANMAR tackled these challenges with a comprehensive HIL simulation based on SCALEXIO and other dSPACE products.

Source: © YANMAR CO., LTD.

Source: © YANMAR CO., LTD.

Source: © YANMAR CO., LTD.

Food demand is increasing due to a growing population. However, arable land is limited, and farming populations are in decline. Nowadays, improving land and labor productivity has become a pressing challenge for farmers. The Japanese manufacturer YANMAR contributes to solving the farmer's challenges with their company products, such as tractors, harvesters, and planters. The agricultural vehicles with high efficiency and functionality help farmers shorten labor time, minimize harvesting loss, and increase yield.

High-Performance and Easy-to-Use Harvesters

Rice harvesters have combined functions for reaping, threshing, and grain separation. They are also optimized for rice farming to perform high-speed and low-loss harvesting. Despite the functional complexity, YANMAR rice harvesters are easy to use and can be operated without stress thanks to a multitude of features for drivers (figure 1). The steer-by-wire system is one of the features that gives the driver the intuitive feeling of a passenger car. Depending on how far the driver rotates the steering wheel, the vehicle performs smooth movements, ranging from a gentle turn to a spin turn by adjusting the direction of movement and the speed for each of the two crawler tracks. It allows the vehicle to run perfectly along the field lane. Another example is the automatic chassis. It works to keep the vehicle body horizontal and deliver maximum performance during reaping and grain separation, even if the vehicle chassis tilts on a soft paddy field. Automatic adjustment of grain separation is a feature of the newest model. A chaff sieve is a device that separates rice grains from straw chaff. Harvest loss changes depending on the sieve aperture and the reaping speed (vehicle speed) during the operation. A sensor detects the amount of loss at the end of the chaff sieve and in return the system automatically adjusts both parameters to minimize the harvest loss. A monitor helps the driver observe how the harvest loss decreases after the adjustment.

Challenges for Software Developers

Electronics and software have become the core contributors to developing the agricultural vehicles with these impressive features, and now the software developers at YANMAR play important roles in introducing innovations. Comprehensive testing and validation therefore involve a growing scope and amount of work, while the developers had to overcome multiple challenges at once: First, they had to eliminate gross errors even before a vehicle was used for field tests, because, for some types of vehicles, the real test drive can be performed only for a limited period of time. For example, if any defects were found during the test drive of a harvester, the rework for the software revision would raise the risk of losing the opportunity of retesting during the harvest season.

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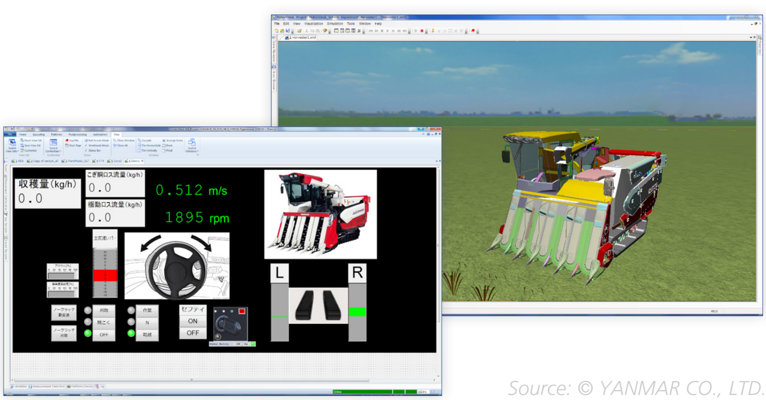
Source: © YANMAR CO., LTD.

Figure 1: A YANMAR rice harvester has many features to benefit farmers, such as a Steer-by-Wire System for low-stress and smooth maneuver (top) and Automatic Chassis to keep the body horizontal (center). Automatic Adjustment of Grain Separation is the feature of the company's newest model: the rice grains threshed by a drum are separated through a chaff sieve adjusted to minimize harvesting loss (bottom).

Figure 2: YANMAR uses ControlDesk (lower left) to create an intuitive user interface for HIL simulation. MotionDesk (upper right) provides a realistic visualization of the vehicle motion that results from the user input.



Source: © YANMAR CO., LTD.

Second, they had to test a vehicle in complex working conditions, such as different conditions of paddy fields or various types of rice plants. It would be time-consuming and expensive to recreate these conditions for real test drives with the real machines.

Quick Setup of a HIL Simulator

To meet these requirements, YANMAR opted for a hardware-in-the-loop (HIL) system with dSPACE SCALEXIO. The HIL simulator enables them to test all the functions of electronic control units (ECUs) without a real machine and to cover a wide range of vehicle operations in realistic working conditions. YANMAR introduced the HIL systems in two steps: In the first step, the company commissioned a simulation environment for a tractor in 2015. In this setup, a central processor rack was complemented by three I/O racks for the engine and vehicle controls as well as the display instruments. Functionalities for the evaluation of the harvester followed in 2016, and two I/O racks were also added. By simply adding I/O boards to the I/O racks, the system finally covers the physical aspects for all ECUs, bus systems, and electric loads of the vehicles.

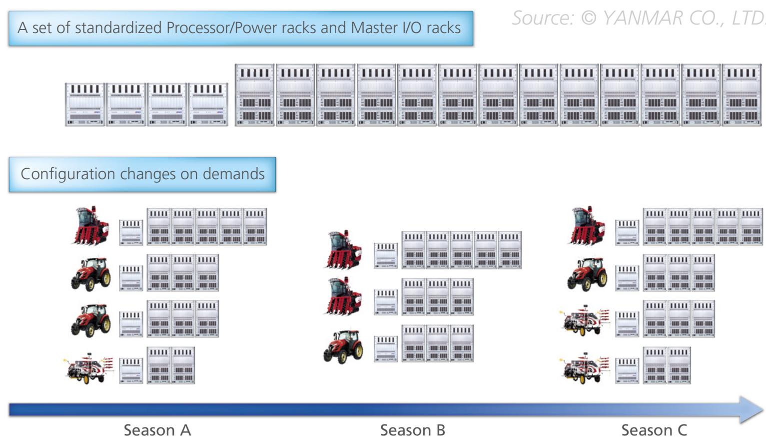
Sophisticated Software Tools

On the virtual model level, while YANMAR relies in part on their own libraries of vehicles and environment models, the company uses diesel engine and exhaust libraries of the dSPACE Automotive Simulation Models (ASM) to simulate the diesel engines and the exhaust gas aftertreatment. The libraries are perfectly adjusted to the YANMAR models. The models can be distributed across multiple processor cores for the simulation to optimize computation time. To monitor and control the HIL simulation, YANMAR uses ControlDesk and MotionDesk from dSPACE. While ControlDesk gives the test engineers customized instru-

ments and an intuitive user interface, MotionDesk lets them realistically visualize all movements of the simulated agricultural vehicle in a three-dimensional environment (figure 2). To reduce work efforts even further, the HIL tests can also be automated to a great extent. This is done with dSPACE AutomationDesk. YANMAR set up a test automation framework with the assistance of dSPACE. It allows them to implement new test cases quickly, where they have to do nothing more than updating the test parameters, such as the given input and expected output signals.

Highly Flexible Multi-Vehicle and Multi-Domain Systems

In the meantime, YANMAR has made the modular SCALEXIO HIL system even more flexible. Instead of using I/O racks that are tailored to certain functional aspects, such as an engine or vehicle components, YANMAR uses standardized 'Master I/O Racks', each of which has the exact same set of hardware interfaces. Various combinations of the Master I/O Racks can cover the entire range of YANMAR agricultural vehicles. Vehicles to be tested are different from moment to moment depending on plans for new product launches. If a sufficient number of Master I/O Racks is available, the developers can use them to set up precisely the HIL system required for the task at hand (figure 3).



Source: © YANMAR CO., LTD.

Figure 3: While YANMAR initially used task-specific I/O racks for HIL simulation, they now exclusively use identical Master I/O Racks. Each set of functions of an agricultural vehicle requires a certain number of the Master I/O Racks.

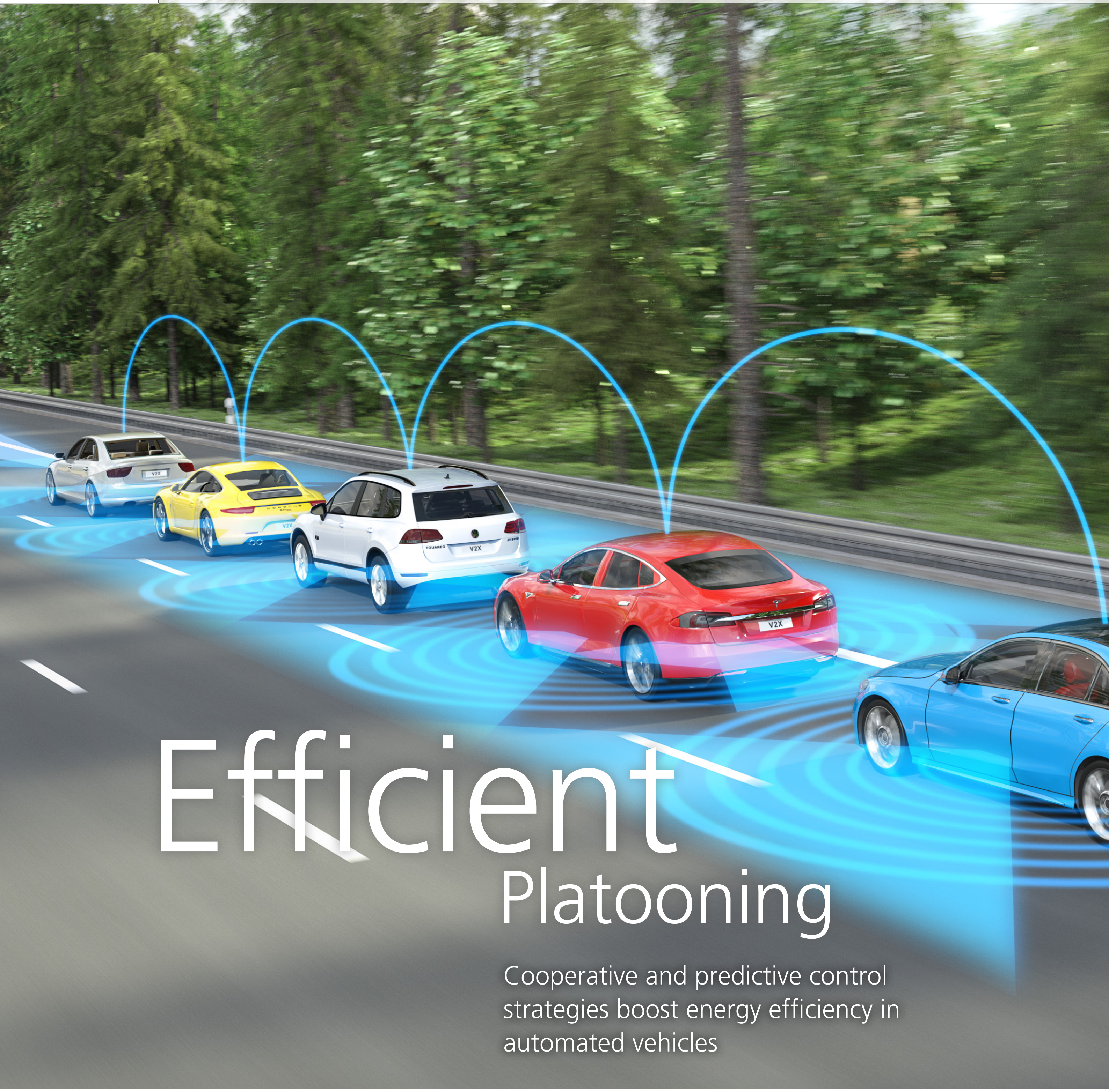
Benefits and Outlook

The flexible and extensible dSPACE SCALEXIO system contributed to the quick setup of the HIL simulator for YANMAR. A mere six months passed from ordering to the first commissioning in late 2015. The HIL simulation and the test automation revealed hidden software defects without the real machines and reduced the workload of testing. It allows the developers to focus more on the analysis of errors. With the successful introduction for the tractor and the harvester as a start, they set up the HIL system for a variety of agricultural vehicles. The more flexible Master I/O Racks enable YANMAR developers to set up HIL systems by themselves. The racks are also used to test more innovative functions, such as tractors that can drive autonomously. After all, thanks to efficient simulation solutions this is just one more area in which agricultural vehicles are on par with modern road vehicles. ■

With the kind permission of YANMAR CO., LTD., Japan

"The flexible, highly scalable SCALEXIO system and the sophisticated software tools from dSPACE quickly gave us the great benefits of HIL simulation."

Isao Takagawa, PhD, a manager of the Software Group in Development Planning Division, Electronic Control Development Division, YANMAR CO., LTD., Japan



Efficient Platooning

Cooperative and predictive control strategies boost energy efficiency in automated vehicles

Researchers from academia and industry are collaborating on a project that aims to improve the energy efficiency of electrified vehicles, thus enabling them to reduce energy consumption and extend range distances. The success of the project hinges on innovative connectivity and optimized automation. Technologies including V2X, platooning, and eco-routing are now being developed and tested thoroughly by the project team. MicroAutoBox and ControlDesk play key roles in this research.

Students and Faculty at Michigan Technological University's Advanced Power Systems Lab (APS Labs) are deeply involved in the NEXTCAR project, alongside General Motors (GM), as they strive to boost vehicle energy efficiency through driverless technologies. NEXTCAR stands for Next-Generation Energy Technologies for Connected and Autonomous On-Road Vehicles – an initiative that is funded through the Advanced Research Projects Agency-Energy (ARPA-E) of the U.S. Department of Energy. ARPA-E currently supports ten innovative NEXTCAR projects which aim to reduce the energy consumption of individual production vehicles by 20 percent. In 2017, project administrators at ARPA-E selected Michigan Tech to conduct a three-year project known as Connected and Automated Control for Vehicle Dynamics and Power Train Operation on a Light-Duty Multi-Mode Hybrid Electric Vehicle. Together with GM, the university has been developing concepts that will enable the intelligent operation of connected electrified vehicle fleets while reducing overall energy consumption. To achieve this goal, researchers are employing the very latest onboard sensors along with vehicle connectivity technologies such as vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-everything (V2X).

Developing an Orchestrated Vehicle Fleet

"The purpose of the project is to use upcoming technologies, such as automated vehicles, V2I, V2V, and sensors, to improve energy consumption on modern vehicles," says Chris Morgan, Operations Manager at Michigan Tech. Morgan takes it one step further: "How can we make an automated car drive efficiently and perhaps even more efficiently than a trained driver? That is the focus of our project." To demonstrate how automated vehicles can operate more efficiently and benefit from reduced energy consumption and emissions, the project team has equipped a fleet of eight Chevrolet Volts with sensors and controls to enable functions for automated propulsion, as well as advanced connectivity to support communication among the vehicles. The project team has also set up a mobile laboratory that can travel with the fleet, serving as a control center and vehicle-to-cloud communication hub.

Energy-Saving Concepts

The fleet and the mobile lab are equipped with solutions and special devices that help the project team perform a number of research tasks:

- Development of eco-routing algorithms for finding the most energy-efficient routes
- EAD (eco-approach and departure) at traffic lights for better speed and trajectory planning
- Platooning (cooperative convoy-style driving) involving several vehicles in conjunction with speed harmonization and cooperative adaptive cruise control

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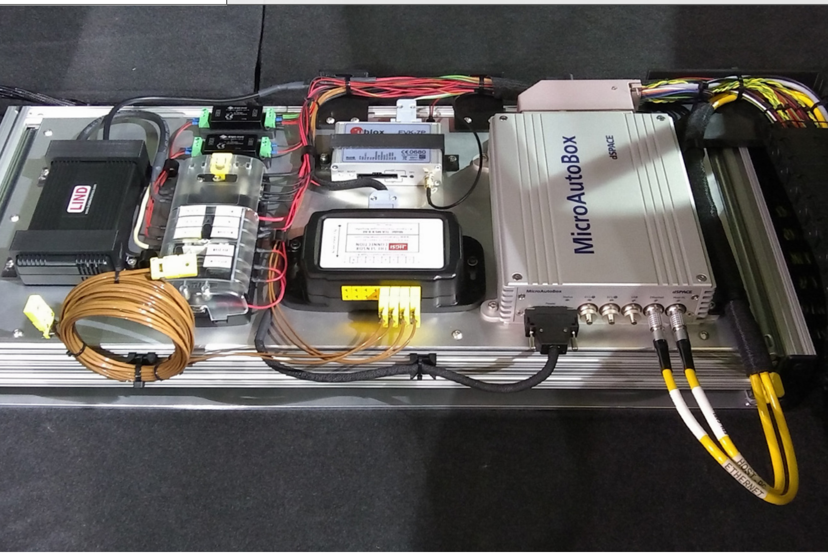
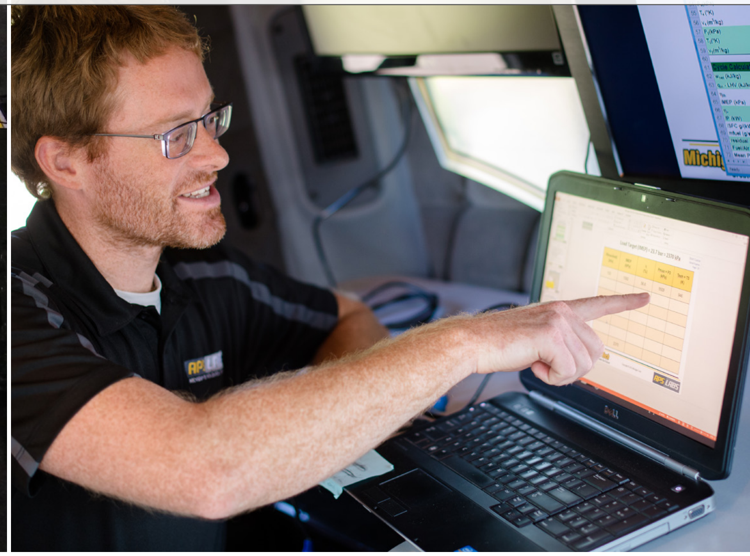
A fleet of Chevrolet Volt vehicles and a mobile laboratory have been deployed to gather data and discover ways to minimize energy consumption.



The dSPACE MicroAutoBox with additional electronic modules installed in the trunk of Chevrolet Volt.



Christopher Morgan shows data collection results from the project vehicles in the Michigan Tech Mobile Lab.

The Sensors Used in Fleet Vehicles

Lidar – Measures distances between vehicles and objects
Radar – Manages adaptive speed control and collision warning
Video cameras – Record driving and traffic behavior
GNSS (global navigation satellite system) – Provides vehicle position data
V2X – Enables cooperative driving
Anemometer – Measures wind speed and aerodynamic drag

- Powertrain energy management to reduce energy consumption
- Model-predictive control algorithms for optimal performance strategies

Platooning is one of the key focal points of the project. The research team plans to analyze specific data sets to determine the impact of platooning on aerodynamic drag, energy consumption, and vehicle emissions. "The major goal of platooning is to reduce fuel consumption over any particular drive cycle through the use of shared aerodynamic loads between vehicles," says Morgan. The project team has developed a unique propulsion control architecture for its vehicle fleet to test and evaluate various energy-saving concepts. The vehicle propulsion system includes several different operating modes, such as all-electric (EV) and hybrid-electric (HEV). The vehicle fleet is driven and monitored at various geographical locations, thus enabling the team to collect data and information from all kinds of different scenarios. They will monitor factors such as traffic conditions and ambient temperatures. "We are performing many different tests to validate and confirm our concept of improved driver and propulsion system behavior leading to dramatic increases in fuel efficiency," says Morgan.

Advanced Prototyping and Analysis Platform

Each vehicle is equipped with a test platform that collects vehicle data, manages control strategies, and supports vehicle communication. Data collection and analysis is performed by a configuration of electronic devices that includes a dSPACE MicroAutoBox. For modeling predictive control algorithms, the research team relies on the dSPACE ControlDesk experiment software. "MicroAutoBox has worked very well for our cooperative connected vehicle communication application," says Morgan. "This compact but powerful solution has enabled us to successfully implement predictive algorithms in our vehicles and establish stable communication." The test platform was installed by

"MicroAutoBox has worked very well for our cooperative connected vehicle communication application. This compact but powerful solution has enabled us to successfully implement predictive algorithms in our vehicles and establish stable communication."

Christopher Morgan, Operations Manager, Michigan Technological University

Result analysis and calibration can be performed right in the vehicle during test drives.

Christopher Morgan and Dr. Bo Chen meet to discuss model predictive control for the cloud computing center.

Pilot Systems, a Michigan-based technology company specializing in mobi-lity-related services and products. Pilot Systems provides Michigan Tech and GM with a number of services, for example, the identification of program requirements along with the installation and calibration of MicroAutoBox, lidar sensors, and related electronics in the vehicle fleet – and much more.

A More Efficient Autonomous Driving Experience

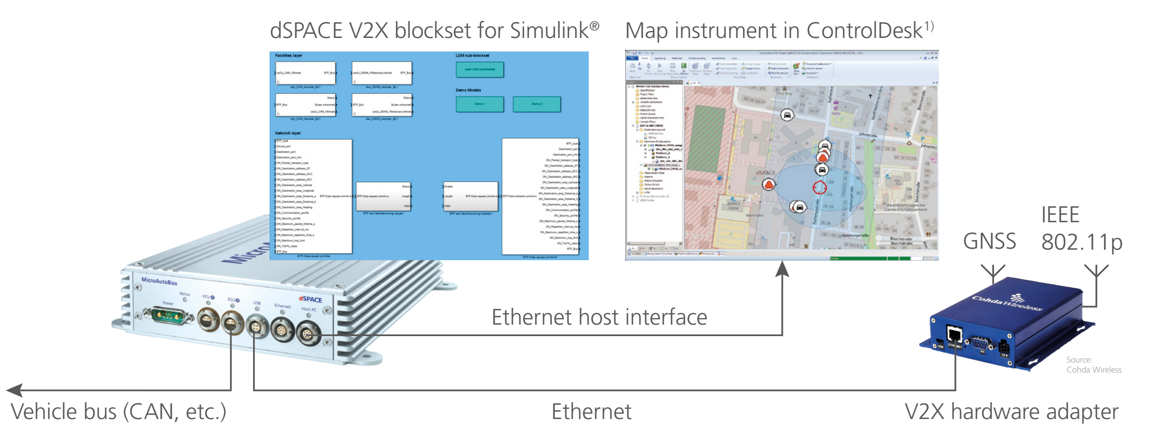
Preliminary test findings indicate that cooperative and predictive driving concepts can indeed reduce energy consumption by 20% while also increasing the range of electric vehicles by 6%. The NEXTCAR project is scheduled for completion in the spring of 2020. Data, optimization, and controls developed in the project will serve as the basis for algorithms that GM can use in future series production vehicles. ■

Courtesy of Michigan Technological University and General Motors

This video provides more insights into the project. www.dspace.com/go/dMag_20191_MTU

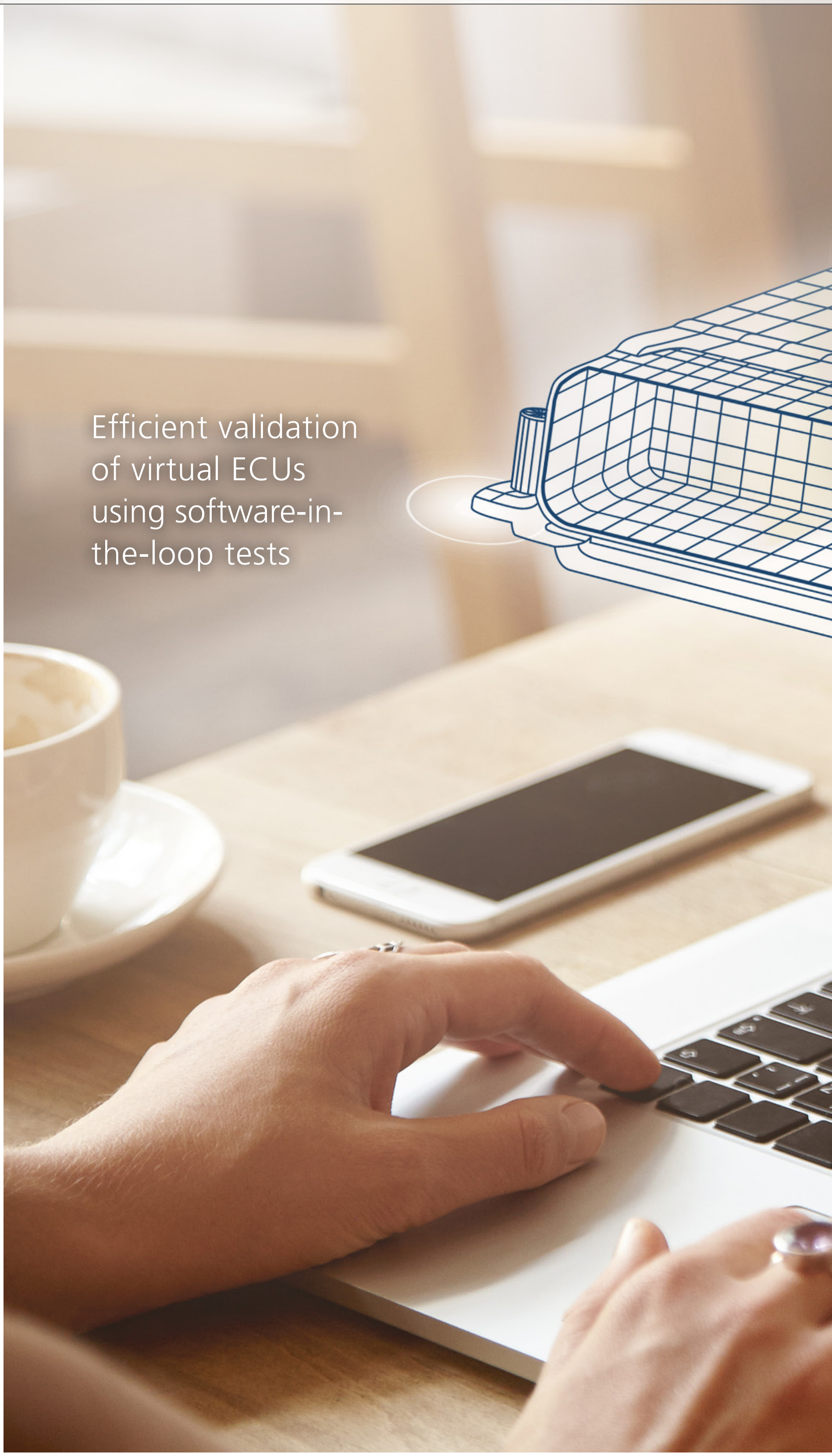
dSPACE V2X Solution

The V2X Solution from dSPACE gives users easy access to V2X communication from Simulink® and enables graphical analysis of V2X-specific data in ControlDesk. Users can focus entirely on developing and testing V2X applications without having to implement specific communication protocols and software layers. For more information, go to www.dspace.com/go/dMag_20191_V2X.



1) Contains information from Open Street Map (openstreetmap.de) which is made available here under the Open Database License (ODbL) opendatacommons.org/licenses/odbl/.

Efficient validation of virtual ECUs using software-in-the-loop tests



To frontload tests for ECU functions and complete them as early as possible in the development process, new test strategies are required. Volkswagen (VW) has therefore decided to use software-in-the-loop (SIL) tests as an addition to the existing hardware-in-the-loop (HIL) tests. This requires virtual ECUs (V-ECUs) that are used at an early stage in place of hardware ECUs for realistic testing. An efficient approach was needed to create and simulate V-ECUs based on existing development artifacts. It had to be generic enough to be suitable for ECUs of different domains and for different vehicle types – from engine control units for internal combustion engines to high-voltage charge management for electric vehicles.

Merging Different Source Formats

Virtual ECUs are based on the same development data as the final ECU: ECU function code and an XML description file for the software architecture. This information is generally distributed across several development departments. Therefore, the first challenge was to identify all required files. Another challenge was to use code that was not based on AUTOSAR as the basis for virtual ECUs, because the software components of various ECUs were only partially developed according to the AUTOSAR standard.

Generating Virtual ECUs

VW chose the dSPACE SystemDesk architecture tool to efficiently create the V-ECUs. With SystemDesk, ECU description files can be imported, the files can be used to build AUTOSAR-compliant architectures, and the architectures can then be prepared for the existing function code. For this purpose, a software component (SWC) is first generated from the imported description file for each function. The code related to the function (C code or object code) serves as the implementation basis for the SWC. To use the non-AUTOSAR-based code, the functions are packed into AUTOSAR elements: For example, function calls and their timing in an SWC are defined in an internal behavior. This encapsulates the implementation and thus the references to the code. Afterwards, the SWCs are connected to an ECU software architecture according to the description file. The last step is to create the

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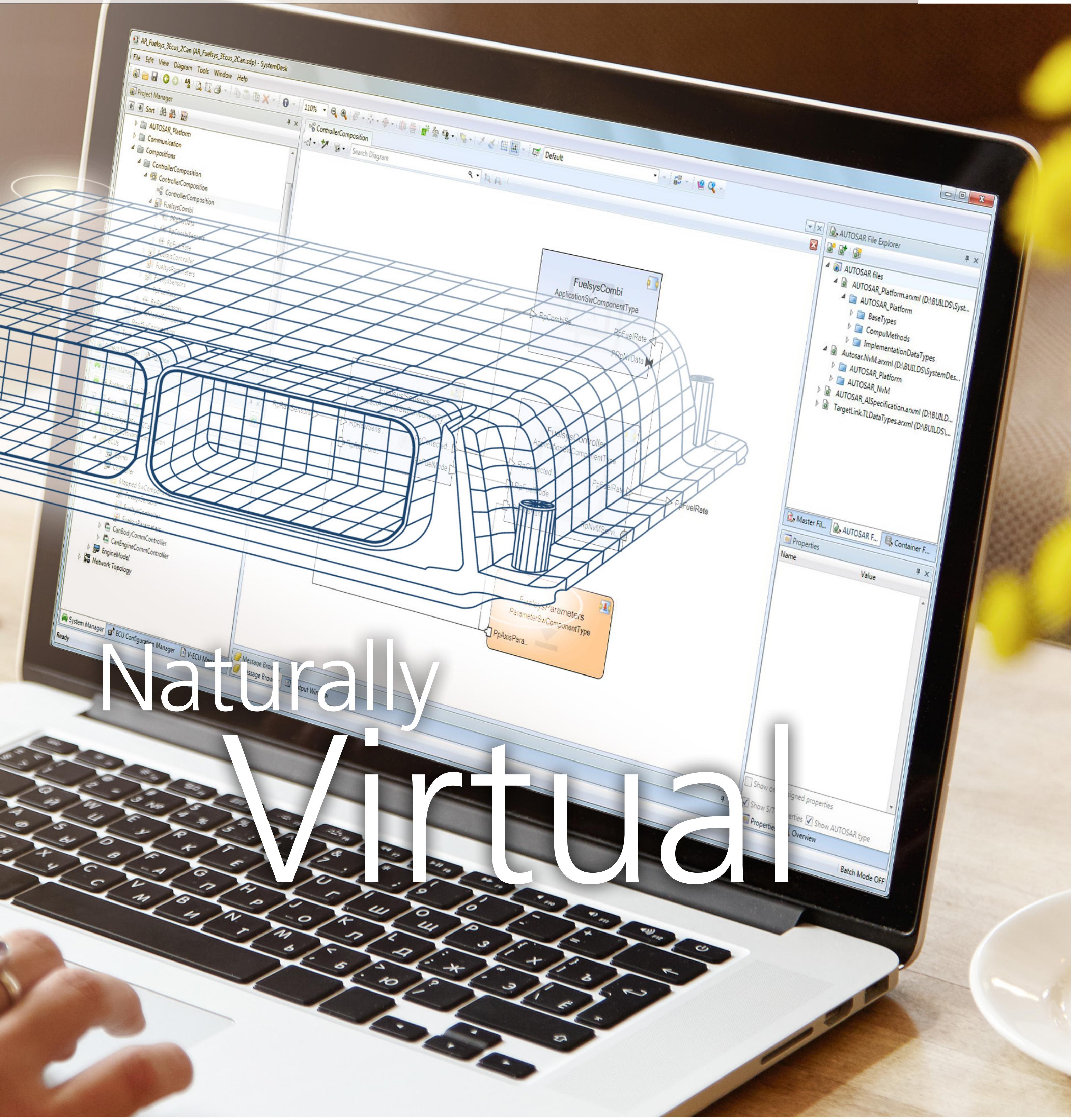

Naturally Virtual

Testing new functions as soon as they become available – a task that requires flexibility and the frontloading of tests. For this purpose, Volkswagen relies on automatically generated virtual ECUs. The dSPACE tools SystemDesk and VEOS help developers generate and simulate the software.

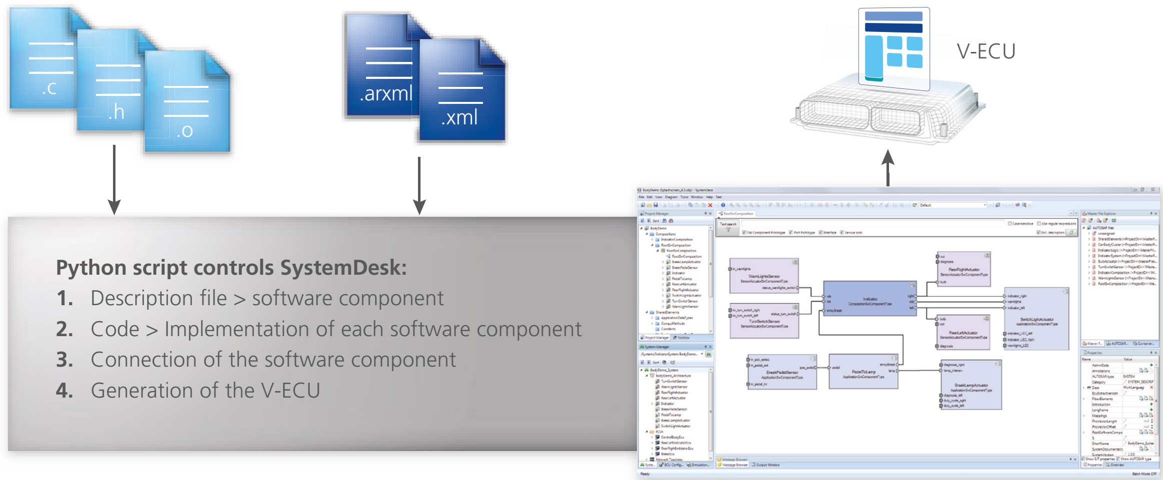

Figure 1: To create a virtual ECU, the existing code is integrated into AUTOSAR software components to generate AUTOSAR-compliant ECUs from non-AUTOSAR-based code.

> "The powerful SystemDesk functions and the very detailed documentation made it so much easier to automatically generate virtual ECUs."
>
> *Kirsten Pankratz, Volkswagen AG*

run-time environment (RTE) and integrate it with the basic software from the SystemDesk templates. Finally, a V-ECU can be generated using SystemDesk (figure 1).

Automated Generation via Script

Aside from the manual method, there is also an efficient option for automatically creating virtual ECUs. For this, the description files are analyzed using a Python script and the work steps are executed via the SystemDesk application programming interface (API). To prepare for automation, only the names of the software components of the desired virtual ECU and the file storage paths of the configuration files are required. If this data is available together with the description and code files, it only takes approximately ten minutes to create a virtual ECU via a script.

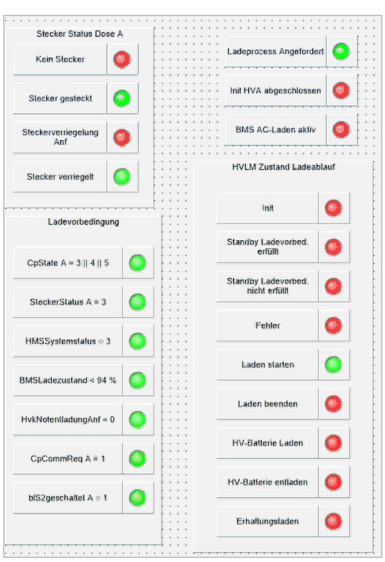

Figure 2: ControlDesk provides an easy-to-understand overview of variable states.

First Project Experience: Engine Control

The first project implemented at VW was focused on the virtual validation of engine ECUs. Specifically, this involved crankshaft-angle-synchronized function calls, which are decisive for precise engine control. A VW-programmed function that evaluates the current crankshaft angle implemented the call of the crankshaft-angle-synchronized raster in the 1 ms raster. Depending on the current position of the crankshaft, the function triggers the call of the SWC implementations. The first setup of the virtual ECU was still done manually to become familiar with the software and the necessary work steps. Based on the acquired knowledge, VW then created the Python script. Thanks to the detailed documentation for SystemDesk, its implementation went smoothly.

Virtual and Real ECU Compared

The dSPACE VEOS simulation platform, which only requires a standard PC as hardware, was used to evaluate the functionality and quality of the generated virtual ECUs. For the test, a V-ECU and a Functional Mock-up Unit (FMU) were connected with VEOS to form a system. Real data

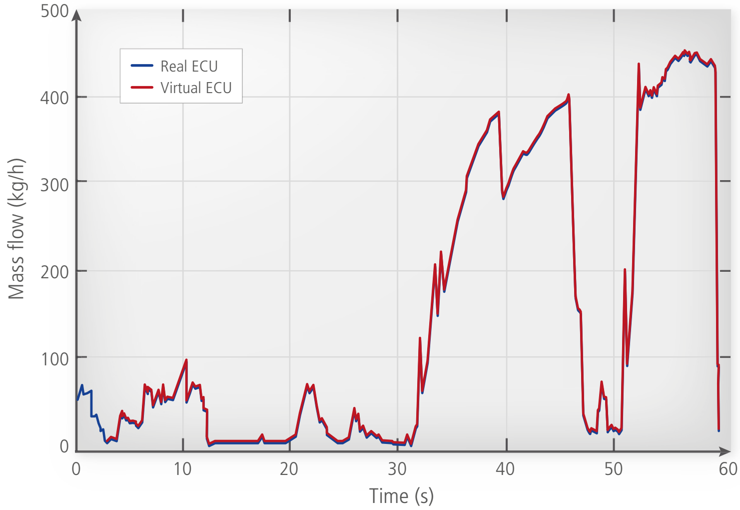

Figure 3: The comparison between the test data of a virtual ECU and that of a production ECU illustrates the very realistic behavior of the virtual ECU.

from vehicle measurements was used as stimulus data. The data was loaded into Simulink and integrated via the FMU to stimulate the virtual ECUs in VEOS. The output values of the virtual ECUs were measured with dSPACE ControlDesk. The input and output variables of both the virtual and the real ECU were then graphically prepared and compared (figure 3). The test results matched almost completely, which illustrates the high quality of the virtual ECUs and makes them a full-fledged supplement to the existing tests. Another advantage is that virtual ECUs can be used in parallel in multiple development projects. This eliminates any dependency on the availability of hardware prototypes.

Experience with dSPACE SystemDesk

SystemDesk has proven to be a powerful, convenient tool for creating virtual ECUs. SystemDesk enables the simple modeling of AUTOSAR architectures and can generate virtual ECUs, including the RTE and basic software. Due to the comprehensive, intelligible documentation, all work steps can be easily automated via an API using a script. It took only a few weeks to go from the first script prototype to the first virtual ECU. The clear graphical representation of the ECU architecture in SystemDesk provides a good overview of the existing functions, their interfaces, and the functional relationships.

Since the functions are usually provided by different teams, SystemDesk also supports an efficient collaboration between developers.

Summary and Outlook

The first project (validation of EECUs) has shown that virtual control units have the maturity level required for developing and testing production projects. Another project dealt with creating a virtual ECU for the high-voltage charging manager that controls the communication between the electric vehicle and the charging station. This project showed that the design process for virtual ECUs covers the entire motor and engine range, from the combustion engine to the electric motor. The virtual ECUs are now being used in various development groups at Volkswagen for software-in-the-loop testing. For this, existing HIL tests and configurations are reused, which noticeably reduces the effort required for test creation. ■

Kirsten Pankratz, Dominik Ott, Volkswagen

> "The clear overall representation of the ECU architecture in SystemDesk supports an efficient collaboration between development teams."
>
> *Dominik Ott, Volkswagen AG*

Kirsten Pankratz
Kirsten Pankratz is responsible for virtual validation in the integration environment at Volkswagen in Wolfsburg, Germany.

Dominik Ott
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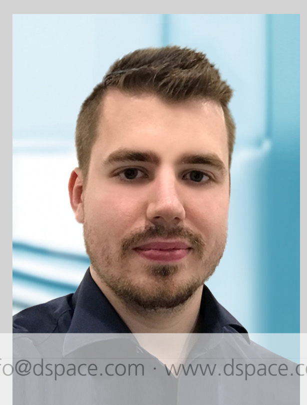
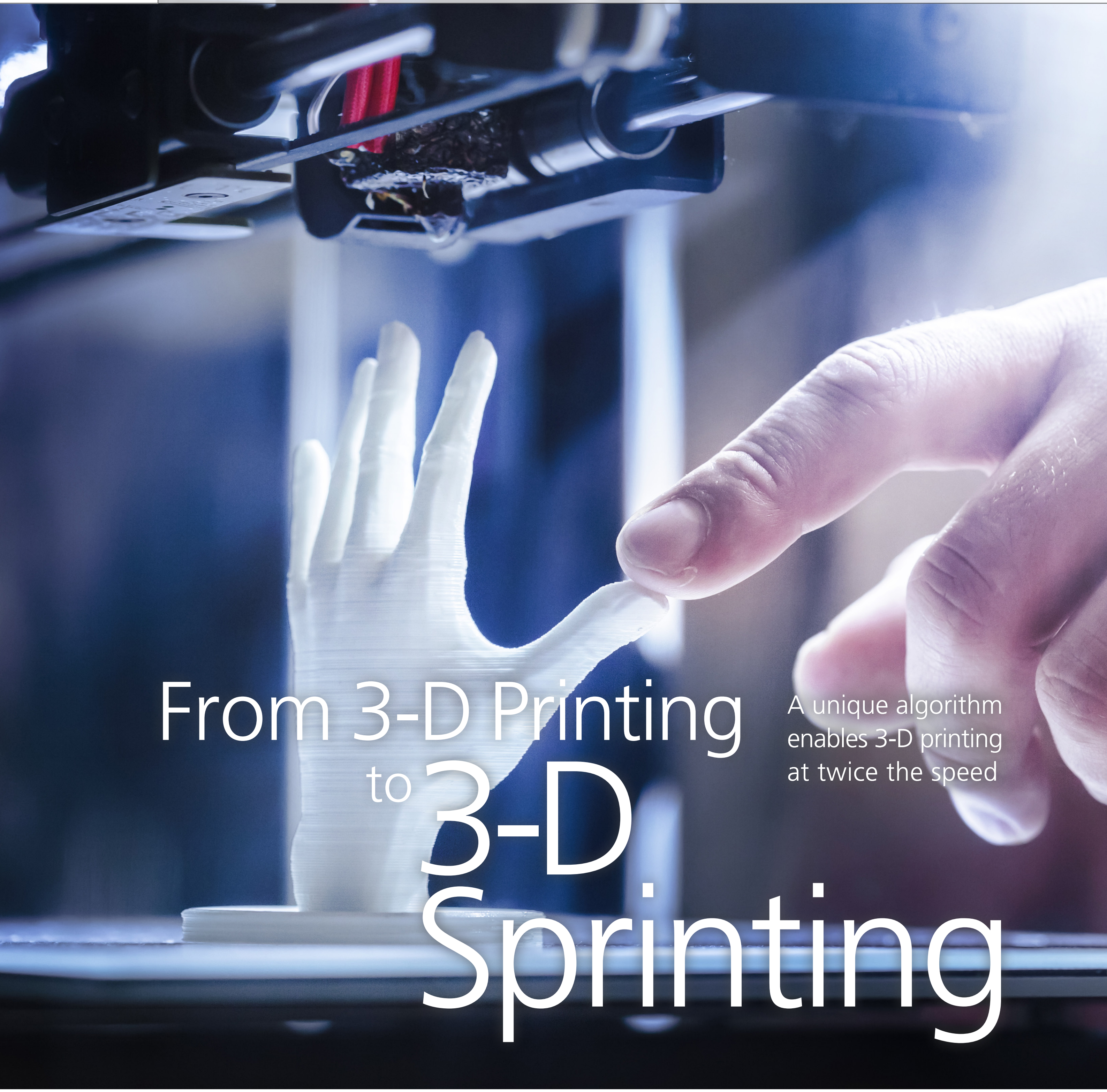




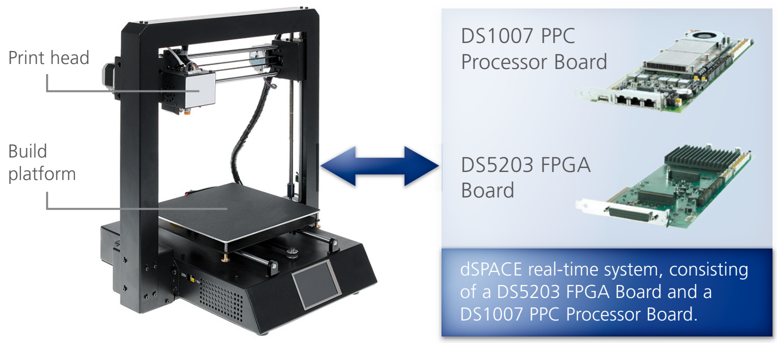
From 3-D Printing to 3-D Sprinting

A unique algorithm enables 3-D printing at twice the speed

Researchers at the Smart and Sustainable Automation (S2A) Lab at the University of Michigan have developed a method that lets them print twice as fast on a 3-D printer without sacrificing print quality. The method is based on a software algorithm that reduces the disturbing vibrations of the printer. To achieve their goal, the researchers used a dSPACE DS1007 PPC Processor Board and a DS5203 FPGA Board.

These days, desktop 3-D printers are everywhere. They are attractive because of their ability to create three-dimensional objects. However, it can take hours to print a simple object. To keep purchase costs low, these printers are designed to be light and flexible, which makes them susceptible to vibrations from stepper motors. These excessive vibrations result in surface waviness of the printed products and incorrect vertical stacking (figure 1b). Industrial-grade 3-D printers, and other manufacturing machines, have similar limitations due to vibrations. A common remedy is to reduce the motion speed or add damping. However, this leads to reduced productivity, because it takes longer to finish a print. Associate Professor Chinedum Okwudire and his team of student engineers at the Smart and Sustainable Automation (S2A) Lab, University of Michigan, have set out to remedy the vibration-induced error issue. They have completed a research project during which they were able to effectively double the speed of a 3-D printer, in a case study, while maintaining high-quality prints. The basis of the improved printing process is a software algorithm that Okwudire and his team developed. The algorithm generates motion commands to avoid or reduce unwanted vibrations, which is a leading cause of errors and distorted parts in 3-D printers. >>

U-M Mechanical Engineering Associate Professor Chinedum Okwudire examines the results of a new, faster 3-D printing algorithm with research engineering students Molong Duon (left) and Deokkyun Yoon (center).



Acc. Limit	1 m/s²	3 m/s²	5 m/s²	10 m/s²	30 m/s²
Printing Time	3:59 h	2:42 h	2:21 h	2:06 h	1:50 h
Baseline					N/A
FBS					

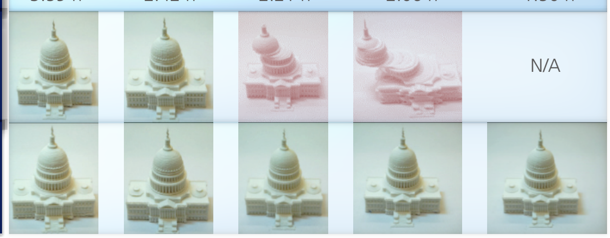


Figure 1a: Commercial 3-D printer controlled by a dSPACE system.
Figure 1b: Thanks to the software algorithm, it is possible to halve the printing time while maintaining the same quality. Photo: Deokkyun Yoon, Michigan Engineering.

Mitigating Unwanted Vibrations

Prior to becoming a professor, Okwudire worked in the machine tool industry. He noticed that machine motors are often operated at lower speeds than they are able to deliver to avoid vibration-induced errors. "I was convinced that with the right algorithm the vibrations could be compensated through software, such that higher speeds and accelerations could be achieved without sacrificing accuracy or increasing hardware costs," Okwudire said. "But a major limitation of machine tools is that their controllers are typically closed to modifications, which makes it hard to use new control algorithms." This limitation led Professor Okwudire and his research team to test their algorithm on 3-D printers. These also suffer from vibration problems which limit their speed and acceleration. However, their controllers are open. The software algorithm that Professor Okwudire and his research team developed can mitigate vibration-induced errors without sacrificing productivity. The algorithm is based on the filtered B-splines (FBS) vibration compensation technique. "The FBS algorithm anticipates when the printer may vibrate excessively and adjusts its motions accordingly to minimize vibration-induced tracking errors subject to the kinematics limits of the machine, without introducing time delays," said Professor Okwudire.

Optimizing Motion Commands

The method used takes all movements of the stepper motors of the print head (x-axis) and the build platform (y-axis) into consideration and actively controls them. Particularly, accelerating the motion of the build platform causes inertial loads to exceed the holding torque of the motors, causing them to skip count and lose position tracking. To control the vibration rate, the 3-D printer is connected to an online system that can control the tracking to remain at a preset, constant level (limited preview FBS approach). The algorithm can look ahead and calculate parameters to make adjustments and achieve optimized motion commands.

High-Quality Printed Parts at Faster Speeds

To put their algorithm to the test, Professor Okwudire and his research team conducted a case study. They set out to print a 3-D scale model of the U.S. Capitol. In their first series of prints, they did not use the FBS algorithm method. Conventional acceleration of the printing process led to grave vibration-induced registration errors which rendered all

"dSPACE provided an easy-to-use and reliable platform for prototyping our algorithm within a very short lead time."

Chinedum Okwudire, Associate Professor Mechanical Engineering, University of Michigan

The Algorithm in Detail

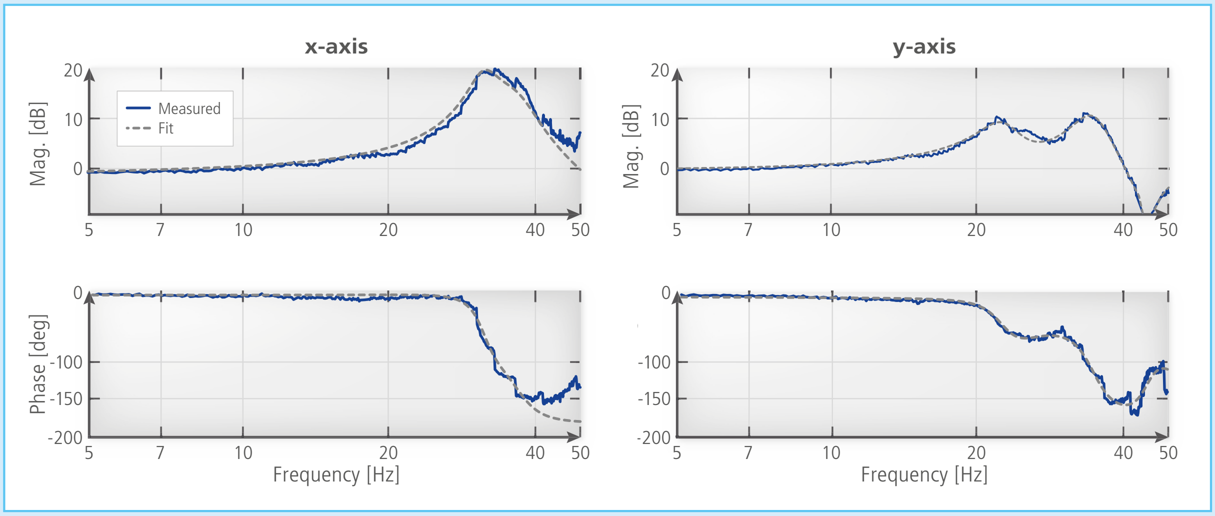


Figure 2: Frequency response functions of the x- and y-axes of the 3-D printer. Least square curve fitting is used to identify the axis level dynamics.

Figure 2 shows the measured and curve fit x- and y-axis frequency response functions (FRFs) of the 3-D printer. The FRFs are measured by applying swept sine acceleration signals to the printer's stepper motors. In addition, the relative acceleration of the build platform and print head is captured using accelerometers. The curve fit model is generated using the MATLAB® invfreqs function. To implement the filtered B-splines (FBS) method, the printer's proprietary motion controller is bypassed. Instead, the dSPACE real-time system consisting of a DS1007 PPC Processor Board and a DS5203 FPGA Board sends the axis-level motion commands to the printer's stepper motors at a sampling rate of 1 kHz via stepper motor drives (Pololu DRV8825).

The dSPACE system loads G-code text files and interprets the data, and then runs the FBS vibration compensation algorithm in real time to optimize the motion trajectories and minimize vibration-induced errors. Additionally, the dSPACE system was used to convert the optimized motion trajectories into stepping and direction pulses, and to send the pulse trains to the stepper drives through digital channels at a pulse width of 0.075 ms.

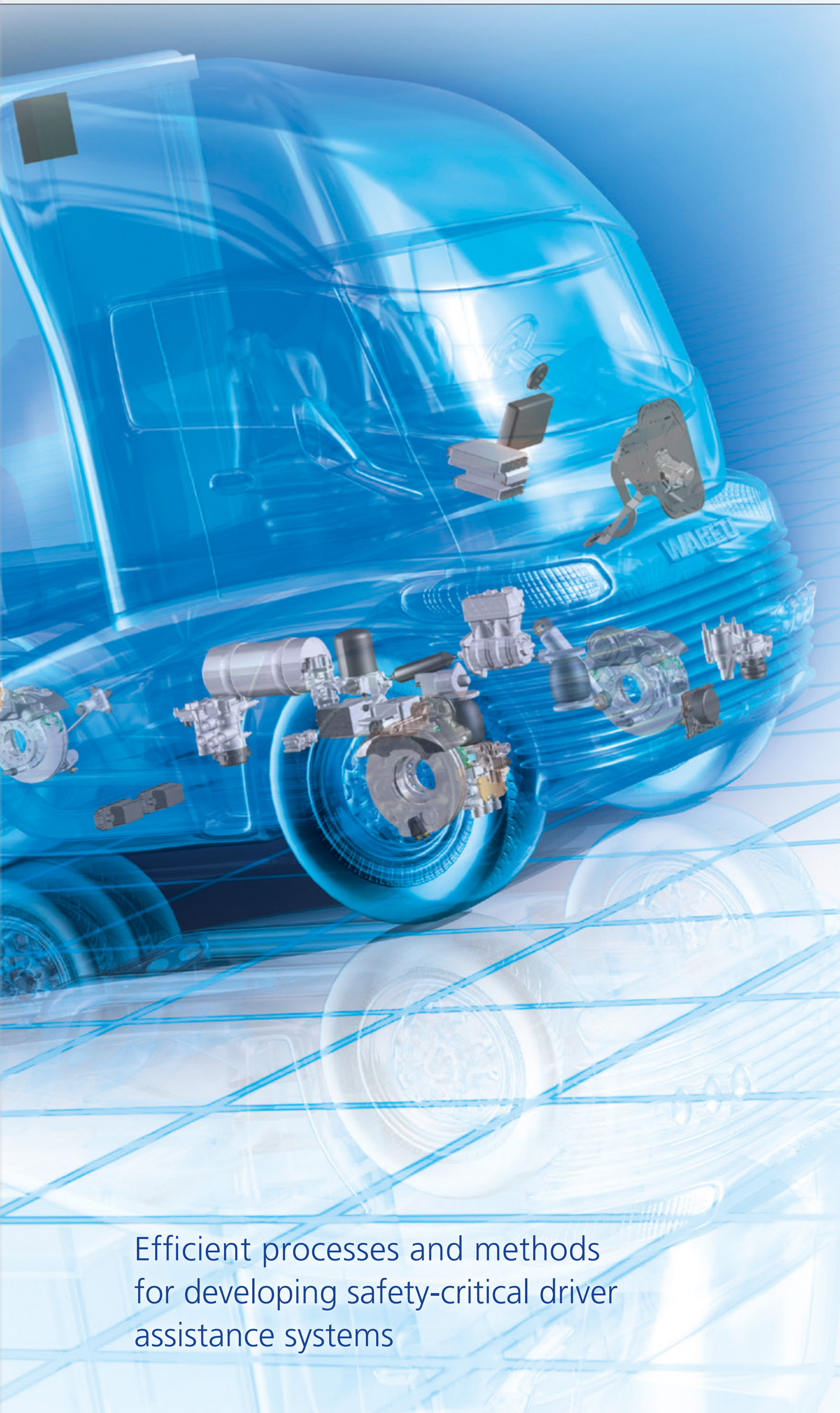
printed 3-D objects useless. In the second series of prints, the FBS algorithm method was applied. It soon became clear that registration errors could be avoided very reliably. The FBS algorithm method enabled high-quality prints at much shorter printing times compared to the baseline print results. By implementing the FBS algorithm method, the U-M Engineering Team was able to reduce 3-D printing time by 50% (from four hours to two hours, using a 3x factor of safety), without sacrificing printing quality. Their work shows that applying the FBS algorithm method can upgrade a 3-D printer's firmware, enabling faster 3-D printing for existing printers at no additional cost. ■

Courtesy of the University of Michigan

For more information about the algorithm, go to the following video: www.dspace.com/go/dMag_20191_UM

Smart Software, Smart Trucks

Safety, efficiency, and availability are the core requirements for commercial vehicles. Technology supplier WABCO has implemented a consistent process to optimize the development of safety-critical, reliable systems. It is based on a comprehensive tool chain in which SystemDesk and TargetLink pave the way to AUTOSAR- and ISO 26262-compliant development.



Efficient processes and methods for developing safety-critical driver assistance systems

Trucks and buses are more efficient and safer when they are in the correct lane at the right speed, have the appropriate tire pressure, and use the smartest collision avoidance systems. Driver assistance systems from WABCO make sure this is the case. The systems are integrated in the complex electrics/electronics (E/E) systems of commercial vehicles from a range of manufacturers. They support the driver by communicating with sensors and actuators in the vehicle. But developing and implementing safety-critical systems involves a number of challenges, which have to be considered when planning tool chain design and the development process. Compliance with important standards, such as ISO 26262 and AUTOSAR, is not the only crucial factor for developers. They also have to optimize development times and costs so that the products are as innovative as they are competitive. The tool chain therefore has to address the following criteria: continuity, traceability, automation, change management, and test frontloading. This is why WABCO uses a process designed like a double V-model (figure 1). It enables developers to quickly perform tests at any time during development.

Developing the AUTOSAR Structure

The development is based on requirements specified in PTC Integrity. Design guidelines ensure that the requirements are sufficiently detailed and formalized to export rudimentary AUTOSAR configuration files (ARXML files) from them with a custom plug-in. The configuration files are imported to the architecture tool dSPACE SystemDesk. This results in a software structure with the names of the structure components. In SystemDesk, the developers add implementation details, data types, and AUTOSAR communication mechanisms to the structure and pass it to the TargetLink Data Dictionary. TargetLink can then be used to generate the frame models for the AUTOSAR software components and the developers can insert function models (figure 2). These processes are directly linked and can be automated by means of a script to ensure more efficiency and prevent errors. The tool coupling makes it possible to trace requirements between requirements management and the development environment. Comments are even passed to the models. >>

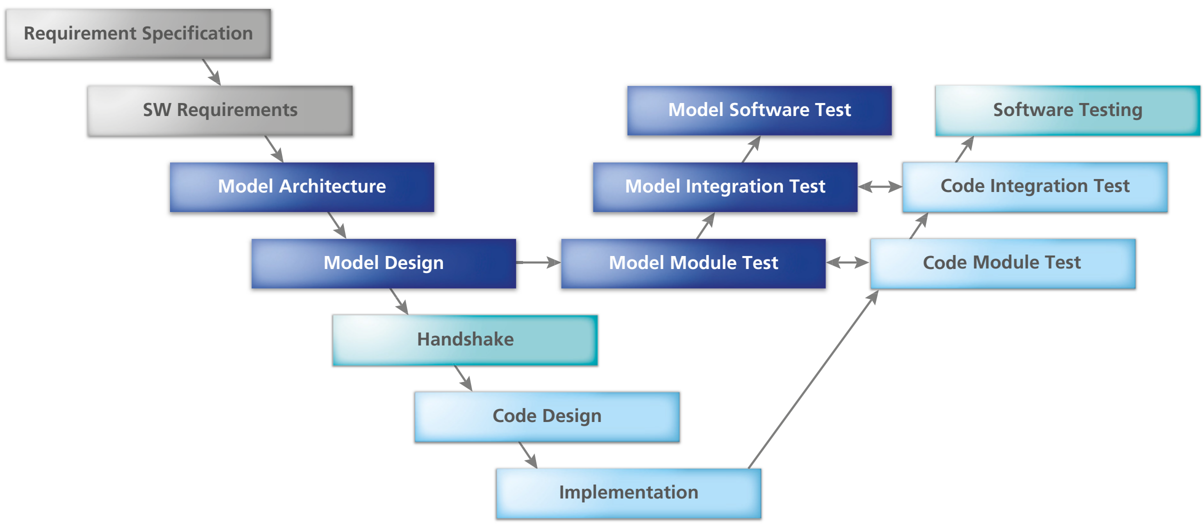


Figure 1: The process established at WABCO is modeled after the V-model, which has been extended to a double-V-model so that software-in-the-loop (SIL) tests can be performed even during the specification and design phase. The aim is a seamless transition between all process steps. This is achieved by means of tool integration.

Model-Based Control Design

WABCO uses Simulink/TargetLink for controller development. These model-based tools transform the requirements into a function model. In the first step, the modeled function has to meet all functional requirements, but not yet the restrictions of the target hardware. The functional requirements are checked by means of model-in-the-loop (MIL) simulation in TargetLink. The requirements and the methods called for by ISO 26262 result in test cases for comparative function testing. In the next step, the function and model are optimized for the target hardware before production code generation with TargetLink. The code and model then pass back-to-back tests in BTC EmbeddedTester from BTC Embedded Systems to verify the code.

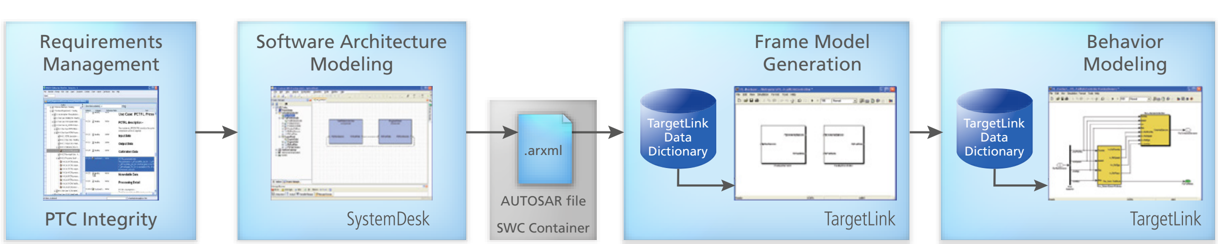
Software Implementation

The AUTOSAR software components that constitute the WABCO software are composed of several modules, which contain the individual functions. Incremental code generation in TargetLink is used to generate code for each model separately. This makes it possible to work in distributed development teams. It also ensures that the tested code of individual modules can be integrated in the AUTOSAR software component (SWC). Incremental code generation is particularly useful for complex SWCs because it is not necessary to generate the module code every time, which significantly reduces code generation times. After the assembled SWC is tested, it is integrated in the overall software for the electronic control unit (ECU).

Efficient Software Verification

A decisive factor for software quality is continuous testing throughout the development process. Early and comprehensive testing means that a high level of maturity is reached faster and more efficiently. WABCO developers use their own tools for consistency and plausibility checks to de-

Figure 2: From requirements to control design. A seamless transition between tools is the basis for the efficient development of complex solutions, such as driver assistance systems.



> "The production code generator TargetLink is particularly valuable because it is certified for software development in line with the safety-relevant standards ISO 26262 and IEC 61508."
>
> *Holger Jakobs, WABCO*

tect and fix design errors right from the start of a project. In the development process, WABCO also uses the following tools from the TargetLink Ecosystem for software validation:
BTC EmbeddedTester: Intelligent test case generation for fully automatic, ISO 26262-certified back-to-back testing.
MES MXAM: Automatic check to determine compliance with relevant guidelines (modeling guidelines, MISRA, TargetLink Modeling Guidelines). The tool is used early in the development process to make sure that even the initial designs are in line with the guidelines. The software is checked before release.
MES M-XRAY: Analysis of model structure and complexity. The tool provides metrics for assessing the complexity and the potential criticality that is relevant for software safety. The tool therefore supports ISO 26262-compliant development.

An in-house reporting tool supports the initiation of tests, summarizes the results, and continuously monitors the project progress.

Results and Outlook

The implemented tool chain made it possible to complete cutting-edge ADAS projects (figure 3). All systems have gone into series production and are used in trucks and buses from various manufacturers. WABCO is planning to use the PC-based simulation platform dSPACE VEOS in addition to the dSPACE Simulator that is currently used for ECU validation to find errors even earlier. ■

Holger Jakobs, WABCO

Figure 3: Examples for successful ADAS projects: The lane keeping assistant OnLaneASSIST™, the turning assistant OnCity™ Urban Turning Assist, and the autonomous emergency braking system (AEBS) OnGuardMAX™.

Mission Accomplished: A Seamless Tool Chain

A tool chain becomes seamless through a direct exchange of data between successive development steps and tools. WABCO has achieved this with the following standard tools and its own automation scripts:

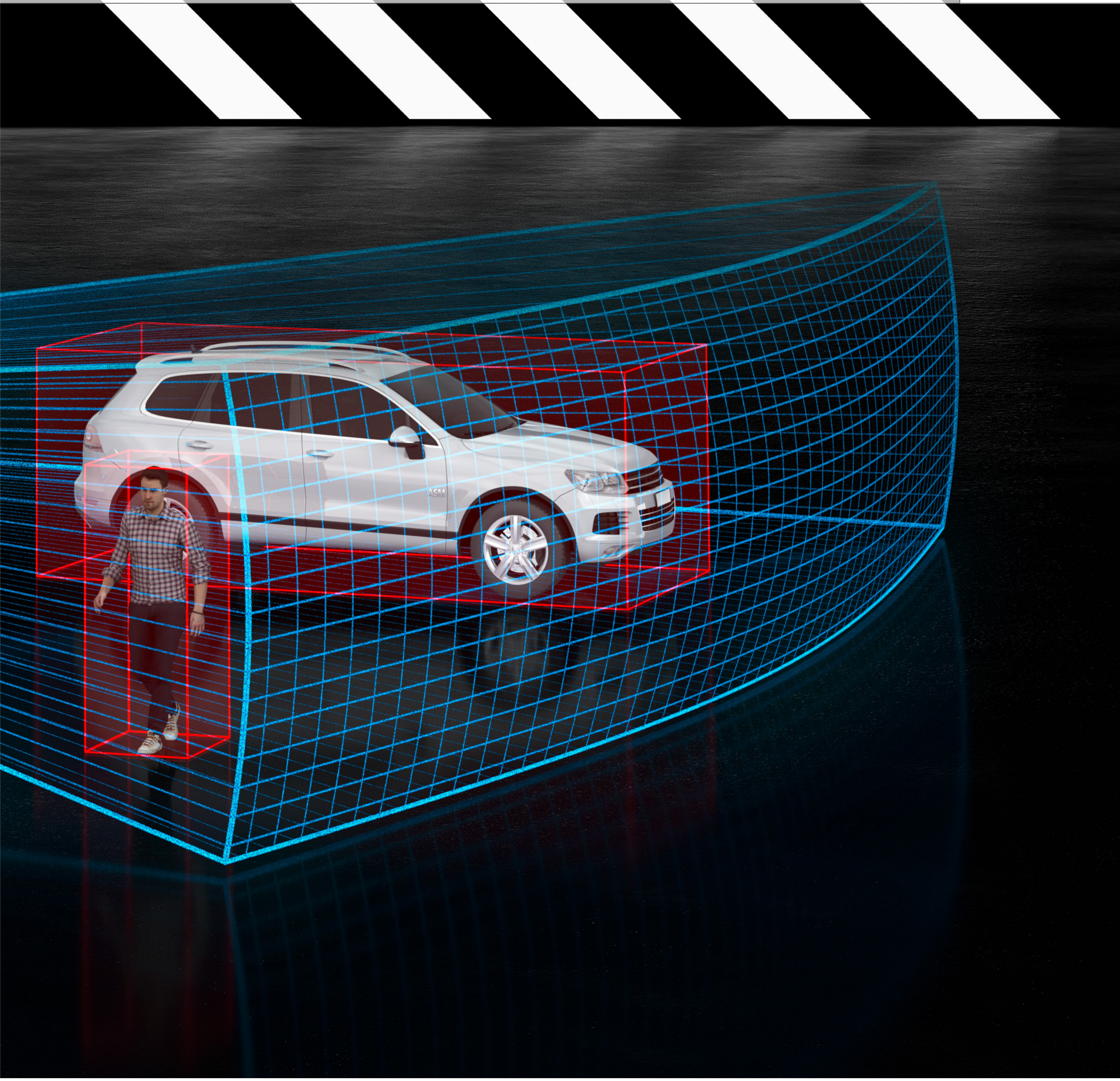
- Requirements management: PTC Integrity™
- Architecture design: dSPACE SystemDesk
- Control design: Simulink®/dSPACE TargetLink
- Code implementation: TargetLink
- Software verification: BTC EmbeddedTester, MES MXAM, MES MXRAY, own custom tools

Holger Jakobs
Holger Jakobs is an expert for model-based software development with Simulink and TargetLink in the competence center for application software at WABCO in Hanover, Germany.

Objective Capture

Validating functions for autonomous driving by means of realistic sensor simulation

Autonomous vehicles use sensors to observe their environment. To efficiently validate vehicle functions at an early stage, the environment, sensors, and vehicle must be realistically simulated and tested in virtual driving tests. For this purpose, dSPACE offers an integrated tool chain comprised of powerful hardware and software.



There is no longer any doubt as to whether autonomous vehicles will become part of road traffic. The real question is when this is expected to happen. Level 4 vehicles that are ready for series production are predicted for 2020/21. To reach this goal, validating the driving functions while they are still in development is crucial. Developers must therefore be able to simulate driving functions in combination with environment sensors (camera, lidar, radar, etc.) in the laboratory in quasi-real traffic scenarios. The alternative to this would involve conducting real test drives on the road, a practice which is not feasible simply because it would require driving many millions of kilometers in real vehicles to cover all mandatory scenarios.

Conditions for the Validation Process

A number of conditions are important when validating functions for

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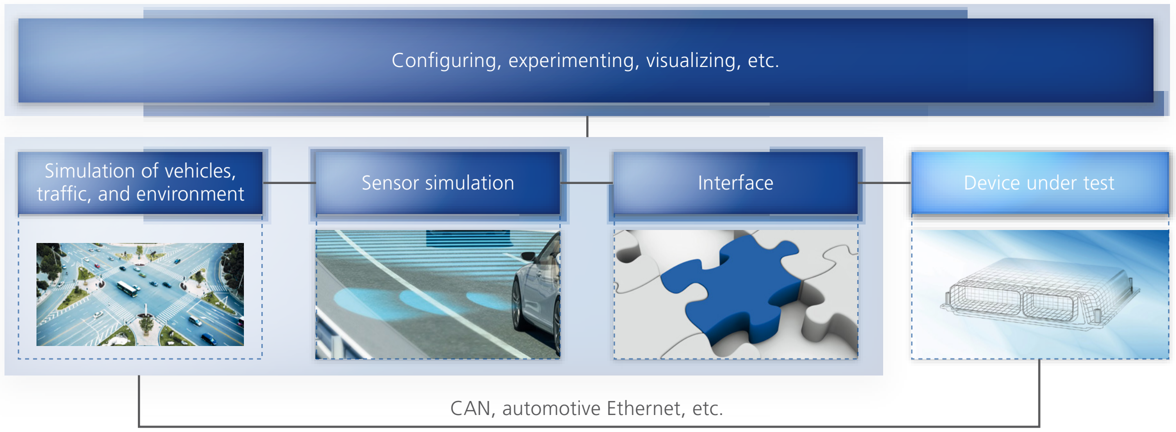


Figure 1: Basic structure of a simulation environment for ADAS and AD functions. The simulation can be performed purely virtually with the aid of standard PC technology (MIL/SIL) or by including real control units (HIL).

autonomous driving:

- Functions for autonomous and highly automated driving are extremely complex, partly because the measured values from numerous (sometimes more than 40) different sensors (camera, lidar, radar, etc.) must be taken into account simultaneously.
- The variety of traffic scenarios to be tested (vehicles, pedestrians, traffic signs, etc.) is almost unlimited, which means that testing requires complex virtual 3-D scenes.
- The physical processes involved in emitting or capturing light pulses, microwaves, etc. must be integrated as physical environment and sensor models, which are rather computation-intensive. This also includes effects of the object material properties, such as permittivity and roughness.
- Many millions of kilometers have to be covered during testing to ensure compliance with the ISO 26262 standard (Road vehicles – Functional safety). Moreover, particular attention must be paid to critical driving situations to make sure the correct types of kilometers are being driven as required.

dSPACE provides a powerful tool chain consisting of hardware and software that takes all of the prerequisites for sensor simulation into account throughout the entire development process. This helps developers identify errors at an early stage and contributes to the design of an extremely efficient test process.

Simulation is Mandatory

To meet the requirements of the validation process, the driving functions must be verified and validated at all stages of the development process. Simulation is the most efficient method to do this. As functions for autonomous driving are highly complex, it is essential that the related test cases are reproducable and reusable at all stages of the development process, from model-in-the-loop (MIL) to software-in-the-loop (SIL) to hardware-in-the-loop (HIL), across all platforms. This can be achieved only with an integrated tool chain.

Structure of the Simulation Environment

The structure of a closed-loop simulation is identical for MIL/SIL and HIL (figure 1). The simulation essentially covers the vehicle, traffic, and environment as well as sensor simulation. An interface is used for connecting the sensor simulation to the device under test (control unit or function software for autonomous driving). Furthermore, the user must have an option for configuring simulation models, conducting experiments, and visualizing scenes, for example. Support for common interfaces and standards, such as FMI, XIL-API, OpenDrive, OpenCRG, Open-Scenario, and Open Sensor Interface, also plays an important role, because it helps integrate data from the German In-Depth Accident Study (GIDAS) accident database or traffic simulation tools as co-simulation.

Simulation of Vehicles, Traffic, and Environment

The basis for the sensor simulation is a traffic simulation in which different road users interact with one another.

> The dSPACE tool chain supports high-precision sensor simulation throughout the entire development process.

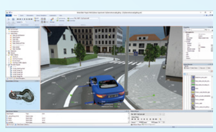
Environment Sensor Interface (ESI) Unit
Insertion of raw data and target lists into sensor ECUs
- Powerful FPGA for synchronized insertion of raw sensor data
- Flexibly adaptable to a wide variety of interfaces

Sensor Simulation PC
Platform for sensor simulation that calculates the environment model of an environment sensor (radar, lidar and camera), which provides target lists or raw data
- Equipped with a powerful NVIDIA® GPU that calculates the environment model

SCALEXIO
Modular real-time system for HIL and RCP projects
- Integration options for various sensors (camera, radar, lidar, etc.)
- Testing of complete functional chains for ADAS and systems for automated driving
- Convenient configuration via ConfigurationDesk

VEOS
PC-based simulation platform for validating ECU software in early development phases, independent of any simulation hardware
- Support of Simulink® models (e.g., dSPACE ASM)
- Scalable combination with clusters – for simulation faster than real time

Automotive Simulation Models (ASM)
Tool suite of various models for simulating automotive applications
- Simulation of driving maneuvers, roads, vehicles, road users, traffic objects, vehicle sensors, etc.
- Model parameterization using ModelDesk



MotionDesk
Software for 3-D animation and sensor simulation
- 3-D real-time visualization of traffic scenarios and generation of video frames for testing mono, stereo and fish-eye cameras
- Sensor environment models with object lists of radar, camera, and ultrasonic sensors as well as 3-D point cloud data

Figure 2: Overview of key products of the dSPACE tool chain for sensor simulation.

For this, dSPACE offers the Automotive Simulation Models (ASM) tool suite, which makes it possible to define virtual test drives in virtual environments. The ASM Traffic model calculates the movement of road users and can therefore simulate passing maneuvers, lane changes, traffic on intersections, etc. Sensor models play a decisive role in the interactions between the vehicle and the virtual environment.

Structure and Functionality of Sensors

The aim of using sensors is to detect objects by first using sensor raw data to determine targets. The data can include a local accumulation of recorded reflection points at a constant relative velocity, for example. In the next step, classified objects (cars, pedestrians, traffic signs, etc.) are identified from the characteristic arrangement of these points. Camera, radar, and lidar sensors are very similar in their basic design: They consist of a front end which usually preprocesses the data. In a subsequent step, a data processing unit generates a raw data stream and outputs a target list. Next, another unit generates the object list and thus supplies the position data. This is followed by the application logic and network management.

Integration Options for the Sensors Used in Sensor Simulation

The similar structures of the different sensor types facilitate the integration of sensors in the simulation, and suitably prepared simulation data can be inserted into the individual data processing units as required (figure 4). The appropriate integration option depends on how complete and realistic the properties of the sensor must be in the simulation and which part of the sensor is to be tested. Over-the-air (OTA) stimulation is an approach for feeding an environment simulation into a camera-based control unit (option 4), for example. The camera sensor captures the image of a monitor which displays the animated surrounding scenery. This approach allows for testing the entire processing chain, including the camera lens and the image sensor. Digital sensor data (option 3) can be divided into raw sensor data, i.e., data returned directly

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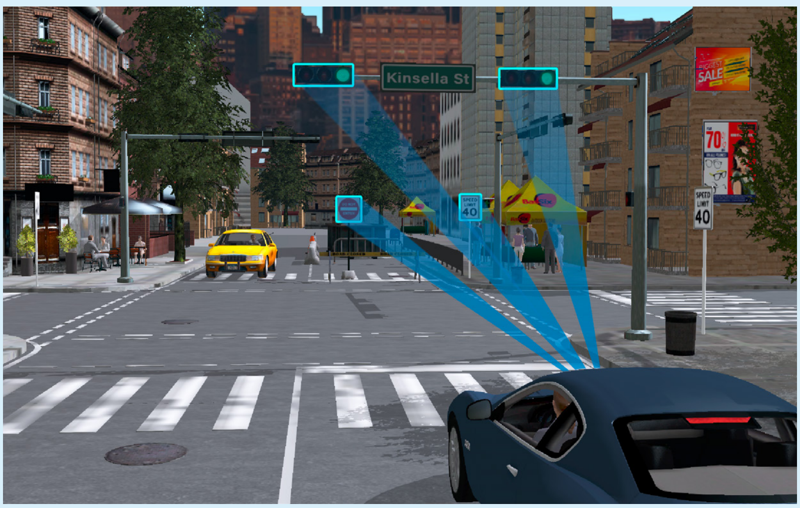
Physical/Phenomenological Models

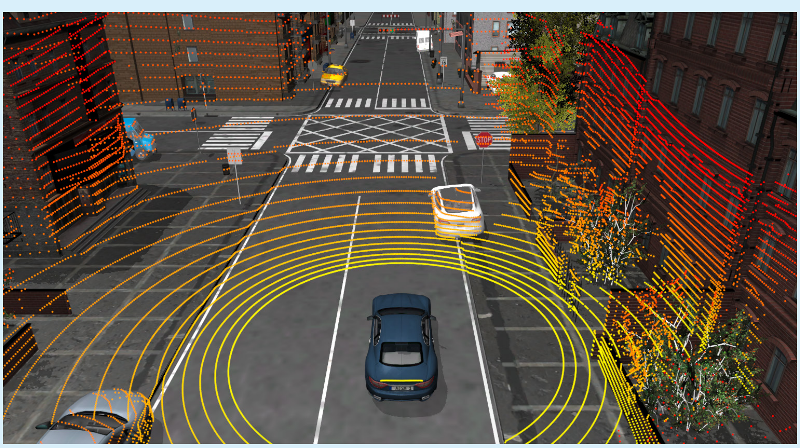
dSPACE has developed highly precise physical sensor environment models for simulating camera, radar, and lidar sensors, which generally provide raw data or target lists. They are designed for calculations on graphics processing units (GPUs).

Camera Model



The validation of functions for camera-based assistance and automated driving essentially requires that different lens types as well as optical effects such as chromatic aberration or vignetting on the lens can be taken into account. Simulating different numbers of image sensors (mono/stereo camera) or multiple cameras for a panoramic view must also be an option. Furthermore, sensor characteristics, color (monochromatic representation, Bayer pattern, HDR, etc.), pixel errors, and image noise, play an important role for the validation.

Lidar Model



Lidar systems emit laser pulses and measure the light reflected from an object. The distance of the object can then be calculated from the elapsed time. In addition to the distance, the system also determines the intensity of the reflected light, which depends on the surface condition of the object. This method of measurement allows for describing the environment in the form of a point cloud, i.e., the data is available as a target list that includes information on distance and intensity. Furthermore, in the lidar model it is essential that the specific operating modes of a sensor, including angular resolution, can be configured for the light waves, and that the objects used in the 3-D scene have surface properties, such as reflectivity. It must also be taken into consideration that the light is scattered differently by rain, snow, or fog and that a single light beam can be reflected by several objects. This results in an amplitude distribution across the sensor surface, which in turn depends on the environment (moving objects, immobile objects, etc.) or the time. The lidar model supports approaches ranging from point clouds to raw data.

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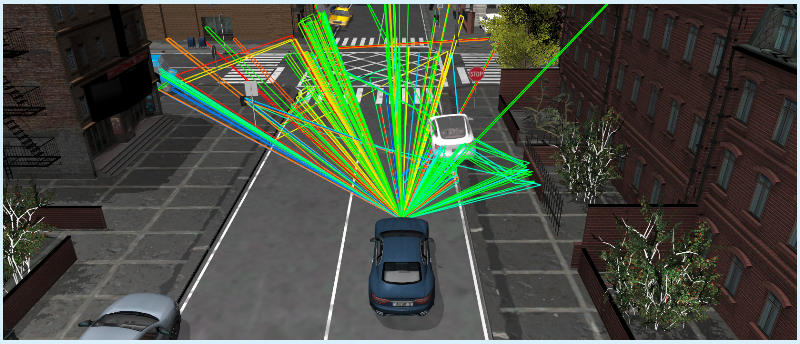
Radar Environment Model



Radar plays an important role in ADAS/AD driving functions, because it is robust in adverse weather conditions such as rain, snow, and fog as well as in extreme lighting conditions. The radar sensor can not only determine the type of objects, i.e., vehicles, pedestrians, cyclists, etc., but also measure their distance, the vertical and horizontal angles as well as the relative and absolute speed. Potentially one of the most important radar technologies is the frequency-modulated continuous wave radar (FMCW, also known as continuous wave radar), which uses frequency-modulated signals. Modern radar systems transmit about 128 frequency-modulated signals in one measuring cycle. The radar detects the signal reflected by the object – also called the echo signal. The frequency change and the generated signal can help measure the distance of the object. The speed of the object is determined by means of the Doppler frequency.
The radar model from dSPACE realistically reproduces the behavior of the sensor path. For example, modeling factors in multipath propagation, reflections, and scattering.

after data preprocessing (option 3b), and target lists (option 3a). For the camera sensor, for example, this is the image data stream (raw data) or a detected target (target list). The next level is object lists that contain classified targets and transaction data (option 2). Restbus simulation is used for sensor-independent tests (option 1). Simulation by means of object and target lists as well as raw data is an application scenario for both HIL and SIL simulation, while the OTA stimulation and the restbus simulation are exclusively HIL application cases.

Types of Sensor Modeling

Each of the different sensor integration options requires a sensor model that provides suitably processed data. Essentially, the models for the sensor simulation can be classified according to how complex and close to reality they are (figure 3). Two types of models return object or target lists: ground truth models based on real reference data and probabilistic models based on the probability of events or states. The raw data is generally supplied by phenomenological models, i.e., based on the parameters of events and states, or by physical models, i.e., based on mathematically formulated laws. Depending on the application and time of the development, the driving functions to be developed can be validated by suitable models.

Ground Truth and Probabilistic Models

The ASM Traffic simulation model contains a large number of sensors for performing tests at object list level in a SIL or HIL case:

- Radar sensor 3-D
- Object sensor 2-D/3-D
- Custom sensor
- Road sign sensor
- Lane marking sensor

These sensor models are designed for CPU-based simulation with the VEOS or SCALEXIO platform. Based on an object list, probabilistic models can superimpose realistic effects, such as environmental conditions for fog and rain, as well as multiple targets per detected object. All of this can be used to emulate the radar characteristics and calculate a target list.

Validation via Software-in-the-Loop Simulation

By using software-in-the-loop (SIL) simulation, the software of a sensor-based control unit can be validated virtually with the aid of standard PC technology. The simulation allows for testing the algorithms at an early stage when hardware prototypes are not yet available. In addition, VEOS (figure 1) and the corresponding models allow for calculation faster than in real time. The additional option of performing the calculations on scalable PC clusters increases the speed even more. This makes it possible to manage the

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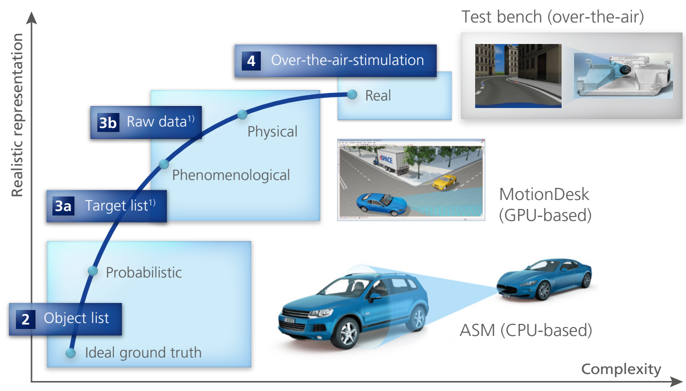


Figure 3: Correlation between the degree of realism and complexity of the different possibilities for sensor simulation.

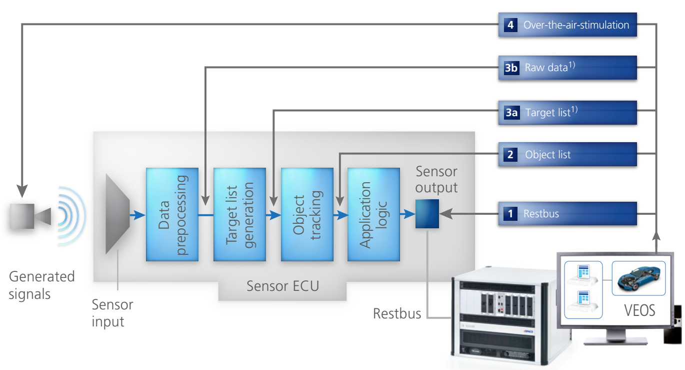


Figure 4: Overview of the various options for stimulating/simulating an environmental sensor.

[1] Options 3a and 3b describe digital sensor data at different object identification stages.

considerable variety and number of test cases, and also to perform tests that require covering millions of test kilometers in a timely manner. In a SIL simulation, the vehicle, environment and traffic simulations as well as virtual control units, if applicable, are calculated with the aid of VEOS. The models are also integrated into VEOS, if a simulation is based on ground truth and probabilistic models. Whenever phenomenological or physical sensor models are used, an application for sensor simulation (camera, radar, lidar), which is calculated on a GPU, runs on the same platform as VEOS. The motion data of the environment simulation is transferred to the sensor simulation, which then calculates the models for radar, lidar, or camera sensors. This means that the raw data is simulated using the motion data and the complex 3-D scene with a realistic environment and complex objects, while taking into account the physical characteristics of the sensors. This calculation is performed on a high-performance graphics processor to simulate the ray tracing algorithms for the environment model calculation of radar and lidar, for example. The result of this sensor simulation is then transmitted to the virtual sensor-based control units. This is done via Ethernet or virtual Ethernet. The same technology is used to exchange the virtual sensor-based control units with the vehicle simulation.

Validation via Hardware-in-the-Loop Simulation

Hardware-in-the-loop (HIL) simulations allow for testing real ECUs in the laboratory by stimulating them with recorded data or artificial test data. In contrast to SIL simulation, HIL simulation makes it possible to investigate the exact time behavior of the control units. The dSPACE SCALEXIO HIL platform performs the traffic, vehicle dynamics, and

The physical sensor models from dSPACE simulate raw data from camera, lidar, and radar sensors with the highest accuracy.

environment simulation. The vehicle simulation is then connected to the vehicle network, for example, via CAN or Ethernet, to perform a restbus simulation. The motion data of the vehicle and the other objects is sent via Ethernet to a powerful PC with a high-performance graphics processor on which the sensor environment models for camera, lidar and radar are calculated. This data (raw data or target lists) from the various sensors is combined and transmitted to the Environment Sensor Interface (ESI) Unit via a display port. The ESI Unit has a highly modular design to support all relevant protocols and interfaces. The ESI Unit's high-performance FPGA converts the data stream from all sensors into individual data streams for the dedicated sensors and transmits them to the corresponding camera, lidar or radar control units via the various interfaces.

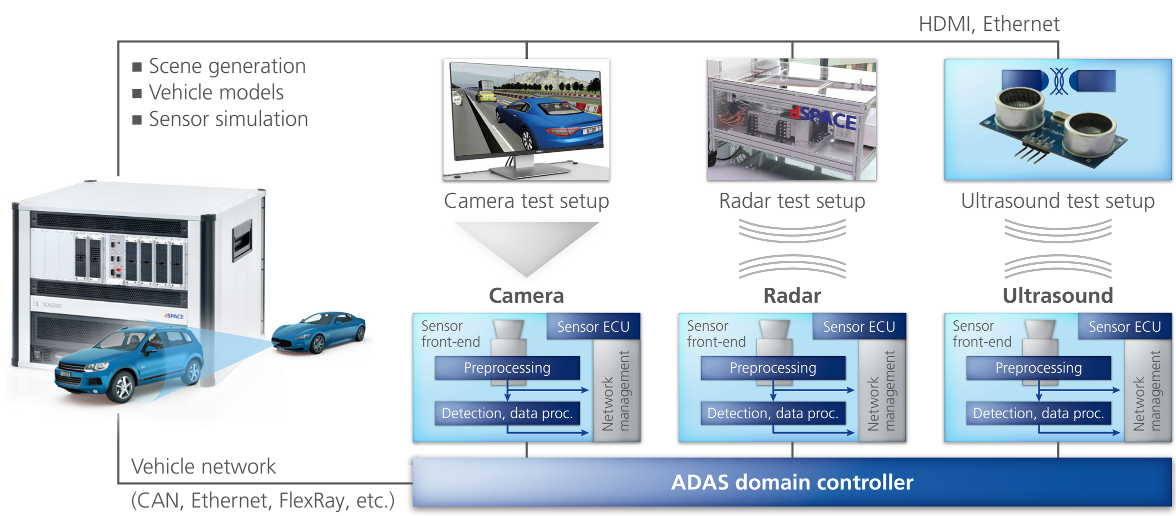
Validation via Over-the-Air-Stimulation

Over-the-air (OTA) stimulation is a classic method of testing sensors. It integrates the complete sensor-based control unit in the control loop (figure 5). This design is ideal for testing the front end of the sensor, such as the lens and image sensor of a camera. For this method, the vehicle, environment, and traffic simulations are calculated with SCALEXIO. If a camera sensor is to be tested, a traffic scene is simulated and displayed on a screen using a SCALEXIO simulator and MotionDesk. For the camera, the virtual scene then represents a real street scene. Radar echoes are directed at the radar sensor in accordance with the driving scenario calculated by the SCALEXIO simulator using the dSPACE Automotive Radar Test System (DARTS). This enables the verification of driving functions such as ACC (adaptive cruise control) or AEB (autonomous emergency braking).

Summary

For autonomous vehicles to move safely in road traffic, the ADAS/AD functions must make the right decisions in all possible driving scenarios. However, due to the virtually unlimited number of possible driving scenarios, testing the required ADAS/AD functions in the laboratory is very complex. These tests can no longer be performed with only one test method. Instead, a combination of different test methods is required. The spectrum includes MIL, SIL, HIL, open-loop, and closed-loop tests as well as real test drives. In light of this complex test and tool landscape, the key to a reliable validation process lies in a flexible and integrated tool chain that offers versatile interfaces and integration options for simulation models and the devices to be tested. This is exactly why the dSPACE tool chain for sensor and environment simulation is so useful and effective: It offers coordinated tools from a single source that interact smoothly with each other to make the validation process very efficient. ■

Figure 5: The principle of over-the-air stimulation for various environmental sensors.



The AUTOSAR Adaptive Platform supports the dynamic deployment of application software

Adaptation Talent

Autonomous driving has extensive and complex requirements. This is where the adaptive AUTOSAR standard can help. The flexible, dynamic, and service-based platform makes it possible to intelligently provide new functions to an existing ECU. SystemDesk and VEOS are well-prepared for this new approach.

Highly automated and, even more so, autonomous driving significantly increase the requirements for an early and automatable validation process, because the test kilometers required for these validations far exceed the possibilities of real-time tests. The solution is software-in-the-loop (SIL) simulation. In contrast to testing real ECU components, this approach tests only the software part of the ECU, an option that is already available in the function development phase. However, to do this, function code must be compiled and executed.

Working with Virtual ECUs

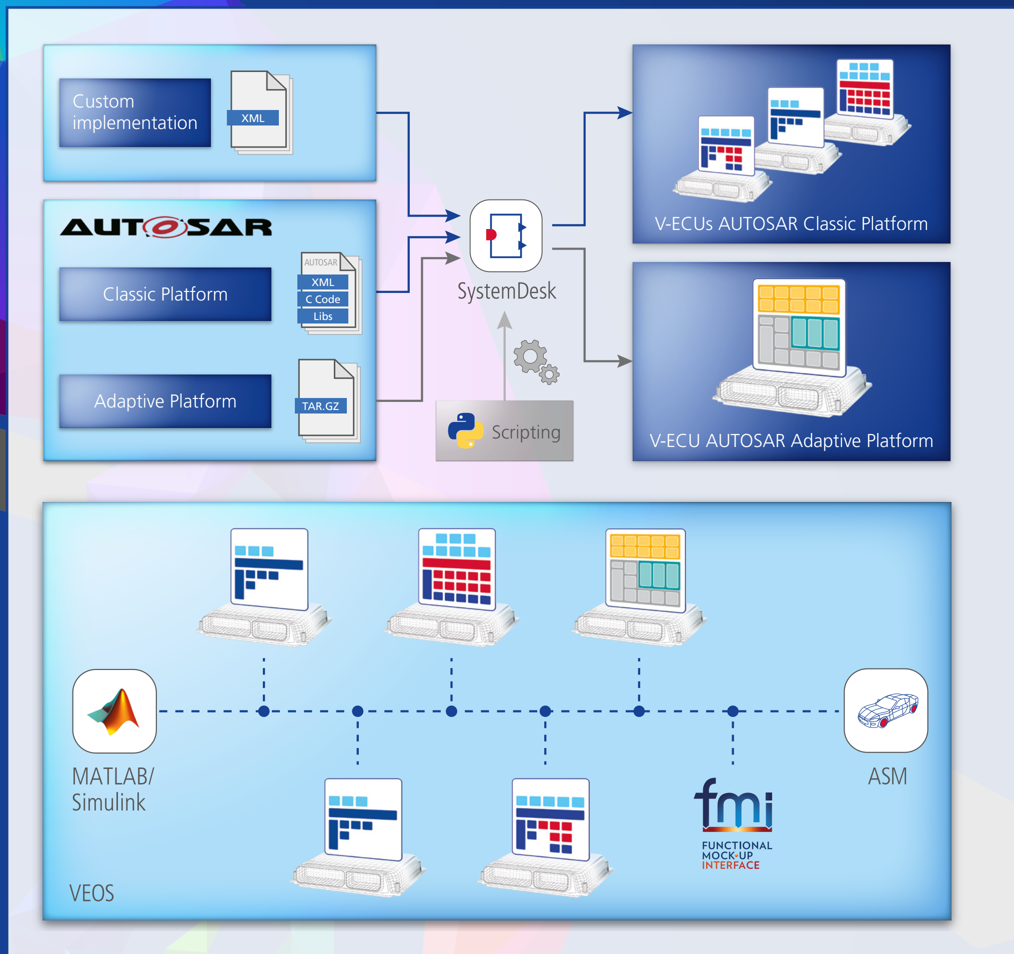
The code is executed on the VEOS simulation platform. Among other things, VEOS simulates virtual ECUs (V-ECUS): Their code corresponds as closely as possible to production code, provided it is independent of the target platform hardware. If code is developed in accordance with the AUTOSAR standard, it becomes platform-independent. For example, AUTOSAR defines a layer model for modularizing the software components of an ECU, which also includes standardized interfaces for basic functionalities. This way, ECU code can be implemented independently of the hardware.

Generating AUTOSAR-Compliant Software

With SystemDesk, dSPACE offers an authoring and system generation tool that facilitates the integration of ECU software components based on AUTOSAR descriptions. Everything can be integrated, whether it is individual components of the application software with the function code or the complete code including all required AUTOSAR basic software modules. Additionally, SystemDesk configures and generates an operating system specifically for simulation purposes. This makes it possible to accurately simulate the behavior of the ECU up to the configuration of different operating system tasks. Generating potentially missing basic software (or integrating externally supplied modules) also enables connecting to simulated bus systems, such as automotive Ethernet.

Service-Based Communication

Today, the AUTOSAR Classic Platform is the tool of choice when developing software for highly efficient control units. However, highly automated and autonomous driving require different framework conditions. In this specific use case, the communication between functions is no longer technically defined in advance and integrated into the generated code of a run-time environment (RTE). Instead, the definition specifies only who communicates with whom. The actual connec-



Top: Integrating application software for the AUTOSAR Adaptive Platform and Classic Platform on virtual ECUs (V-ECUs) with SystemDesk.
Bottom: Simulating V-ECUs of different complexity in combination with plant models (MATLAB®/Simulink®; Automotive Simulation Models, ASM for short) on VEOS.

tions for communication are established only after starting the control unit. This way, individual functions can be updated via wireless connections after the vehicle has been delivered. New functions can also be added later (over-the-air update). The required software architectures are described by using the AUTOSAR Adaptive Platform, which notably differs from the Classic Platform. However, some of the structure still remains. For example, the platform is still divided into an application layer and basic services, which each ECU must provide. It is also still independent of hardware interfaces thanks to an operating system that provides standardized interfaces (Portable Operating System Interface, POSIX for short).

Validating AUTOSAR-Based Virtual ECUs

The integrated simulation of environment models with virtual ECUs poses a validation challenge if some of these ECUs are developed on the Classic Platform and others on the Adaptive Platform. VEOS enables simulating both types in combination with environment models as well as routing intercommunication via a simulated Ethernet bus. Because the related software-in-the-loop approach is decoupled from real-time processes, development and integration of all kinds of virtual ECUs can be accelerated, which is particularly beneficial for functions for autonomous driving. ■

> Efficient software development for the AUTOSAR Adaptive Platform with the dSPACE tool chain.

Process Consulting – New in the dSPACE portfolio

Efficient Processes – Not by Coincidence

There may be many ways to reach a goal, and detours can broaden our horizon. However, this learning-by-doing approach usually costs time and money and involves a greater risk. Jann-Eve Stavesand and Anne Geburzi, responsible for dSPACE Process Consulting, explain how dSPACE supports companies in creating optimized processes for developing and testing automotive software – without the detours.

Mr. Stavesand, what is process consulting and why is it new for dSPACE?

Stavesand: To keep it short: We advise our customers on how to optimize their development and validation processes, adapt them to new requirements, or redesign them. It is new for dSPACE, because we now offer consulting as an additional, product-independent service. This means that we not only advise our customers with regard to our own products and tool chains, but we take their entire tool landscape into consideration. Needless to say, the specialists from other suppliers are still the ones answering the detailed questions about their tools. However, because we look at things more comprehensively, we are the designated experts for creating a tool-independent process design.

And why is dSPACE offering process consulting at this specific point in time?

Stavesand: For some time now, we have been receiving regular requests from our customers, who explicitly want to use our experience and our know-how for optimizing processes and who see us as a partner for comprehensively designing process architectures. Therefore, now is the right time to honor their requests by offering the new dSPACE Process Consulting service. In this context, I well remember an occasion when

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Figure 1: Jann-Eve Stavesand and Anne Geburzi explain dSPACE Process Consulting – the latest addition to the dSPACE portfolio.

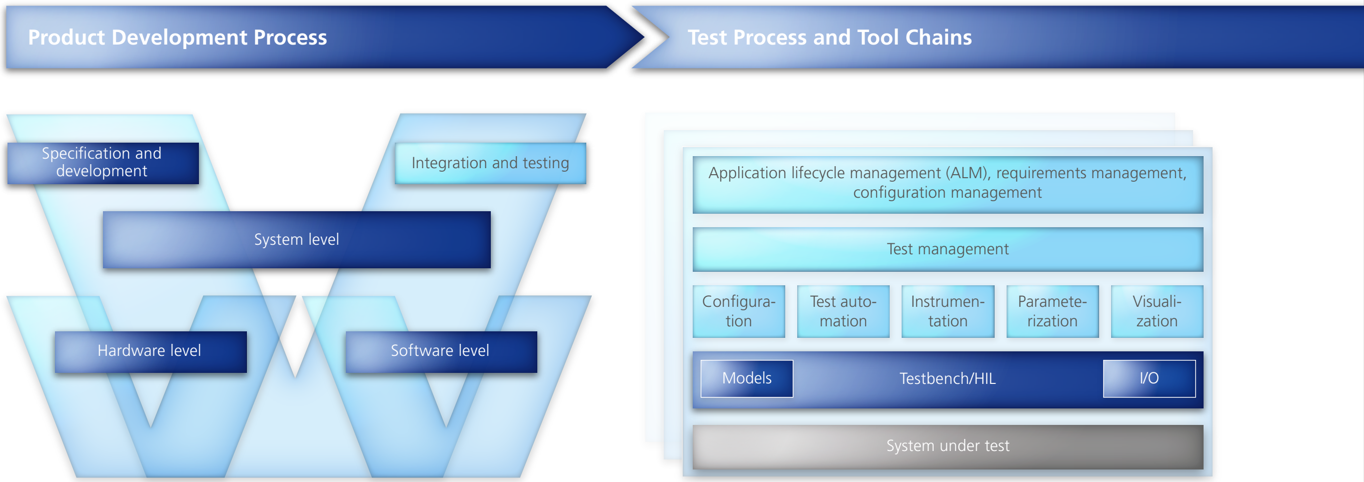


Figure 2: dSPACE assessment model – A detailed analysis of the current situation is the basis of every recommendation.

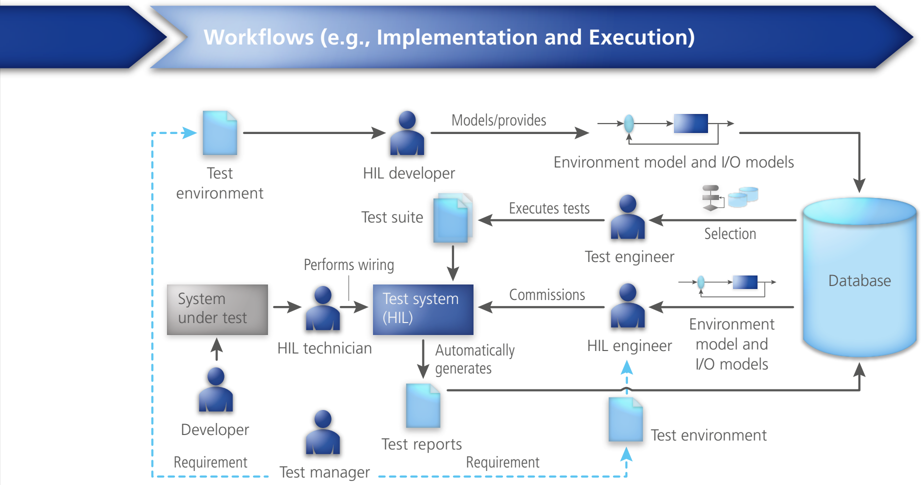
we met with a major automotive supplier. The talks involved the interplay of different software and hardware products. After several interesting discussions with the customer about their tool landscape, the responsible employee told us at the end: "You know all that! We would like you to advise us comprehensively and do not want to contact every tool manufacturer individually about the process before we have the full picture." These types of requests have become more frequent in recent years, and we can now meet this customer demand by offering dSPACE Process Consulting.

Ms. Geburzi, what specifically prompts customers to avail of the dSPACE Process Consulting services?
Geburzi: New challenges, such as developing functions for autonomous driving, the increased use of virtual test methods, and the demand for more agile processes or compliance with standards, such as ISO 26262, are typical triggers. In these cases, existing processes are often no longer ideal. Wherever you look, the complexity of processes is generally increasing. This requires customers to move away from the usual processes, starting with a simple restructuring and extending all the way to agile development or designing completely new processes. It might sound mundane, but our customers often simply lack the time and detailed knowledge to develop tailor-made concepts for process design in parallel to daily business proceedings.

Can you give an example of how you proceed in a typical consulting project?
Stavesand: Generally, the content and scope are very specific to each project and therefore the processes differ. However, most projects begin with an initial assessment, which we carry out on-site by personally speaking to all persons involved in the project. We then correlate the current status with the development goals. For this, we take existing tool chains into account as well as assigned roles, specified requirements, and best practices from comparable processes. Looking at all this information, we then identify the potential for improvement and derive a concept for process extensions or reorganizations. After implementing the proposed measures, it is essential for customer acceptance to be able to evaluate success by means of key figures.

Can you name specific cases in which you advise customers?
Geburzi: We often receive requests for supporting the design of new processes for the development of safety-critical functions according to ISO 26262, including writing documents such as safety manuals.
In the context of ADAS[1)], the task

> Requirements that change during the development process or functions that are added during the life cycle – dSPACE Process Consulting also offers consulting and support for the introduction of agile development.



might be to restructure established processes or, if necessary, to develop completely new processes. With regard to model-based development, compliance with the AUTOSAR standard, or agile approaches, the benefit evaluation and the process-related introduction of these technologies and methods also play a major role for our customers. For example, one of the challenges when introducing virtual test methods such as SIL and HIL[2] is the aspect of design for testability. This means that hardware and software have to be developed with regard to validation and verification processes based on the system design. The management of extremely large data volumes in the development and verification process also plays an increasing role. However, comprehensive and integrated tool solutions are often not available yet.

Surely, these are all areas in which dSPACE has software development experience. Yet, what qualifies dSPACE to be a consultant in these areas?
Stavesand: For all these areas, we can draw on our existing know-how and many years of practical experience in countless engineering projects with international corporations. Our experience with best practices in different companies from different industries makes it possible for us to develop an individual, optimal, and, above all, practicable solution in cooperation with each customer.

How do you proceed with the process design, particularly in view of the fact that the customers as specialists tend to have established processes that are tailored specifically to their needs?
Geburzi: Let me quote Henry Ford: "If you always do what you've always done, you'll always get what you've always got." Often, these established processes are the reason the customers ask for our advice. If a process is established, it can simply mean that it has become outdated and no longer fits the new challenges. In addition, the respective experts are not responsible for all aspects of the process, because IT, safety managers, generally applicable standards and norms, or company-wide decisions repeatedly introduce new external requirements. Existing processes can form the basis, but they must be specifically adapted to meet all new requirements. In addition, and this is a decisive factor for us as process consultants, all measures must be communicated and coordinated within the company. In these cases, we can translate and connect the different worlds.

Ms. Geburzi, Mr. Stavesand, thank you for this interview.

1) *Advanced driver assistance systems (editor's note)*
2) *Software-in-the-loop, hardware-in-the-loop (editor's note)*

Anne Geburzi
Anne Geburzi is Senior Process Consultant at dSPACE.

Jann-Eve Stavesand
Jann-Eve Stavesand is Team Leader Process Consulting at dSPACE.

Innovations for SCALEXIO Systems

The product portfolio for dSPACE SCALEXIO systems is growing continuously. With dSPACE Release 2018-B, a more compact version of SCALEXIO LabBox and new SCALEXIO I/O boards for analog signal generation and Ethernet communication are now available. SCALEXIO is suitable for both rapid control prototyping and hardware-in-the-loop applications.

SCALEXIO LabBox (8-Slot)

The SCALEXIO LabBox is now also available in a more compact version with eight slots. Any type of SCALEXIO I/O board can be installed in seven of them. Five of the seven slots also support CompactPCI Serial boards, for example, for the integration of Ethernet or fieldbus interfaces. The eighth slot is reserved as a system slot for the processing hardware. You can use it to plug in the DS6001 Processor Board or the DS6051 IOCNET Router via which the SCALEXIO Processing Unit can be connected as an external processing unit. The small footprint, which is comparable to that of a 14-inch notebook, means that the new SCALEXIO LabBox fits on any desk. This means function developers always have their test system within reach. Alternatively, two narrow LabBoxes can be connected and installed in a 19-inch rack. Equipped with a DS6001 Processor Board each, a multiprocessor system is thus quickly available for computation-intensive applications in the smallest of spaces.

Numerous D/A channels

The new DS6241 D/A Board can be used both in the SCALEXIO LabBox and in a SCALEXIO rack system. Its 20 analog channels are suitable for generating actuator control signals and simulating sensors. In addition to static voltages, analog wavetables can also be played back based on time and angle. As with all other SCALEXIO boards, the channels are configured graphically with dSPACE ConfigurationDesk.

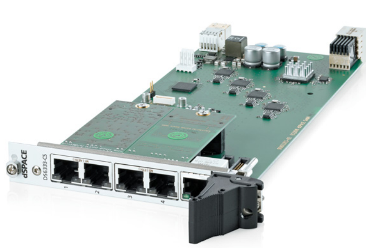
Supporting Automotive Ethernet

dSPACE offers two new boards for using automotive Ethernet with SCALEXIO:

- The DS6333-CS Automotive Ethernet Board is used in a SCALEXIO LabBox together with the DS6001 Processor Board.
- The DS6333-PE Automotive Ethernet Board is plugged into the SCALEXIO Processing Unit.

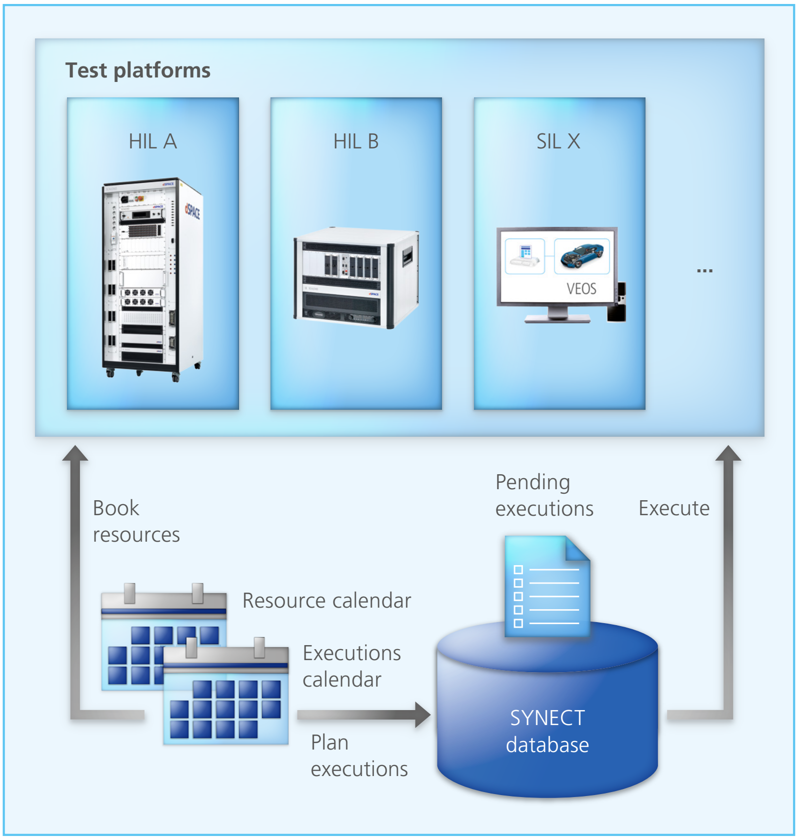
Both automotive Ethernet boards offer a fixed standard Ethernet port and four additional ports, which can be used with BroadR-Reach (100/1000 MBit/s) or standard Ethernet (10/100/1000 MBit/s), depending on the modules used.

A wide variety of applications can be covered thanks to an integrated configurable network switch and four internal Ethernet controllers. Especially for bypassing and simulator coupling applications, the less expensive DS6334-PE and DS6335-CS versions are also available. ■



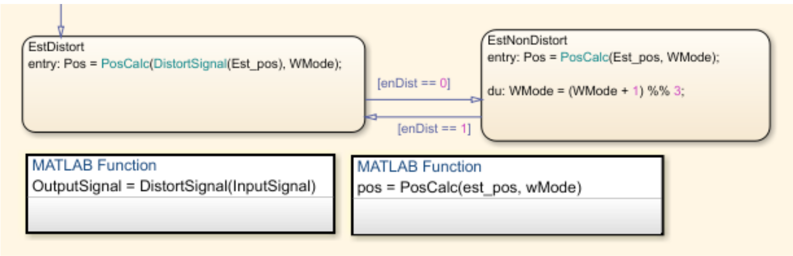
Achieving Efficiency with SYNECT-Based HIL Test Automation

A challenge for the efficient development and validation of electronic control units is the best possible use of the available test systems. One key to tackling this challenge is automated processes, both for test system preparation and test execution.
The dSPACE data management software SYNECT provides powerful solutions for these tasks. It manages the data for validation with software-in-the-loop (SIL) and hardware-in-the-loop (HIL) platforms, and it provides direct support for a range of test automation tools, such as dSPACE AutomationDesk, Vector vTESTstudio/CANoe, and NI TestStand. All data required for test execution, such as real-time applications, parameterizations, and tests, can automatically be provided to the test system. The subsequent HIL system configuration can be automated to a high degree as well. With the new version 2.6, SYNECT offers even more support for efficient testing. Lists of the artifacts to be tested and of the available test systems can be stored in SYNECT and used for test scheduling. In the future, it will also be possible to book test systems for different tasks, such as automated tests, a reconfiguration of the system, or general maintenance tasks, in a calendar view. This booking information is then considered in the subsequent test scheduling. ■



TargetLink: Support for MATLAB Code in Simulink Models

Sometimes it is desirable to describe algorithms and behavior in a Simulink® model using MATLAB® code. With the new TargetLink Module for MATLAB Code, TargetLink now supports this modeling process. To make this possible, dSPACE GmbH and MathWorks, Inc. have signed a license agreement on the TargetLink support for certain MATLAB code in Simulink models. As a result, production code developers are now for the first time able to generate TargetLink's highly efficient C production code directly from control functions described using MATLAB code in Simulink models, for example, by using the MATLAB Function block or MATLAB functions in Stateflow®. Consequently, in addition to using predefined blocks and state machines, developers can benefit from yet another resource for modeling in TargetLink. The TargetLink Module for MATLAB Code supports the complete range of TargetLink optimizations and customizations. The new, optional module is available with dSPACE Release 2018-B and TargetLink 4.4. ■



TargetLink users can generate production code from MATLAB code in Simulink model constructs (here in Stateflow charts), using the new TargetLink Module for MATLAB Code.

Embedded SPU Expands Product Portfolio for In-Vehicle Prototyping

With the MicroAutoBox Embedded SPU (Sensor Processing Unit), which is now available, dSPACE is adding to its product portfolio for in-vehicle prototyping of multisensor applications and offering its customers a solution that is as powerful as it is compact. After MicroAutoBox Embedded PC and Embedded DSU (Data Storage Unit), the Sensor Processing Unit is the third product geared primarily to the needs of developers working on complex driver assistance systems and functions for automated driving. The result is a unique combination of high computing power based on a six-core CPU with integrated GPU from NVIDIA®, interfaces to automotive networks and environmental sensors, and an extremely compact and robust design for in-vehicle use. The graphical development environment RTMaps for multisensor systems can be used for the fast and easy implementation of perception, fusion, and application algorithms on the Sensor Processing Unit. ■

dSPACE on Board

Intriguing and innovative applications, achieved with dSPACE development tools

Driverless Motorcycle

With the aid of an automated motorcycle, BMW is gathering knowledge on driving dynamics to make motorized two-wheelers safer and more exciting to drive by means of assistance systems. In addition, the test vehicle paves the way for the participation of motorcycles in future networked road traffic. A MicroAutoBox in a side case of the R 1200 GS ensures that the functions for autonomous driving are reliably carried out.

The video shows a riderless motorcycle autonomously accelerate, brake, and take corners – without falling over.
www.dspace.com/go/dMag_20191_BMW

With MicroAutoBox, innovations for motorcycles can also be quickly implemented and experienced on the road.

Safe Even with Defective Sensors

The VEDECOM (VÉhicule DÉcarboné COmmuniquant et sa Mobilité) Institute investigates, among other things, the behavior of autonomous vehicles in the event of sensor failure. The researchers are working on a fault-tolerant control strategy for the longitudinal dynamics of the vehicles. The aim is to detect possible faults and then keep the vehicle in a safe condition. RTMaps and a MicroAutoBox are used to develop and implement the algorithms.

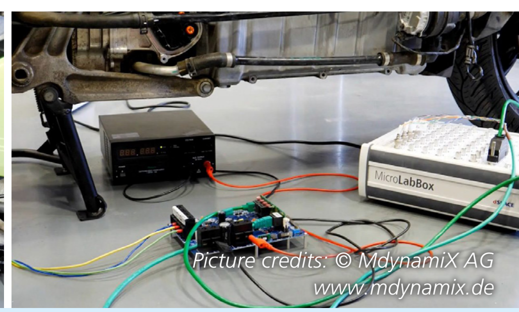
A test vehicle is used to demonstrate the performance of the fault-tolerant algorithms.
www.dspace.com/go/dMag_20191_VED

The fault-tolerant strategies are tested in the real-time software RTMaps and implemented in the vehicle with a MicroAutoBox.

Active Sound Generation

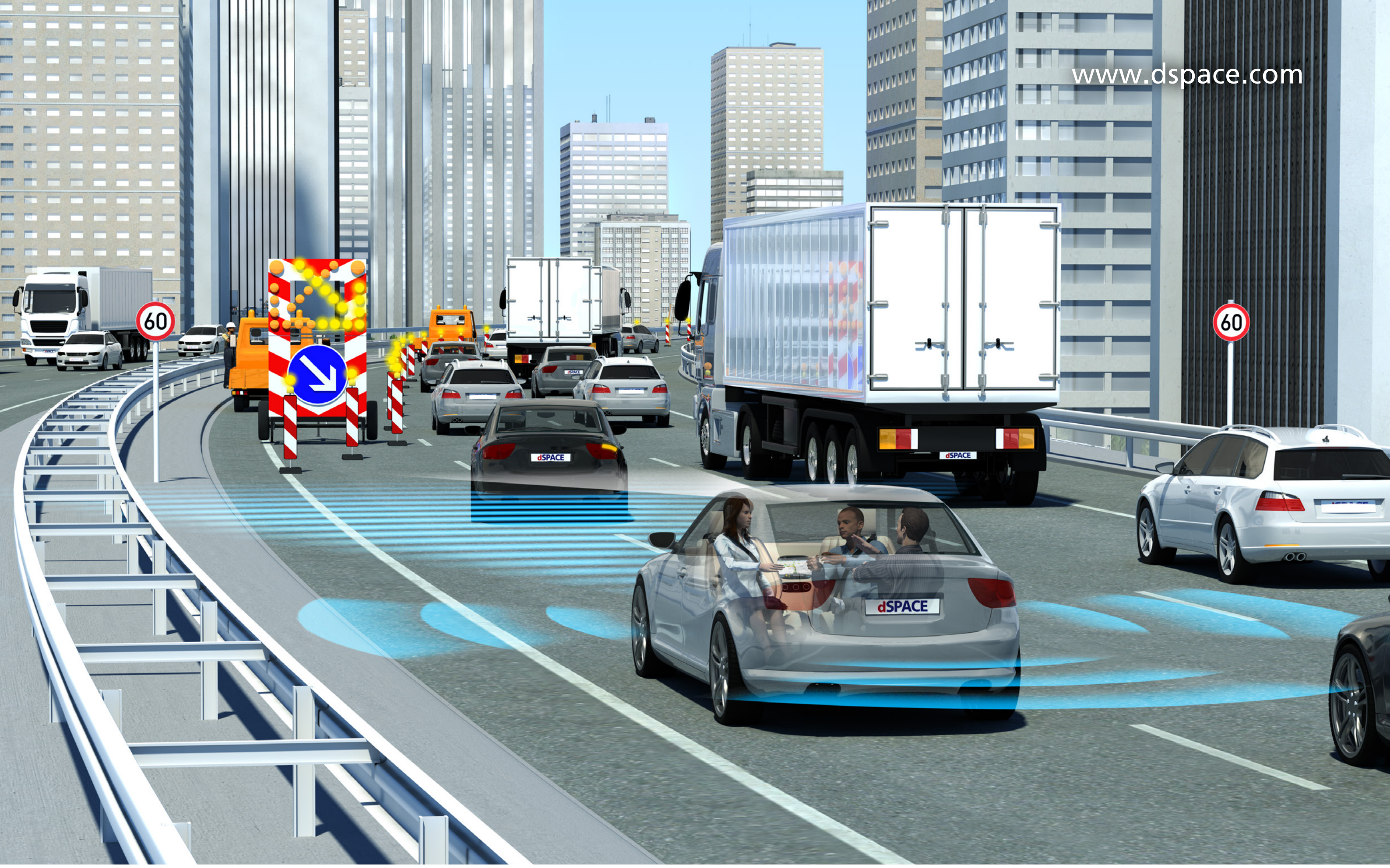
MdynamiX AG uses the electric motors installed in vehicles for targeted noise development – for example, to give electric mobility a sound and thus more safety and emotionality. It also aims at making combustion engines sound more sonorous and pleasant and at reducing disturbing noises in the vehicle through selective interference. A MicroLabBox plays an active role in the laboratory concert.

Targeted noise generation with electric motors creates new fields of application in conventional and electric vehicles.
www.dspace.com/go/dMag_20191_Sound

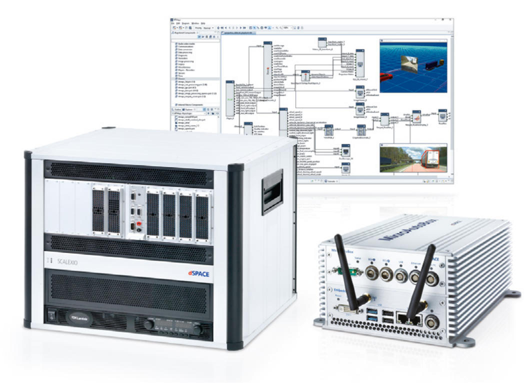


The video gives an overview of the research on sound shaping by electric motor – supported by a MicroLabBox.

Learn more about these applications online, via videos, photos, and reports:
www.dspace.com/go/dMag_20191_REF_E



Functions for Autonomous Driving – Faster Development with dSPACE



The idea of self-driving vehicles offers great potential for innovation. However, the development effort has to stay manageable despite the increasing complexity. The solution is to use a well-coordinated tool chain for function development, virtual validation, hardware-in-the-loop simulation, and data logging in the vehicle. Benefit from perfectly matched tools that interact smoothly throughout all the development steps. No matter whether you're developing software functions, modeling vehicles, environment sensors and traffic scenarios, or running virtual test drives on PC clusters.

Get your functions for autonomous driving on the road – fast and safe!

www.dspace.com/adas

Embedded Success dSPACE